Materials Testing Manual

Edition 4, Amendment 1

March 2016
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<td>Road roughness – surface evenness - two laser profilometer</td>
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</tr>
<tr>
<td>Q708C</td>
<td>Road roughness – surface evenness - static level and staff</td>
<td>November 2014</td>
</tr>
<tr>
<td>Q708D</td>
<td>Road roughness – surface evenness - ARRB walking profiler</td>
<td>November 2014</td>
</tr>
<tr>
<td>Q711A</td>
<td>Field spread rate of cover aggregate - canvas mat</td>
<td>November 2014</td>
</tr>
<tr>
<td>Q712</td>
<td>Surface evenness of road surface - three metre straightedge</td>
<td>February 2016</td>
</tr>
<tr>
<td>Q713</td>
<td>Skid resistance - mobile, variable slip technique</td>
<td>November 2014</td>
</tr>
<tr>
<td>Q714</td>
<td>Skid resistance - mobile, continuous reading, fixed slip technique</td>
<td>November 2014</td>
</tr>
<tr>
<td>Q719</td>
<td>Field spread rate of solid stabilising agents - fabric mat</td>
<td>November 2014</td>
</tr>
<tr>
<td>Q720</td>
<td>Loose aggregate on sprayed seals</td>
<td>November 2014</td>
</tr>
</tbody>
</table>
Materials Testing Manual

Part 1: Introduction
1   Scope

The Materials Testing Manual (MTM) is published to assist the Department of Transport and Main Roads (TMR) in the design, construction and maintenance of the state road network.

The 4th Edition of the MTM was published in 2014 and is available in electronic form only.

To reduce costs for industry, the manual contains a “Table of Equivalencies” so that testing laboratories will no longer need to obtain separate NATA accreditations for identical test methods.

The methods published in the MTM are also referenced in the following departmental publications:

- Pavement Design Manual
- Pavement Rehabilitation Manual
- Technical Specifications
- Western Queensland Best Practice Guidelines

2   Content

The manual contains eleven parts as follows:

a) Part 1 - Introduction
b) Part 2 - General
c) Part 3 - Sampling
d) Part 4 – Soils, Crushed Rock and Stabilised Materials
e) Part 5 - Geotechnical, Environmental, Rock
f) Part 6 - Aggregates
g) Part 7 – Asphalt
h) Part 8 - Bituminous materials
i) Part 9 – Concrete
j) Part 10 – Chemical
k) Part 11 - Pavements

3   Definitions

3.1   Standard definitions

The standard definitions listed in Table 1 shall apply to the Materials Testing Manual.

3.2   Definitions in technical specifications

Further relevant definitions are contained in the test methods and following TMR technical specifications:

a) MRTS01 - Introduction to technical specifications
b) MRTS04 - General earthworks
c) MRTS05 - Unbound pavements
d) MRTS07A - Insitu stabilised subgrades using quicklime or hydrated lime
e) MRTS07B – In situ stabilised pavements using cement or cementitious blends
f) MRTS07C – In situ stabilised pavements using foamed bitumen
g) MRTS08 - Plant-mixed stabilised pavements using cement or cementitious blends

4 Using other standards

The Transport and Main Roads technical specifications require that the testing of all work carried out within a contract be undertaken in accordance with the MTM. These methods are prefixed with the letter “Q”.

The original issue of the manual contained only full text methods published by the then Department of Main Roads. Since the early 1980s the MTM has referred to other methods and standards, initially for concrete testing but expanding to include the testing of soils, aggregates, asphalt and other bituminous materials.

The current manual contains the following:

- methods that directly reference existing test methods (for example, Australian Standards, Austroads)
- methods that reference other test methods but include some mandatory variations
- full text methods either developed in-house or based on existing test methods.

5 Safety

This manual does not attempt to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this manual to establish appropriate occupational health and safety practices that meet statutory regulations.

6 Approved methods (table of equivalencies)

A list of methods that are approved as replacements for Transport and Main Roads methods are shown in Table 2.

Table 1 – Standard definitions

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earthworks</td>
<td>All operations involved in loosening, removing, depositing, shaping and compacting soil or rock. Earthworks include excavation, placement and compaction of topsoil, select and general fills, permeable, and oversize and unsuitable materials, disposal of surplus materials, trimming the batters, surface drains and formation, and preparation of the subgrade surface.</td>
</tr>
<tr>
<td>In situ stabilisation</td>
<td>Is a mobile process, during which a stabilisation agent is added to an existing material and mixed with a purpose-designed road recycler. The quality of the in situ stabilised materials is often variable and in some cases requires the addition of other unbound granular materials to correct deficiencies in the in situ material.</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Plant-mixed stabilisation</td>
<td>Involves the stationary pug mill mixing of a stabilisation agent with an unbound granular material sourced from a quarry or reclaimed construction and demolition waste (usually concrete). The quality of unbound granular pavement material used in plant mixing must conform to an unbound pavement specification.</td>
</tr>
<tr>
<td>Quarry material</td>
<td>Construction materials that are won by blasting, ripping or other excavation means for use in their natural state or after processing such as by crushing, screening or combining with other materials.</td>
</tr>
<tr>
<td>Stabilisation</td>
<td>Process by which the intrinsic properties of a pavement material are altered by the addition of a stabilisation agent to meet performance expectations in its operating, geological and climatic environment.</td>
</tr>
<tr>
<td>Unbound materials</td>
<td>Quarry materials, natural gravels or recycled materials produced for base and sub-base pavement construction.</td>
</tr>
</tbody>
</table>

**Table 2 - Approved replacement methods**

<table>
<thead>
<tr>
<th>TMR method</th>
<th>Equivalent</th>
<th>TMR method</th>
<th>Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q116A</td>
<td>AS 5101.3.2</td>
<td>Q308A</td>
<td>AS 2891.3.1</td>
</tr>
<tr>
<td>Q124</td>
<td>AS 1289.3.7.1</td>
<td>Q308D</td>
<td>AG:PT/T234</td>
</tr>
<tr>
<td>Q181A</td>
<td>AS 1289.6.2.2</td>
<td>Q313</td>
<td>AG:PT/T236</td>
</tr>
<tr>
<td>Q190</td>
<td>ASTM D6244</td>
<td>Q317</td>
<td>AS 2891.8</td>
</tr>
<tr>
<td>Q212A</td>
<td>AS 1141.50</td>
<td>Q317</td>
<td>AG:PT/T237</td>
</tr>
<tr>
<td>Q301</td>
<td>AS 2891.1</td>
<td>Q334</td>
<td>AG:PT/T131</td>
</tr>
<tr>
<td>Q302A</td>
<td>AS 2891.1.2</td>
<td>Q334</td>
<td>AS 2341.18</td>
</tr>
<tr>
<td>Q302B</td>
<td>AS 2891.1.2</td>
<td>Q336</td>
<td>AS 2341.3</td>
</tr>
<tr>
<td>Q306B</td>
<td>AS 2891.9.2</td>
<td>Q476</td>
<td>AS 1478.2</td>
</tr>
<tr>
<td>Q306D</td>
<td>AS 2891.9.3</td>
<td>Q705</td>
<td>AG:PT/T250</td>
</tr>
<tr>
<td>Q307A</td>
<td>AS 2891.7.1</td>
<td>Q706</td>
<td>AG:PT/T251</td>
</tr>
</tbody>
</table>

TMR - Transport and Main Roads  
AS - Australian Standard  
AG:PT/- - Austroads  
ASTM - American Society for the Testing of Materials  
Superseded
Materials Testing Manual

Part 2: General
Test Method Q010: Establishing the relationship between standard and subsidiary test methods

1 Source

This method is based on the principles adopted in AS 1289.2.3.1: Establishment of correlation - subsidiary method and the standard method. It also adopts a value of maximum standard error for the relationship between the standard and subsidiary methods as recommended from an internal departmental research investigation into moisture content determinations.

2 Scope

This method provides a means for determining the relationship between a standard test method and a subsidiary test method. It assumes a linear relationship and allows a test result from a subsidiary method to be corrected to the standard method result. The method is applicable to all test methods having standard and subsidiary forms, but assumes that repeatability values for both the standard and subsidiary methods are known.

3 Procedure

The procedure shall be as follows:

3.1 Select at least 10 representative samples of the particular material to be tested to cover the expected range in the test property in a reasonably even distribution. The samples shall be of sufficient size to allow testing using both the standard and subsidiary tests.

3.2 Subdivide each sample to obtain a representative test portion of appropriate size for each of the two test methods.

3.3 Perform the standard and subsidiary tests on the two test portions from each sample as detailed in the specified test methods.

3.4 Record the test results obtained from the standard test method as values of the dependent variable \(y\) and the corresponding test results obtained from the subsidiary test method as values of the independent variable \(x\).

4 Calculations

4.1 Assume the relationship between the dependent and the independent variables to be linear of the form:

\[y = bx + a\]

where 
- \(y\) = dependent variable (standard test method)
- \(b\) = slope of linear relationship
- \(x\) = independent variable (subsidiary test method)
- \(a\) = \(y\) intercept of linear relationship

4.2 Calculate the linear regression relationship as follows:

4.2.1 Calculate the slope of the linear relationship as follows:

\[b = \frac{n \sum xy - \sum x \sum y}{n \sum x^2 - (\sum x)^2}\]
Test Method Q010: Establishing the relationship between standard and subsidiary test methods

where
- $b$ = slope of linear relationship
- $n$ = number of pairs of test results
- $\sum xy$ = sum of the products of the corresponding test results from the subsidiary and standard methods
- $\sum x$ = sum of the test results from the subsidiary method
- $\sum y$ = sum of the test results from the standard method
- $\sum x^2$ = sum of the squares of the test results from the subsidiary method

4.2.2 Calculate the y intercept of the linear relationship as follows:

$$a = \frac{1}{n} \left( \sum y - b \sum x \right)$$

where
- $a$ = y intercept of linear relationship
- $\sum y$ = sum of the test results from the standard method
- $b$ = slope of linear relationship
- $\sum x$ = sum of the test results from the subsidiary method
- $n$ = number of pairs of test results

4.3 Calculate the standard error of the relationship as follows:

$$S_E = \left( \frac{\sum y^2 - a \sum y \sum x}{n - 2} \right)^{1/2}$$

where
- $S_E$ = standard error of the relationship
- $\sum y^2$ = sum of the squares of the test results from the standard method
- $a$ = y intercept of linear relationship
- $\sum y$ = sum of the test results from the standard method
- $b$ = slope of linear relationship
- $\sum xy$ = sum of the products of the corresponding test results from the subsidiary and standard methods
- $n$ = number of pairs of test results

4.4 Calculate the maximum standard error for the relationship as follows (Note 6.1):

$$S_{E,\text{max}} = \left( s_1^2 + b^2 s_2^2 + 2bs_1s_2 \right)^{1/2}$$

where
- $S_{E,\text{max}}$ = maximum standard error for the relationship
- $s_1$ = 0.36 $R_{\text{stand.}}$
- $b$ = slope of linear relationship
- $s_2$ = 0.36 $R_{\text{sub.}}$
Test Method Q010: Establishing the relationship between standard and subsidiary test methods

\[ s_x = \text{the larger of } s_1 \text{ and } s_2 \]

and

\[ R_{\text{stand.}} = \text{repeatability of the standard method} \]

\[ R_{\text{sub.}} = \text{repeatability of the subsidiary method} \]

4.5 Accept the calculated values of \( b \) and \( a \) provided that the value of \( S_E \) does not exceed \( S_{E,\text{max}} \).

4.6 Where the calculated value of \( S_E \) exceeds \( S_{E,\text{max}} \), obtain an additional data point(s) in accordance with Steps 3.1 to 3.3 and combine with the existing data. Analyse the combined test results in accordance with Steps 3.4 and 4.1 to 4.5.

4.7 Repeat Step 4.6 (with judicious elimination of data points if necessary) until the relationship determined from a minimum ten data points has an associated standard error which does not exceed the calculated maximum value.

4.8 Perform regular checks of the relationship by obtaining an additional data point in accordance with Steps 3.1 to 3.3 (Note 6.2).

4.9 Accept the relationship provided that:

a) Check data points fall within ±2 \( S_E \) of the linear regression (Note 6.3).

b) The distribution of check data points about the linear regression appears to be random, that is, not biased or skewed.

Otherwise, determine a new relationship in accordance with this test method.

5 Reporting

Report the following values and general information:

5.1 The relationship between the standard and subsidiary test methods in the form: \( y=bx+a \). The values of \( a \) and \( b \) shall be reported to a number of significant figures which exceeds by one that normally reported for the standard and subsidiary tests.

5.2 Standard and subsidiary test methods used.

5.3 Test property range tested.

6 Notes on method

6.1 The appropriate value of maximum standard error will be dependent on test method variation but may also be affected if the corrected test result is to be used in further calculations. In the case of moisture content measurement where the repeatability values for the standard and subsidiary methods are presently unknown, a value of 0.6% should be adopted for the maximum standard error.

6.2 The frequency of checks on the relationship will be dependent on the number of subsidiary tests performed and the variability of the test material. For high testing frequency, the number of check tests should be about one per hundred or once per week, whichever is the lesser. This number should be increased to about one in 10 for infrequent testing.

6.3 It is expected that, in the long term, check data points will fall beyond ±2 \( S_E \) of the linear regression relationship in about one case in twenty. If this frequency of failure is observed, the existing relationship may be assumed to be valid.
Test Method Q020: Calculation of characteristic value of a lot

1 Source

This method is based on the process for calculation of characteristic value as detailed in the Department of Transport and Main Roads Technical Specifications MRTS01 *Introduction to Technical Specifications* and MRTS40 *Concrete Base in Pavements*.

2 Scope

This method provides a means for calculating a characteristic value determined by the analysis of several individual test results, tested using the same methods, using a statistical process. The characteristic value may then be used to determine the compliance of a product.

3 Procedure

The procedure shall be as follows:

3.1 Perform the requested tests, using the same test methods, as detailed in the specified test methods (Notes 6.1 and 6.2).

3.2 Using the reported values perform the calculations detailed in Section 4.

4 Calculations

4.1 Calculate the mean of the individual test results as follows:

\[
X_{av} = \frac{1}{n} \sum_{i=1}^{n} X_i
\]

where

- \( X_{av} \) = mean of the individual test results for \( i=1, 2, 3, \ldots, n \)
- \( n \) = number of test results
- \( X_i \) = the individual test result for \( i=1, 2, 3, \ldots, n \)

4.2 Calculate the standard deviation of the individual test results as follows:

\[
s = \sqrt{\frac{\sum_{i=1}^{n} (X_i - X_{av})^2}{n - 1}}
\]

where

- \( s \) = standard deviation of the individual test results for \( i=1, 2, 3, \ldots, n \)
- \( n \) = number of test results
- \( X_i \) = the individual test result for \( i=1, 2, 3, \ldots, n \)
- \( X_{av} \) = mean of the individual test results
4.3  Calculate the characteristic value using the appropriate method as follows:

4.3.1  For a minimum limit:

\[ CV = X_{av} - ks \]

where

- \( CV \) = characteristic value
- \( X_{av} \) = mean of the individual test results
- \( k \) = an acceptance constant dependent upon the number of tests (Refer to Table 1 or 2)
- \( s \) = standard deviation of the individual test results

4.3.2  For a maximum limit:

\[ CV = X_{av} + ks \]

where

- \( CV \) = characteristic value
- \( X_{av} \) = mean of the individual test results
- \( k \) = an acceptance constant dependent upon the number of tests (Refer to Table 1 or 2)
- \( s \) = standard deviation of the individual test results

5  Reporting

5.1  Report the following values rounded as detailed in Table 3:

5.1.1  Characteristic value of the individual test results.

5.1.2  Mean of the individual test results.

5.1.3  Standard deviation of the individual test results.

5.2  Report the following additional values:

5.2.1  Number of individual tests.

5.2.2  Acceptance constant (k) used to the nearest 0.001 for Table 1 and 0.01 for Table 2.

6  Notes on method

6.1  This method is usually applied to the results of Test Methods Q134, Q140A, Q146, Q311, Q314 and Q482.

6.2  For example, when determining the relative compaction of asphalt, the method used to determine the compacted density may be one of Q306A, Q306B, Q306C, Q306D or Q306E.
Table 1 - Acceptance constants (Q134, Q140A, Q146, Q311 and Q314)

<table>
<thead>
<tr>
<th>Number of tests or measurements</th>
<th>Acceptance constant (k)</th>
<th>Number of tests or measurements</th>
<th>Acceptance constant (k)</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 10</td>
<td>0.828</td>
<td>35</td>
<td>1.020</td>
</tr>
<tr>
<td>11</td>
<td>0.847</td>
<td>40</td>
<td>1.036</td>
</tr>
<tr>
<td>12</td>
<td>0.863</td>
<td>45</td>
<td>1.049</td>
</tr>
<tr>
<td>13</td>
<td>0.877</td>
<td>50</td>
<td>1.059</td>
</tr>
<tr>
<td>14</td>
<td>0.890</td>
<td>60</td>
<td>1.077</td>
</tr>
<tr>
<td>15</td>
<td>0.901</td>
<td>70</td>
<td>1.097</td>
</tr>
<tr>
<td>20</td>
<td>0.946</td>
<td>80</td>
<td>1.103</td>
</tr>
<tr>
<td>25</td>
<td>0.978</td>
<td>90</td>
<td>1.112</td>
</tr>
<tr>
<td>30</td>
<td>1.002</td>
<td>100</td>
<td>1.120</td>
</tr>
</tbody>
</table>

Table 2 - Acceptance constants (Q482)

<table>
<thead>
<tr>
<th>Number of cores per lot</th>
<th>Acceptance constant (k)</th>
<th>Number of cores per lot</th>
<th>Acceptance constant (k)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1.48</td>
<td>11-15</td>
<td>1.35</td>
</tr>
<tr>
<td>6-7</td>
<td>1.42</td>
<td>16-40</td>
<td>1.32</td>
</tr>
<tr>
<td>8-10</td>
<td>1.38</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 3 - Rounding intervals

<table>
<thead>
<tr>
<th>Test or measurement</th>
<th>Test method</th>
<th>Rounding value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stabilising agent content</td>
<td>Q134</td>
<td>0.01%</td>
</tr>
<tr>
<td>Relative compaction</td>
<td>Q140A</td>
<td>0.1%</td>
</tr>
<tr>
<td>Degree of saturation</td>
<td>Q146</td>
<td>1%</td>
</tr>
<tr>
<td>Relative density (asphalt)</td>
<td>Q314</td>
<td>0.1%</td>
</tr>
<tr>
<td>Air voids</td>
<td>Q311</td>
<td>0.1%</td>
</tr>
<tr>
<td>Relative compaction (concrete)</td>
<td>Q482</td>
<td>0.1%</td>
</tr>
</tbody>
</table>
Test Method Q050: Random selection of sampling or test locations

1 Source
This method applies the principles of AS 1289.1.4.1: Selection of sampling or test sites – Random number method and AS 1289.1.4.2: Selection of sampling or test sites – Stratified random number method. The principles within these methods have been modified and enhanced to provide procedures which better suit local methodology and practices.

2 Scope
This method describes the procedure for establishing sampling locations, sampling intervals or test locations within a lot, which has been defined in terms of mass, volume, area or batches, using random selection techniques. The method contains procedures which allow locations or intervals to be selected using either Random Sampling, Random Stratified Sampling or Systematic Random Stratified Sampling. These procedures ensure that samples or tests are taken at locations or intervals which are distributed within a lot in such a way that bias is removed from the selection process.

3 Application
Where the procedure for the selection of sampling and test locations is not specified in the appropriate specification, sampling plan or test method, the following shall apply:

3.1 Random Stratified Sampling procedures will be used for the selection of all sampling locations, sampling intervals or test locations.

3.2 Stockpiles, windrows or heaps are to be sampled using Random Stratified Sampling described in Subsection 9.2: Selection of Location – Available Perimeter.

4 Apparatus
The following apparatus is required:

4.1 Tape measure, wheel meter, and staff and level as required.

4.2 Marking system, suitable marking equipment appropriate for the lot under consideration (for example, spray paint, flagging tap, pegs).

5 Definitions
5.1 Random Sampling is a system in which the selection of sampling locations, sampling intervals or test locations is made for a lot or sub-lot so that each location or interval in the lot or sub-lot has an equal chance of being selected.

5.2 Random Stratified Sampling is a system in which the selection of sampling locations, sampling intervals or test locations is made by dividing the lot or sub-lot into strata of equal size, followed by the random selection of a single location or interval for sampling or testing in each stratum. A different random number is used for each stratum.

5.3 Systematic Random Stratified Sampling is a system in which the selection of sampling locations, sampling intervals or test locations is made by dividing the lot or sub-lot into strata of equal size, followed by the random selection of a single location or interval for sampling or testing in each stratum. The same random number is used for each stratum.
6 Lot size and sampling or testing frequencies
6.1 Determine the size or extent of the lot, together with the number of samples or tests to be taken, using the specification, sampling plan or test methodology as appropriate.

6.2 Where more than one representative sample is to be taken, divide the lot into the same number of approximately equal size sub-lots (Note 13.1). Mark the boundaries of each sub-lot using a suitable marking system.

7 Random numbers
7.1 Obtain a listing of sequential random numbers using Table 1 for the monthly date on which the work is undertaken (Note 13.2).

7.2 Each random number shall be used for the calculation of only one.

7.2.1 Longitudinal, lateral or vertical coordinate, or
7.2.2 Position on the perimeter of a lot or sub-lot, or
7.2.3 Sampling or testing interval.

8 Random sampling
8.1 Selection of location – available area
8.1.1 Determine the extent of the area within the lot or sub-lot which is available for sampling or testing by referring to the specification, sampling plan or test methodology as appropriate (Note 13.3).

8.1.2 Measure the length of the available area and, for an area with a uniform cross section, its width. Where a lot or sub-lot is comprised of multiple layers or is a stockpile, measure the height.

8.1.3 Determine the longitudinal coordinate for each sample, sample increment or test location as follows:

\[ x_i = r_I L \]

where

- \( x_i \) = longitudinal coordinate for the \( i^{th} \) sample, sample increment, or test number, measured from one end of the available area (m)
- \( r_I \) = random number specific quantity of material produced, processed, batched or loaded before taking the \( i^{th} \) sample, sample increment or test number
- \( L \) = length of the available area (m)

8.1.4 Determine the lateral coordinate for each sample, sample increment or test location as follows (Note 13.4):

\[ y_i = r_w W_i \]

where

- \( y_i \) = lateral coordinate for the \( i^{th} \) sample, sample increment or test number, measured from one side of the available area (m)
- \( r_w \) = random number specific to the lateral coordinate for the \( i^{th} \) sample, sample increment or test number
8.1.5 For lots or sub-lots containing multiple layers or for a stockpile, determine the vertical coordinate for each sample, sample increment or test location as follows:

\[ z_i = r_h (H - D) + D \]

where:
- \( z_i \) = vertical coordinate for the \( i^{th} \) sample, sample increment or test number measured from the bottom of the lot or sub-lot (m)
- \( r_h \) = random number specific to the vertical coordinate for the \( i^{th} \) sample, sample increment or test number
- \( H \) = height of the lot or sub-lot (m)
- \( D \) = depth to which sampling or testing is to be undertaken (m)

8.2 Selection of location – available perimeter

8.2.1 Measure the accessible perimeter of the lot or sub-lot (Notes 13.5 and 13.6).

8.2.2 Determine the sample or test location as follows:

\[ p_i = r_L \]

where:
- \( p_i \) = position on the perimeter for the \( i^{th} \) sample, sample increment or test number measured from the starting point (m)
- \( r_L \) = random number specific quantity of material produced, processed, batched or loaded before taking the \( i^{th} \) sample, sample increment or test number
- \( L \) = length of the accessible perimeter (m)

8.3 Selection of location – interval

8.3.1 Determine the sampling or testing interval as follows (Note 13.7):

\[ t_i = r_Q \]

where:
- \( t_i \) = quantity of material produced, processed, batched or loaded before taking the \( i^{th} \) sample, sample increment or test number (m³, t or batch)
- \( r_Q \) = random number specific quantity of material produced, processed, batched or loaded before taking the \( i^{th} \) sample, sample increment or test number
- \( Q \) = quantity of material in the lot or sub-lot (m³, t or batch)

9 Random stratified sampling

9.1 Selection of location – available area

9.1.1 Determine the extent of the area within the lot or sub-lot which is available for sampling or testing by referring to the specification, sampling plan or test methodology as appropriate (Note 13.3).
9.1.2 Measure the length of the available area and, for an area with a uniform cross section, its width. Where a lot or sub-lot is comprised of multiple layers or is a stockpile, measure the height.

9.1.3 Stratify the length of the available area as follows:

\[ l = \frac{L}{n} \]

where
- \( l \) = length of each stratum (m)
- \( L \) = length of the available area (m)
- \( n \) = number of samples, sample increments or tests

9.1.4 Determine the longitudinal coordinate for each sample, sample increment or test location as follows:

\[ x_i = l(i-1+r_i) \]

where
- \( x_i \) = longitudinal coordinate for the \( i \)th sample, sample increment or test number measured from one end of the available area (m)
- \( l \) = length of each stratum (m)
- \( i \) = particular sample, sample increment or test number
- \( r_i \) = random number specific quantity of material produced, processed, batched or loaded before taking the \( i \)th sample, sample increment or test number

9.1.5 Determine the lateral coordinate for each sample, sample increment or test location as follows (Note 13.4):

\[ y_i = r_w W_i \]

where
- \( y_i \) = lateral coordinate for the \( i \)th sample, sample increment or test number measured from one side of the available area (m)
- \( r_w \) = random number specific to the lateral coordinate for the \( i \)th sample, sample increment or test number
- \( W_i \) = width of the available area at the actual longitudinal coordinate for the \( i \)th sample, sample increment or test location number (m)

9.1.6 For lots or sub-lots containing multiple layers or for a stockpile, determine the vertical coordinate for each sample, sample increment or test location as follows:

\[ z_i = r_h (H-D) + D \]

where
- \( z_i \) = vertical coordinate for the \( i \)th sample, sample increment or test number measured from the bottom of the lot or sub-lot (m)
- \( r_h \) = random number specific to the vertical coordinate for the \( i \)th sample, sample increment or test number
- \( H \) = height of the lot or sub-lot (m)
- \( D \) = depth to which sampling or testing is to be undertaken (m)
9.2 **Selection of location – available perimeter**

9.2.1 Measure the accessible perimeter of the lot or sub-lot (Notes 13.5 and 13.6).

9.2.2 Stratify the accessible perimeter as follows:

\[ l = \frac{L}{n} \]

where

- \( l \) = length of each stratum (m)
- \( L \) = length of the accessible perimeter (m)
- \( n \) = number of samples, sample increments or tests

9.2.3 Determine the sample or test location as follows:

\[ p_i = l(i-1+r_i) \]

where

- \( p_i \) = position on the perimeter for the \( i^{th} \) sample, sample increment or test number measured from the starting point (m)
- \( l \) = length of each stratum (m)
- \( i \) = particular sample, sample increment or test number
- \( r_i \) = random number specific quantity of material produced, processed, batched or loaded before taking the \( i^{th} \) sample, sample increment or test number

9.3 **Selection of location – interval**

9.3.1 Stratify the volume, mass or batches in the lot or sub-lot as follows (Note 13.7):

\[ q = \frac{Q}{n} \]

where

- \( q \) = quantity of material in each stratum (m³, t or batch)
- \( Q \) = quantity of material in the lot or sub-lot (m³, t or batch)
- \( n \) = number of samples, sample increments or tests

9.3.2 Determine the sampling or testing interval as follows:

\[ t_i = q(i-1+r_i) \]

where

- \( t_i \) = quantity of material produced, processed, batched or loaded before taking the \( i^{th} \) sample, sample increment or test number (m³, t or batch)
- \( q \) = quantity of material in each stratum (m³, t or batch)
- \( i \) = particular sample, sample increment or test number
- \( r_i \) = random number specific quantity of material produced, processed, batched or loaded before taking the \( i^{th} \) sample, sample increment or test number
10 Systematic random stratified sampling

10.1 Selection of location – available area

10.1.1 Determine the extent of the area within the lot or sub-lot which is available for sampling or testing by referring to the specification, sampling plan or test methodology as appropriate (Note 13.2).

10.1.2 Measure the length of the available area and, for an area with a uniform cross section, its width. Where a lot or sub-lot is comprised of multiple layers or is a stockpile, measure the height.

10.1.3 Stratify the length of the available area as follows:

\[ l = \frac{L}{n} \]

where

- \( l \) = length of each stratum (m)
- \( L \) = length of the available area (m)
- \( n \) = number of samples, sample increments or tests

10.1.4 Determine the longitudinal coordinate for each sample, sample increment or test location as follows:

\[ x_i = l(i-1+r) \]

where

- \( x_i \) = longitudinal coordinate for the \( i^{th} \) sample, sample increment or test number measured from one end of the available area (m)
- \( l \) = length of each stratum (m)
- \( i \) = particular sample, sample increment or test number
- \( r \) = random number

10.1.5 Determine the lateral coordinate for each sample, sample increment or test location as follows (Note 13.4):

\[ y_i = r_w W_i \]

where

- \( y_i \) = lateral coordinate for the \( i^{th} \) sample, sample increment or test number measured from one side of the available area (m)
- \( r_w \) = random number specific to the lateral coordinate for the \( i^{th} \) sample, sample increment or test number
- \( W_i \) = width of the available area at the actual longitudinal coordinate for the \( i^{th} \) sample, sample increment or test location number (m)
10.1.6 For lots or sub-lots containing multiple layers or for a stockpile, determine the vertical coordinate for each sample, sample increment or test location as follows:

\[ z_i = r_h (H-D) + D \]

where
- \( z_i \) = vertical coordinate for the \( i^{th} \) sample, sample increment or test number measured from the bottom of the lot or sub-lot (m)
- \( r_h \) = random number specific to the vertical coordinate for the \( i^{th} \) sample, sample increment or test number
- \( H \) = height of the lot or sub-lot (m)
- \( D \) = depth to which sampling or testing is to be undertaken (m)

10.2 Selection of location – available perimeter

10.2.1 Measure the accessible perimeter of the lot or sub-lot (Notes 13.5 and 13.6).

10.2.2 Stratify the accessible perimeter as follows:

\[ l = \frac{L}{n} \]

where
- \( l \) = length of each stratum (m)
- \( L \) = length of the accessible perimeter (m)
- \( n \) = number of samples, sample increments or tests

10.2.3 Determine the sample or test location as follows:

\[ p_i = l(i-1+r) \]

where
- \( p_i \) = position on the perimeter for the \( i^{th} \) sample, sample increment or test number measured from the starting point (m)
- \( l \) = length of stratum (m)
- \( i \) = particular sample, sample increment or test number
- \( r \) = random number

10.3 Selection of location – interval

10.3.1 Stratify the volume, mass or batches in the lot or sub-lot as follows:

\[ q = \frac{Q}{n} \]

where
- \( q \) = quantity of material in each stratum (m³, t or batch)
- \( Q \) = quantity of material in the lot or sub-lot (m³, t or batch)
- \( n \) = number of samples, sample increments or tests

Superseded
10.3.2 Determine the sampling or testing interval as follows:

\[ t_i = q(i-1+r) \]

where

- \( t_i \) = quantity of material produced, processed, batched or loaded before taking the \( i^{th} \) sample, sample increment or test number (m³, t or batch)
- \( q \) = quantity of material in each stratum (m³, t or batch)
- \( i \) = particular sample, sample increment or test number
- \( r \) = random number

11 **Records**

Record the following information as appropriate:

11.1 Date of sampling/testing.
11.2 Random numbers used.
11.3 Longitudinal, lateral and, if required, vertical coordinates of each sampling/test site.
11.4 Position on the perimeter of each sampling/test location.
11.5 Quantity of material produced, processed, batched or loaded at which a sample/test is taken.
11.6 Lot identification, sub-lots, field sample numbers, increment numbers.
11.7 Name of sampler.
11.8 Specific sampling procedure used with reference to the relevant sub-section of this method.
11.9 For selection of locations by available area or perimeters, a dimensioned plan of the lot/sub-lots showing sample increment locations together with points of reference and, where appropriate, sub-increment locations.
11.10 Any other relevant information.

12 **Reporting**

Report the following as appropriate:

12.1 Date of sampling/testing.
12.2 Longitudinal, lateral and, if required, vertical location of each sampling/test site.
12.3 Quantity of material produced, processed, batched or loaded at which a sample/test is taken.
12.4 Lot identification.
12.5 Specific sampling procedure used with reference to the relevant sub-section of this method.

13 **Notes on method**

13.1 The sample increments for each representative sample are taken randomly throughout a particular sub-lot in the same way that spot samples and tests are taken throughout a lot.
13.2 When using Table 1, where more than 30 random numbers are required in a day, obtain additional numbers from the listing for the previous day.
13.3 For compaction lots when exclusions have not been specified, exclude any parts of the lot or sub-lot which are within 200 mm of any top edge or construction joint.

13.4 For a lot or sub-lot with a non-uniform cross-section, measure the width at each determined longitudinal coordinate.

13.5 It is not always possible to obtain free access to all sides of some lots or sub-lots (for example, a stockpile lot). In such cases, determine the combined accessible length.

13.6 For windrows, it is only necessary to measure the length of each lot or sub-lot.

13.7 When determining a sampling or testing interval for batches, any determination that identifies a batch already selected can be ignored and the next random number used.

### Table 1 – Table of random numbers

<table>
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<th>Date of month</th>
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<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<th>7</th>
<th>8</th>
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<th>10</th>
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Test Method Q060: Representative sampling of soils, crushed rock and aggregates

1 Source

This method applies the principles of AS 1141.3.1: Sampling – Aggregates but expands the scope to include soils and crushed rock. The method provides for sample increment sizes and numbers of increments that are considered more appropriate for the testing of construction materials. In addition, the procedure contains enhanced techniques for the sampling of materials both in motion during production and when stationary.

2 Scope

This method describes the procedures for obtaining representative samples of soils, crushed rock and aggregates having a nominal size up to 63 mm. The method is applicable to produced materials in motion on a conveyor belt or at the point of discharge, as well as stationary materials contained within a stockpile, truck, bin, heap or windrow. The method may not be applicable to circumstances where spot sampling techniques are more appropriate (for example where determining stockpile segregation).

3 Application

Generally it is preferable to sample produced materials when in motion prior to or during discharge. However, this may not be safe or practical for all such circumstances and this approach is not applicable for sampling non-processed materials or produced materials which are stationary. Adequate samples can be obtained from stationary materials provided due care is exercised.

Each procedure for sampling moving or stationary material as contained within this method is considered to be of equal technical validity. Where a number of sampling options is available for a particular situation, there is no hierarchy of preference and each procedure will provide an adequate representative sample.

The following limitations need to be considered when selecting a sampling procedure:

- A sampling tube can only be used for sampling free flowing fine grained material.
- The use of hand tools to sample aggregates from a stockpile, heap or windrow is limited to those aggregates having a nominal size of up to and including 28 mm.

4 Apparatus

The following apparatus is required:

4.1 Sample containers, woven sample bags or other suitable sealable containers which will prevent loss of fines. Airtight containers are required for moisture content samples. Containers are to be of a size or so configured that their maximum capacity is approximately 20 kg.

4.2 Sampling frame, of rigid construction with parallel end plates. The end plates are to be shaped to fit the full width of the conveyor belt while preventing leakage of material. The distance between the end plates is to be such that the minimum sample increment mass in Table 1 can be obtained.

4.3 Flat bottomed scoop or trowel and brush.

4.4 Loader, having a bucket with a capacity of at least 1 m³, capable of obtaining a slice of material from the total height of the side of the stockpile under consideration in a single movement (Note 13.1).
4.5 Excavator, having a bucket with a capacity of at least 1 m³, capable of reaching to the total height of the stockpile.

4.6 Shovels:

4.6.1 Standard shovel, a standard square mouth shovel with raised sides having a blade of approximate dimensions 300 mm length and 200 mm width.

4.6.2 Posthole shovel, a square mouth posthole shovel having a blade of approximate dimensions 300 mm length and 200 mm width.

4.6.3 Farmer's shovel, with a minimised square mouth having a blade of approximate dimensions 300 mm length, 240 mm width and mouth width of 130 mm for coarse materials such as railway ballast.

4.7 Shield board, a rigid sheet of material such as timber or metal of suitable size. A plywood sheet of dimensions 800 mm length, 400 mm width and 12 mm thickness has been found suitable.

4.8 Sampling tube, consisting of a 75 mm to 100 mm diameter thin walled tube with an opening or a series of openings in a straight line parallel to the longitudinal axis.

4.9 Digging tools such as a pick or crowbar.

4.10 Mechanical stream cutter, a bucket cutter complying with the requirements of AS 2884.1, capable of moving through the entire discharge stream at a constant rate.

4.11 Tape measure, wheel meter and staff and level as required.

4.12 Sample divider, complying with the requirements of AS 1141.2.

5 Definitions

5.1 Nominal Size - The designation of a material that gives an indication of the largest size particles present. The nominal size is expressed as a whole number above the sieve size through which nearly all of the material passes.

5.2 Sample - The material to be forwarded for examination and/or testing which is representative of a lot or sub-lot. A sample is either a single entity (a spot sample) or more usually a representative sample derived by combining sample increments and then dividing the composite into a suitable quantity for examination and/or testing.

5.3 Sample Increment – The amount of material taken to form part of a sample. The number of sample increments required to form a sample is dependent on the lot or sub-lot size (see Table 2). When material is being sampled from a truck, heap or stockpile using hand tools, each sample increment is comprised of a number of sub-increments. The minimum mass of an increment or sub-increment is determined from Table 1.

5.4 Sampling Location - The location, described in terms of longitudinal, lateral and, if required, vertical distance from where a sample increment or a number of sub-increments is obtained.

5.5 Sampling Interval – The mass or volume of material to be produced, processed or loaded before a sample increment or a number of sub-increments is obtained.

5.6 Sampling Point – The position within a body of material, where a sub-increment is obtained for combination with other sub-increments to form a sample increment. The term "sampling point" is only used when material is taken from more than one position for a particular sampling location or sampling interval.
5.7 Lot – A portion of material that has been supplied and/or processed under essentially uniform conditions and contains material of essentially uniform quality.

5.8 Sub-lot – The subdivision of a lot, with each sub-lot containing an approximately equal quantity of material. A lot is subdivided whenever more than one representative sample is required. The number of sub-lots is the same as the number of samples to be taken.

6 Sampling procedure and locations

6.1 Taking into account the type of material to be sampled and the type and scope of testing, select a sampling procedure which is appropriate for existing conditions and available resources.

6.2 Determine the number of samples to be taken within the lot in accordance with the requirements of the specification, sampling plan or testing methodology as appropriate.

6.3 Where more than one sample is required, divide the lot into the same number of approximately equal sub-lots. Determine the number of sample increments to be taken from the lot or each sub-lot from Table 2 to form a sample (Note 13.2).

6.4 Determine the minimum mass of material for each sample increment or sub-increment from Table 1 (Note 13.2).

6.5 Use random stratified sampling to determine sampling locations, or sampling intervals during production, for each sample increment as detailed in Test Method Q050.

7 Sampling during discharge

7.1 Moving stream

7.1.1 Ensure that the production plant is in a stable phase of production operation (that is, not in a start-up or wind-down phase).

7.1.2 At the predetermined sampling interval, activate the mechanical cutter ensuring that it moves through the entire stream of material production at a constant rate and at right angles to the direction of discharge.

7.1.3 Transfer all of the collected material into the sample container to form a sample increment. The collected material may need to be first split to an appropriate sample increment size (Note 13.3).

7.1.4 Label or otherwise identify the sample container with the field sample number and increment number (Note 13.4).

7.1.5 Repeat Steps 7.1.1 to 7.1.4 until the required number of sample increments, having a similar quantity of material, is obtained for each sample.

7.2 Stopped conveyor belt

7.2.1 Ensure that the production plant is in a stable phase of production (that is, not in a start-up or wind-down phase). At the predetermined sampling interval, have the belt stopped and isolated by an authorised operator.

7.2.2 Place the sampling frame on the material with the end plates perpendicular to the direction of travel. Use a sawing motion to cleanly cut the material stream with the frame.

7.2.3 Obtain a sample increment by removing all material from within the frame using the scoop and brush and place it in the sample container.
7.2.4 Label or otherwise identify the sample container with the field sample number and increment number (Note 13.4).

7.2.5 Allow the plant to be restarted. Once production is again stable, repeat Steps 7.2.1 to 7.2.4 until the required number of sample increments, having a similar quantity of material, is obtained for each sample.

8 Sampling from formed stockpiles

8.1 Single layer formed stockpile – loader remove and mix

8.1.1 At a predetermined sampling location, expose a fresh face by removing a slice of material from the total height of the side of the stockpile. Dump the removed material on the stockpile at a location which will not interfere with the sampling process.

8.1.2 Remove sufficient material from the total height of the fresh face to form a level mixing pad adjacent to the stockpile. The pad must be of sufficient area to accommodate material from each of the nominated sampling locations and allow uniform mixing.

8.1.3 Obtain material for depositing on the mixing pad by removing a further slice of at least 1 m³ from the total height of the exposed face. Deposit the material in the centre of the prepared mixing pad, ensuring that the bucket discharge height is kept as low as possible.

8.1.4 Repeat Steps 8.1.1 and 8.1.3, obtaining a similar quantity of material from each nominated sampling location.

8.1.5 Thoroughly mix the deposited material with the loader, working from various points around the pad, ensuring that the material deposited on the pad is uniformly mixed (Note 13.5). Level the mixed material to form a layer approximately 500 mm thick above the mixing pad.

8.1.6 Obtain the required number of sample increments at positions which are uniformly distributed across the surface of the layer and not less than 500 mm from any top edge (Note 13.6). At each position undertake the following:

a) Insert the blade of the standard shovel vertically into the layer for the full depth of the blade, then place the excavated material into the sample container (Note 13.7). If more material is required, widen the hole helically by obtaining adjacent shovels-full of material using the excavation technique described in this step.

b) Label or otherwise identify the sample container with the field sample number and increment number (Note 13.4).

8.1.7 Repeat Steps 8.1.1 to 8.1.6 for each sample.

8.2 Single layer formed stockpile – loader remove

8.2.1 At a predetermined sampling location, expose a fresh face by removing a slice of material from the total height of the side of the stockpile. Dump the removed material on the stockpile at a location which will not interfere with the sampling process.

8.2.2 Obtain a further slice of at least 1 m³ from the total height of the exposed face. Deposit the material near the base of the stockpile, ensuring that the bucket discharge height is kept as low as possible.

8.2.3 Level the material to form a layer approximately 500 mm thick.

8.2.4 Obtain a sample increment from near the centre of the layer using the standard shovel (Notes 13.6 and 13.7). Insert the blade vertically into the formed layer for the full depth of the blade, then place the excavated material into the sample container. If more material is
required, widen the hole helically by obtaining adjacent shovels-full of material using the excavation technique described in this step.

8.2.5 Label or otherwise identify the sample container with the field sample number and increment number (Note 13.4).

8.2.6 Repeat Steps 8.2.1 to 8.2.5 until the required number of sample increments, having similar quantities of material, is obtained for each sample.

8.3 Single layer formed stockpile – loader backblading

8.3.1 At a predetermined sampling location, climb the loader up the side of the stockpile, then dig the bottom lip of the bucket into the top of the stockpile. Drag at least 1 m$^3$ of material down the face and form a level layer approximately 250 mm thick at the base of the stockpile.

8.3.2 Repeat Step 8.3.1 adding the material to the existing layer.

8.3.3 Obtain a sample increment from near the centre of the layer using the standard shovel (Notes 13.6 and 13.7). Insert the shovel blade vertically into the formed layer for the full depth of the blade, then place the excavated material in the sample container. If more material is required, widen the hole helically by obtaining adjacent shovels-full of material using the excavation technique described in this step.

8.3.4 Label or otherwise identify the sample container with the field sample number and increment number (Note 13.4).

8.3.5 Repeat Steps 8.3.1 to 8.3.4 until the required number of sample increments, having similar quantities of material, is obtained for each sample.

8.4 Single layer formed stockpile – hand tools

8.4.1 At a predetermined sampling location, mark sampling points at approximately 1500 mm spacings up the side of the stockpile, measured from the base. Exclude any point which is within 500 mm of the top of the stockpile.

8.4.2 At each sampling point, obtain a sub-increment to form a sample increment as follows:

a) Insert the shield board vertically into the material. Remove the material down face from the shield, using a horizontal digging action, to a depth of 200 mm to form a bench. Adjust the position of the shield as necessary to prevent material falling onto the bench. Remove material from the front of the bench in order to form a vertical face (Note 13.8).

b) Obtain at least two shovels-full of material by driving the standard shovel horizontally into the stockpile for the full depth of the blade, at a point approximately 100 mm below the bench. Each shovel insertion must be at least 300 mm apart. Place the excavated material into the sample container (Note 13.9). If necessary, extend the length of the excavation horizontally using the excavation technique detailed in Step 8.4.2 (a), ensuring that successive shovel insertions are separated by at least 300 mm.

c) Label or otherwise identify the sample container with the field sample number and increment number (Note 13.4).

8.4.3 Repeat Steps 8.4.1 and 8.4.2 until the required number of sample increments, having similar quantities of material, is obtained for each sample.

8.5 Multiple layer formed stockpile – excavator remove and mix

8.5.1 At a predetermined sampling location, expose a fresh face for the total height of the side of the stockpile and at least to twice the width of the excavator bucket by dragging material down
with the excavator bucket. Dump the removed material on the stockpile at a location which will not interfere with the sampling process.

8.5.2 Remove sufficient material from the total height of the fresh face using the technique described in Step 8.5.1 to form a level mixing pad adjacent to the stockpile. The pad must be of sufficient area to accommodate material from each of the nominated sampling locations and allow uniform mixing.

8.5.3 Obtain material for depositing on the mixing pad by removing a uniform slice, at least one excavator bucket wide, for the total height of the exposed face using the technique described in Step 8.5.1. Deposit the material in the centre of the prepared mixing pad, ensuring that the bucket discharge height is kept as low as possible.

8.5.4 Repeat Steps 8.5.1 and 8.5.3, obtaining a similar quantity of material from each nominated sampling location.

8.5.5 Thoroughly mix the deposited material using a loader, working from various points around the pad, ensuring that the material deposited on the pad is uniformly mixed (Note 13.5). Level the mixed material to form a layer approximately 500 mm thick above the mixing pad.

8.5.6 Obtain the required number of sample increments at positions which are uniformly distributed across the surface of the layer and not less than 500 mm from any top edge (Note 13.6). At each position undertake the following:

a) Insert the blade of the standard shovel vertically into the layer for the full depth of the blade, then place the excavated material in the sample container (Note 13.7). If more material is required, widen the hole helically by obtaining adjacent shovels-full of material using the excavation technique described in this step.

b) Label or otherwise identify the sample container with the field sample number and the increment number (Note 13.4).

8.6 Multiple layer formed stockpile – loader remove and mix

8.6.1 At a predetermined sampling location, expose a fresh face for the total height of the side of the stockpile and at least to twice the width of the loader bucket. This can be achieved by removing material from the stockpile base in order to cause the face above to collapse.

8.6.2 Remove enough material from the total height of the fresh face using the technique described in Step 8.6.1 to form a level mixing pad adjacent to the stockpile. The pad must be of sufficient area to accommodate material from each of the nominated sampling locations and allow uniform mixing.

8.6.3 Obtain material for depositing on the mixing pad by removing a uniform slice, at least one loader bucket wide, from the total height of the exposed face using the technique described in Step 8.6.1. Deposit each bucket of material in the centre of the prepared mixing pad, ensuring that the bucket discharge height is kept as low as possible.

8.6.4 Repeat Steps 8.6.1 and 8.6.3, obtaining a similar quantity of material from each nominated sampling location.

8.6.5 Thoroughly mix the deposited material with the loader, working from various points around the pad, ensuring that the material deposited on the pad is uniformly mixed (Note 13.5). Level the mixed material to form a layer approximately 500 mm thick above the mixing pad.
8.6.6 Obtain the required number of sample increments at positions which are uniformly distributed across the surface of the layer and not less than 500 mm from any top edge (Note 13.6). At each location undertake the following:

a) Insert the blade of the standard shovel vertically into the layer for the full depth of the blade, then place the excavated material into the sample container (Note 13.7). If more material is required, widen the hole helically by obtaining adjacent shovels-full of material using the excavation technique described in this step.

b) Label or otherwise identify the sample container with the field sample number and increment number (Note 13.4).

9 Sampling from heaps or windrows

9.1 Heap - hand tools

9.1.1 At a predetermined sampling location, mark sampling points at approximately 1500 mm spacings up the side of the heap, measured from the base. Exclude any point which is within 500 mm of the top of the heap.

9.1.2 At each sampling point, obtain a sub-increment to form a sample increment as follows:

a) Insert the shield board vertically into the material. Remove the material down face from the shield, using a horizontal digging action, to a depth of 200 mm to form a bench. Adjust the position of the shield as necessary to prevent material falling onto the bench. Remove material from the front of the bench in order to form a vertical face (Note 13.8).

b) Obtain at least two shovels-full of material by driving the standard shovel horizontally into the stockpile for the full depth of the blade, at a point approximately 100 mm below the bench. Each shovel insertion must be at least 300 mm apart. Place the excavated material into the sample container (Note 13.9). If necessary, extend the length of the excavation horizontally using the excavation technique detailed in Step 9.1.2(a), ensuring that successive shovel insertions are separated by at least 300 mm.

c) Label or otherwise identify the sample container with the field sample number and increment number (Note 13.4).

9.1.3 Repeat Steps 9.1.1 and 9.1.2 until the required number of sample increments, having similar quantities of material, is obtained for each sample.

9.2 Heap - sampling tube

9.2.1 At a predetermined sampling location, mark sampling points at approximately 1500 mm spacings up the side of the heap, measured from the base. Exclude any point which is within 500 mm of the top of the heap (Note 13.10).

9.2.2 At each sampling point, obtain a sub-increment to form a sample increment as follows:

a) Insert the tube horizontally into the side of the heap with the slot facing downwards. Rotate the tube through 180°, then withdraw the tube. Place the material from the tube into the sample container (Note 13.11).

b) Label or otherwise identify the sample container with the field sample number and increment number (Note 13.4).

9.2.3 Repeat Steps 9.2.1 and 9.2.2 until the required number of sample increments, having similar quantities of material, is obtained for each sample.
9.3 Windrow – hand tools

9.3.1 At a predetermined sampling location, level the top of the windrow by removing material to a depth of at least 200 mm in order to form a level surface approximately 500 mm wide and 750 mm long.

9.3.2 Obtain a sample increment from near the centre of the levelled surface using the standard shovel. Insert the blade vertically into the surface for the full depth of the blade, then place the excavated material into the sample container. If more material is required, widen the hole helically by obtaining adjacent shovels-full of material using the excavation technique described in this step.

9.3.3 Label or otherwise identify the sample container with the field sample number and increment number (Note 13.4).

9.3.4 Repeat Steps 9.3.1 to 9.3.3 until the required number of sample increments, having similar quantities of material, is obtained for each sample.

10 Sampling from bins and trucks

10.1 Bins

10.1.1 At the predetermined sampling interval, have an authorised operator discharge at least 1 m³ of material onto a level surface such as a truck body.

10.1.2 If the material appears segregated, thoroughly remix using the standard shovel. Level the heap to form a layer which is approximately 500 mm thick.

10.1.3 Obtain a sample increment from near the centre of the layer using the standard shovel (Note 13.7). Insert the blade vertically into the layer for the full depth of the blade, then place the excavated material into the sample container. If more material is required, widen the hole helically by obtaining adjacent shovels-full of material using the excavation technique described in this step.

10.1.4 Label or otherwise identify the sample container with the field sample number and increment number (Note 13.4).

10.1.5 Repeat Steps 10.1.1 to 10.1.4 until the required number of sample increments, having similar quantities of material, is obtained for each sample.

10.2 Trucks

10.2.1 At the predetermined sampling interval, have the selected truck parked in a safe location away from other traffic.

10.2.2 Gain access to the tray of the truck using a ladder or platform. Locate the longitudinal axis of the load or, if the truck is loaded off-centre, the axis which passes through the highest points.

10.2.3 Locate the centre of the longitudinal axis and points on the axis approximately 1000 mm either side of the centre. At each of these points, flatten the load by removing material to a depth of at least 200 mm in order to form a level surface approximately 500 mm wide and 750 mm long.

10.2.4 At each sampling point, obtain a sub-increment to form a sample increment as follows:

a) Insert the blade of the standard shovel vertically into the layer for the full depth of the blade, then place the excavated material into the sample container (Note 13.7). If more material is required, widen the hole helically by obtaining adjacent shovels-full of material using the excavation technique described in this step.
b) Label or otherwise identify the sample container with the field sample number and increment number (Note 13.4).

10.2.5 Repeat Steps 10.2.1 to 10.2.4 until the required number of sample increments, having similar quantities of material, is obtained for each sample.

11 Records
Record the following information on each sample container or on a tag affixed to the container using a durable permanent marker (Note 13.12).

11.1 Date of sampling.
11.2 Material type.
11.3 Source of material.
11.4 Nominal size (mm).
11.5 Sampling location including GPS reference if required.
11.6 Amount of material represented.
11.7 Lot identification, sub-lots, field sample numbers, increment numbers.
11.8 Name of sampler.
11.9 Specific sampling procedure used with reference to the relevant sub-section of this method.
11.10 For material in a stockpile, heap or windrow, a dimensioned plan of the lot showing sample increment locations together with points of reference and, where appropriate, sub-increment locations.
11.11 Any other relevant information.

12 Reporting
The following shall be reported:

12.1 Date of sampling.
12.2 Material type.
12.3 Source of material.
12.4 Sampling location.
12.5 Lot identification.
12.6 Specific sampling procedure used with reference to the relevant sub-section of this method.

13 Notes on method
13.1 Since the loader is capable of stockpiling to a height approximately 300 mm more than its reach, it is acceptable to use the same loader for sampling as was used for stockpile formation.

13.2 The increment numbers and masses of sample increments and sub-increments are the minimum requirements to obtain a representative sample. For particular testing programmes, more increments and/or larger increment masses may be needed in order to obtain sufficient representative material.
13.3 A sample divider must be used where it is necessary to reduce the quantity of any collected material. However, coning and quartering may be used for large essentially single-sized aggregates such as ballast.

13.4 The increment number must also include the number of sample increments required for the sample. For example, 1/4 identifies the first sample increment in a total of four increments.

13.5 While it is acceptable that some pad material may be included in the mixing process, the sampling exercise must be terminated if the mixture becomes contaminated with foreign material from the stockpile floor.

13.6 If the surface of the levelled material is rippled due to the loader bucket, remove sufficient material to expose a fresh and level surface at each sampling position.

13.7 When sampling coarse materials such as rail ballast, the farmer’s friend shovel should be used. To facilitate removal of aggregate, place the shovel mouth on the surface of the material to be sampled. Stabilise the shovel by placing two hands on the upper half of the shovel handle and one foot on the broad footing area on the top of the shovel head. Step up on the footing area of the shovel head and, by placing the second foot together with the operator’s jolting body weight, drive the shovel home.

13.8 A step will now be formed consisting of a horizontal bench with a vertical face below. For some materials, a step can be cut without the need to use a shield board. Other materials, particularly consolidated soils, may need to be loosened in order to form the step and facilitate sampling.

13.9 If material falls onto the shovel from above the bench during sampling, discard the shovel-full of material. If the sampling point cannot be repaired, select a new point adjacent to the benched area.

13.10 When sampling for moisture content, it is necessary to consider the likely moisture gradient within the heap. Select additional sampling points in order to achieve a distribution which is consistent with the cross-section of the heap.

13.11 For a moisture content sample, take all necessary precautions to prevent moisture loss both during and following sampling.

13.12 Sampling information may be recorded on a sampling log or worksheet provided there is a clear and unambiguous link from the record to each container.

Table 1 – Sample increment or sub-increment masses

<table>
<thead>
<tr>
<th>Nominal size (mm)</th>
<th>63</th>
<th>53</th>
<th>40</th>
<th>28</th>
<th>20</th>
<th>16</th>
<th>14</th>
<th>10</th>
<th>7</th>
<th>5</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum mass (kg)</td>
<td>30</td>
<td>25</td>
<td>20</td>
<td>14</td>
<td>10</td>
<td>8</td>
<td>7</td>
<td>5</td>
<td>3.5</td>
<td>2.5</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 2 - Number of increments

<table>
<thead>
<tr>
<th>Lot or sub-lot size (t)</th>
<th>&lt;1000</th>
<th>1000-2000</th>
<th>&gt;2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of increments</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>
Test Method Q061: Spot sampling of soils, crushed rock and aggregates

1 Source
This method was developed in-house using techniques evolved through internal departmental investigations.

2 Scope
This method specifies the procedures for obtaining spot samples of soils, crushed rock and aggregates of nominal size up to 63 mm from pavements or earthworks.

This method does not cover sampling soils for environmental purposes or representative sampling of lots or sub-lots. Representative sampling is covered by Test Method Q060.

3 Apparatus
Following is a comprehensive listing of apparatus required for this method. While some items are common to all procedures, others are specific to particular procedures.

3.1 Sample containers which prevent loss of fines. Airtight containers are required for moisture content samples. Containers are to be of a size or so configured that their maximum capacity does not exceed approximately 20 kg.

3.2 Flat bottomed scoop or trowel and brush.

3.3 Shovels:
3.3.1 Standard shovel, a standard square mouth shovel with raised sides having a blade of approximate dimensions, 300 mm length and 200 mm width.
3.3.2 Post hole shovel, a square mouth post hole shovel having a blade of approximate dimensions, 300 mm length and 200 mm width.
3.3.3 Farmer's shovel, with a minimised square mouth having a blade of approximate dimensions, 300 mm length, 240 mm width and mouth width of 130 mm for coarse materials such as railway ballast.

3.4 Digging tools such as a pick, crowbar or light electric hammer with variable speed control.

3.5 Tape measure, wheel meter, and survey levelling equipment as required.

3.6 Sample divider, complying with the requirements of AS 1141.2.

3.7 Marking system, suitable marking equipment appropriate for the lot under consideration (for example, spray paint, flagging tape, pegs).

4 Definitions
4.1 Nominal Size - The designation of a material that gives an indication of the largest size particles present. The nominal size is expressed as a whole number above the sieve size through which nearly all of the material passes.

4.2 Sample - The material to be forwarded for examination and/or testing.

4.3 Sampling Location - The location, described in terms of longitudinal, lateral and, if required, vertical distance from where a sample is obtained.

4.4 Lot - A portion of material which has been supplied and/or processed under essentially uniform conditions and contains material of essentially uniform quality.
5 Sampling location

5.1 Determine the number of samples to be taken within the lot in accordance with the requirements of the specification, sampling plan or testing methodology as appropriate.

5.2 If not documented in the specification, sampling plan or testing methodology, use random stratified sampling as detailed in Test Method Q050 to determine sampling location for each sample.

6 Compacted layer of earthworks or pavement

Sample the compacted layer using the appropriate sampling procedure as follows:

6.1 General

6.1.1 Determine the quantity of material required for the testing programme, ensuring compliance with the minimum sample mass requirements in Table 1.

6.1.2 At the predetermined sampling location, remove any foreign material, making a note of its presence in the sampling record.

6.1.3 If not sufficiently loose, the layer shall be carefully loosened using suitable tools. Care should be taken not to unnecessarily break down any discrete rock particles.

6.1.4 Excavate a hole with approximately vertical sides and a flat bottom to the full depth of the layer being sampled. Ensure all loose material is recovered and that all material removed is retained as the sample.

6.1.5 For a moisture content sample, take all necessary precautions to prevent moisture loss, both during and following sampling. Ensure the sample container is sealed at the completion of sampling.

6.1.6 Label or otherwise identify the sample container with the field sample number. Sampling information may be recorded on a sampling log or worksheet provided there is a clear and unambiguous link from the record to each container.

6.2 Reference density sample – sand replacement

6.2.1 Determine the quantity of material required, ensuring compliance with the minimum sample mass requirements in Table 1.

6.2.2 Ensure the location for the sample and the surrounding surface is cleaned of loose density sand and any other foreign material.

6.2.3 Enlarge the test hole to obtain sufficient compacted material to determine the laboratory reference density. Ensure the enlarged hole is to the same depth as the sand replacement test hole, the sides are approximately vertical and the bottom of the hole is flat.

6.2.4 If not sufficiently loose, the layer shall be carefully loosened using suitable tools. Care should be taken not to unnecessarily break down any discrete rock particles.

6.2.5 Ensure all loose material is recovered and that all material removed is retained as the sample.

6.2.6 Label or otherwise identify the sample container with the field sample number. Sampling information may be recorded on a sampling log or worksheet provided there is a clear and unambiguous link from the record to each container.

6.3 Reference density sample and/or moisture content sample – nuclear gauge

6.3.1 Determine the quantity of material required, ensuring compliance with the minimum sample mass requirements in Table 1.
6.3.2 Ensure the location for the sample and the surrounding surface is cleaned of loose sand and any other foreign material.

6.3.3 Locate the sampling position for the sample as shown in Figure 1.

6.3.4 Excavate a hole to one of the following depths:
   a) The full depth of the layer where the sampled material is from a pavement, or
   b) The depth used in the nuclear gauge measurement of wet density where the sampled material is from earthworks.

6.3.5 Excavate a hole to obtain sufficient compacted material to determine the laboratory reference density and/or moisture content. Ensure the excavated hole has approximately vertical sides and a flat bottom.

6.3.6 If not sufficiently loose, the layer shall be carefully loosened using suitable tools. Care should be taken not to unnecessarily break down any discrete rock particles.

6.3.7 Ensure all loose material is recovered and that all material removed is retained as the sample.

6.3.8 For a moisture content sample, take all necessary precautions to prevent moisture loss, both during and following sampling. Ensure the sample container is sealed at the completion of sampling.

6.3.9 Label or otherwise identify the sample container with the field sample number. Sampling information may be recorded on a sampling log or worksheet provided there is a clear and unambiguous link from the record to each container.

7 Uncompacted layer of earthworks or pavement

7.1 Determine the quantity of material required for the testing programme, ensuring compliance with the minimum sample mass requirements in Table 1.

7.2 At the predetermined sampling location, remove any foreign material making a note of its presence in the sampling record.

7.3 If required, level the surface using a shovel.

7.4 If not sufficiently loose, the layer shall be loosened using suitable tools. Care should be taken not to unnecessarily break down discrete rock particles.

7.5 Excavate a hole with approximately vertical sides and a flat bottom to the full depth of the layer being sampled. Ensure all loose material is recovered and that all material removed is retained as the sample.

7.5.1 When sampling coarse materials such as rail ballast, the farmer’s shovel should be used. To facilitate removal of aggregate, place the shovel mouth on the surface of the material to be sampled. Stabilise the shovel by placing two hands on the upper half of the shovel handle and one foot on the broad footing area on the top of the shovel head. Step up on the footing area of the shovel head and, by placing the second foot together with the operator’s jolting body weight, drive the shovel home.

7.5.2 For a moisture content sample, take all necessary precautions to prevent moisture loss, both during and following sampling. Ensure the sample container is sealed at the completion of sampling.
7.6 Label or otherwise identify the sample container with the field sample number. Sampling information may be recorded on a sampling log or worksheet provided there is a clear and unambiguous link from the record to each container.

8 Recording

Record the following information using a durable permanent marker on each sample container, sampling log, worksheet or on a tag affixed to the container:

8.1 Date of sampling.
8.2 Name of sampler.
8.3 Material type.
8.4 Sampling location, including GPS reference if required.
8.5 Lot identification, field sample number and increment number.
8.6 Specific sampling procedure used with reference to the relevant section or sub-section of this method.
8.7 Any other relevant information.

9 Reporting

The following shall be reported:

9.1 Date of sampling.
9.2 Material type.
9.3 Sampling location, including GPS reference if required.
9.4 Lot identification.
9.5 Specific sampling procedure used with reference to the relevant section or sub-section of this method.

Table 1 – Minimum sample masses

<table>
<thead>
<tr>
<th>Nominal size (mm)</th>
<th>63</th>
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<th>40</th>
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<th>20</th>
<th>16</th>
<th>14</th>
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<tr>
<td>Minimum mass (kg)</td>
<td>30</td>
<td>25</td>
<td>20</td>
<td>14</td>
<td>10</td>
<td>8</td>
<td>7</td>
<td>5</td>
<td>3.5</td>
<td>2.5</td>
<td>1</td>
</tr>
</tbody>
</table>

These sample masses are based on material with an apparent particle density of 2.65. The masses may need to be adjusted for exceptionally heavy or light material to provide a sample of equivalent volume.
Figure 1 – Sampling location

A: gauge probe access hole location (smaller circle).
B: location for reference density sample and/or moisture content sample (larger circle).
Test Method Q070: Dry coring of bound materials

1 Source
This method was developed in-house using techniques evolved through internal departmental research investigations.

2 Scope
This method describes the procedure to obtain core specimens from bound materials such as concrete and other earthen materials stabilised with bituminous, hydraulic or ionic stabilising agents. The method is suitable for most weakly bound materials, however difficulty may be encountered if coring is attempted at an early age before substantial strength development has occurred.

3 Apparatus
The following apparatus is required:

3.1 Coring machine, consisting of a motor and drill stand. The motor is to be equipped with a swivel assembly and hollow output shaft to allow air to flow via the inside of the coring bit to the cutting face during operation. The drill stand must be able to be held securely in position during coring by either using ballast, applying a vacuum or engaging a mechanical locking device. The drill stand must allow linear vertical movement of the coring bit.

3.2 Thin walled coring bit, capable of producing core specimens having a diameter complying with the requirements of Table 1.

3.3 Core extraction equipment, including pincers with curved blades, a length of 20 mm diameter rod and rubber mallet. The rod and mallet are to facilitate removal of cores retained within the coring bit.

3.4 Mechanical compactor, such as an electric demolition hammer for the compaction of patching material other than non-shrink grout. The compactor is to be equipped with a circular compaction plate having a diameter similar to that of the core hole.

3.5 Vacuum extraction system, capable of removing expelled air and dust from the region of the coring bit. The system should:
   a) provide an adequate seal around the coring bit and with the surface to ensure removal of dust
   b) be fitted with high efficiency particulate air (HEPA) filters, and
   c) include a detachable hose that can be fitted with a nozzle to allow removal of dust from the surface and equipment.

4 Materials
The following materials are required:

4.1 Patching material, of a type which is compatible with the material being cored:
   4.1.1 Concrete - non-shrink grout (Note 8.1).
   4.1.2 Stabilised granular - fresh mixture of the material under test or a low strength non-shrink grout (Note 8.1).

4.2 Compressed air, a continuous supply to remove cuttings from the cutting face and to cool the coring bit.
4.3 Water-proof marker and plastic bags.

4.4 Bituminous emulsion for priming holes (asphalt patching only) (Note 8.1).

5 Procedure

The procedure shall be as follows:

5.1 Select a coring bit which is suitable for the material being cored and which will provide specimens with a diameter specified in Table 1 (Note 8.2).

5.2 Assemble the coring machine and configure the machine to provide the appropriate rotational speed (Notes 8.3 and 8.4).

5.3 Locate the coring bit centrally over the selected test site and adjust the drill stand so that the coring bit is at right angles to the surface being cored.

5.4 Check the alignment of the bit by lowering it to the surface. Adjust the stand until the cutting face makes full contact with the surface, then secure the drill stand into position.

5.5 Raise the coring bit, and then start the motor. Adjust the air flow to ensure there is sufficient air return to flush fines from the cutting face and to cool the coring bit. Ensure the flow rate does not exceed the capacity of the dust extraction system. Start the dust extraction system.

5.6 Lower the bit and bed it into the surface using slight downward pressure if necessary. Once the bit is bedded, apply sufficient pressure to allow coring to proceed at a uniform rate without clogging the bit or significantly reducing the speed of rotation. Monitor and adjust the air flow to ensure there is sufficient air return to flush fines from the cutting face and to cool the coring bit without exceeding the capacity of the dust extraction system (Note 8.5).

5.7 Continue coring until the full depth of the layer has been cored or, where the coring is to be terminated partway through a layer, to a depth of at least 75 mm greater than that specified.

5.8 When coring is complete, raise the coring bit carefully from the hole and stop the motor and air flow. Remove any dust from the surface with the dust extraction system.

5.9 Remove the core without damage as follows:

5.9.1 Where the core is sitting in the core hole, use the pincers to remove the core.

5.9.2 Where the core is still attached to its base, use the pincers to grip and support the core over as much of its length as possible. Apply either a slight sideways pressure or a twisting action to detach the core. A twisting action is preferred if the core is to be separated at a layer interface.

5.9.3 Where the core is retained within the coring bit, use the rubber mallet to gently tap the sides of the bit to facilitate removal. If the core cannot be freed easily, remove the coring bit and use the 20 mm rod to push the core from the threaded end of the coring bit.

5.10 Inspect the core to ensure that it is intact, of the required length, cylindrical in shape, free from unwanted defects and that it has not been damaged or fractured during coring or extraction (Note 8.7).

5.11 Discard any defective core and obtain a replacement core in close proximity to the nominated site as detailed in Steps 5.4 to 5.11.

5.12 Label the core using a waterproof marker, and seal cores other than asphalt in plastic bags. All cores must be packaged and stored so that they are not damaged in transit nor subjected to any artificial temperature conditions.
5.13 Reinstate the cored surface using an appropriate patching material as follows:

5.13.1 Concrete pavement
   a) Remove loose fines from the hole using the vacuum system.
   b) Mix and fully compact the patching material in accordance with the manufacturer’s instructions. Finish the surface flush with the cored surface and protect the patching material from traffic and the environment until final set has occurred.

5.13.2 Stabilised granular pavement
   a) Remove loose fines from the hole using the vacuum system.
   b) Prepare a patching material by obtaining either fresh stabilised material, mix unbound material with the stabilising agent or obtain a low strength low shrink grout.
   c) Compact the patching material in 50-75 mm lifts using the mechanical compactor to fully compact each layer.
   d) Slightly overfill the hole so that the compacted patching material is at a height of approximately 5 mm above the cored surface.
   e) Use the mechanical compactor to form the patching material into a convex mound.

6 Records
   Record the following information for each sample:
   6.1 Date of sampling.
   6.2 An identification number for each core.
   6.3 Type of material.
   6.4 Nominal size (mm).
   6.5 The location of each core including a longitudinal (chainage) and a lateral (offset) reference. Where appropriate, include a plan to show the location of each test site.
   6.6 Manufacturer of material.
   6.7 Name of sampler.
   6.8 A description of each core in terms of general condition, defects and density appearance.

7 Reporting
   When the sample is tested, the following shall be reported:
   7.1 Date of sampling
   7.2 Type of material.
   7.3 Nominal size (mm).
   7.4 The location of each core including a longitudinal (chainage) and a lateral (offset) reference.
   7.5 Manufacturer of material.

8 Notes on method
   8.1 Before handling any patching materials, the operator must consult the relevant Safety Data Sheet (SDS).
8.2 Carefully examine the selected bit to ensure that it is not damaged or excessively worn. Out of shape bits, bits which rotate eccentrically or bits without sufficient diamond matrix must not be used since they are prone to produce cores which are irregularly shaped or fractured.

8.3 The appropriate rotational speed will vary for different coring machines. Typical speeds will be in the range of 700 to 1000 rpm for 100 mm cores and 350 to 650 rpm for 150 mm cores.

8.4 When coring interlayers such as polymer modified binder (PMB) seals, use the highest speed of rotation available.

8.5 Should fines build up on the surface around the rotating bit, do not remove these with compressed air. They should be removed using the dust extraction system.

8.6 Some common causes of defective cores are as follows:
   
a) Rounded edges on the upper surface are caused by poor coring bit seating or by a bit which rotates eccentrically.

b) Irregular sides are a result of incremental change in the rotational plane of the coring bit due to the use of a worn bit and/or excessive downward pressure during coring.

c) Loss of fines from the surface of weakly bound (stabilised) materials can be due to the abrasive action of loose pieces of aggregate.

**Table 1 – Core diameter**

<table>
<thead>
<tr>
<th>Material/application</th>
<th>Test</th>
<th>Nominal size (mm)</th>
<th>Core diameter (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete* or stabilised material#</td>
<td>USC and density</td>
<td>Aggregate &gt; 20</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aggregate ≤ 20</td>
<td>100# or 150</td>
</tr>
</tbody>
</table>

*It is preferred that concrete UCS specimens have a height to diameter (h/d) ratio of 2. Where the stipulated diameter isn't practical for thin layers, cores having lesser diameters can be taken provided the diameter is 4 times the nominal maximum particle size and the h/d ratio is not less than 1.

#It is preferred that stabilised material UCS specimens have a height to diameter (h/d) ratio of 1.15. Generally 100 mm diameter cores should always be taken provided the height diameter ratio is not less than 1.15 or greater than 2.0.
Materials Testing Manual

Part 4: Soils, Crushed Rock and Stabilised Materials
Test Method Q101: Preparation of disturbed samples

1 Source
This method was developed in-house using techniques evolved through internal departmental investigations.

2 Scope
This method describes procedures for preparing samples of soil and aggregate as received from the field for testing. The preparation procedures include breaking up of aggregations of fines and soil clods, removal of coatings of fines from aggregate particles, crushing, separation by screening and splitting out of representative subsamples. This method may also be applied to the preparation of Winton Sandstone (Note 7.1).

3 Apparatus
The following apparatus is required:

3.1 Drying oven of suitable capacity, having a temperature of 45-50°C and complying with AS 1289.0.
3.2 Screen, 10 mm.
3.3 Sieves, 37.5, 19.0, 9.50, 4.75 and 2.36 mm complying with AS 1152.
3.4 Sample preparation machine (shredder).
3.5 Sample preparation machine (mulcher).
3.6 Knife for slicing clay lumps.
3.7 Mixing apparatus, for example, shovel, scoop or trowel.
3.8 Cone and quartering equipment:
   3.8.1 Quartering cross (optional)
   3.8.2 Shovel, flat bottomed scoop or trowel
3.9 Brush.
3.10 Sample containers which prevent loss of fines. Airtight containers are required for moisture content samples. Containers are to be of a size or so configured that their maximum capacity does not exceed approximately 20 kg.
3.11 Suitable trays or containers for oven or air drying of subsamples.

4 Materials
The following materials are required:

4.1 Dispersing agent
   • Prepare by dissolving 33 g of sodium hexametaphosphate (LR Grade) and 7 g of anhydrous sodium carbonate (LR Grade) or 18.9 g of sodium carbonate decahydrate (LR Grade) in one litre of water (Notes 7.2 and 7.3).
5 Preliminary sample preparation

Preliminary sample preparation shall be as follows:

5.1 Sample assessment

5.1.1 Assess the bulk sample to determine if it is in a free-flowing condition and contains any large aggregations of fines or soil clods (Notes 7.4 and 7.5).

5.1.2 If the sample is free-flowing and contains no large aggregations, then conduct the preliminary sample preparations as detailed in Subsection 5.3.

5.1.3 If the sample is not in an acceptable condition then precondition it as detailed in Subsection 5.2 and prepare the preconditioned sample as detailed in Subsection 5.3.

5.2 Sample preconditioning

5.2.1 If the moisture content "as received" is required, combine and split by coning and quartering the bulk sample as detailed in the appropriate subsection(s) in Test Method Q101A until the required test subsample is obtained.

5.2.2 Test the subsample to determine its moisture content (w) as detailed in Test Method Q102A or one of the subsidiary Test Methods Q102B or Q102D, for which a relationship with Test Method Q102A has been established and used in accordance with Test Method Q010. Alternatively, seal the subsample in an airtight container and test as detailed in Subsection 6.1 (Note 7.6).

5.2.3 Air dry or oven dry at 45-50°C the remaining material until a free-flowing condition is reached. To facilitate drying, any clay lumps may be sliced prior to drying or shredded using a shredder or mulcher.

5.2.4 Break up any large aggregations of fines or soil clods as detailed in the appropriate subsection(s) in Test Method Q101D and mix back into the remainder of the sample.

5.2.5 For Winton Sandstone samples, screen the sample on a 2.36 mm sieve and remove coatings of fines from the retained material by using the appropriate subsection(s) in Test Method Q101D. Recombine the material retained on the 2.36 mm sieve with the material passing the 2.36 mm sieve (Note 7.7).

5.3 Sample combination and splitting

5.3.1 Combine the bulk sample if necessary to form representative subsamples as detailed in the appropriate subsection in Test Method Q101A (Note 7.6).

5.3.2 Estimate the approximate quantity of material required for the testing program from the appropriate test method(s).

5.3.3 Further split the representative subsample(s) to provide subsamples for each test in the testing program using the appropriate subsection in Test Method Q101B.

5.3.4 Air or oven dry the subsamples which require drying prior to further preparation or testing. Use a temperature of 45-50°C for oven drying unless otherwise specified in the appropriate test method.

5.3.5 Set aside subsamples which do not require drying for further preparation or testing.

5.4 Pretreatment

Where there is a requirement to simulate the material breakdown that will occur during the construction process, pre-treat the subsample as detailed in Test Method Q101E (Note 7.8).
6 Test subsample preparation

Test subsample preparation shall be as follows:

6.1 Moisture content subsamples

6.1.1 Reduce the subsamples prepared as detailed Step 5.2.1 or Subsection 5.3 using the appropriate subsection(s) in Test Method Q101B (Note 7.6).

6.1.2 Test the subsample to determine its moisture content (w) as detailed in Test Method Q102A or one of the subsidiary Test Methods Q102B or Q102D, for which a relationship with Test Method Q102A has been established and used in accordance with Test Method Q010.

6.2 Compaction subsamples

6.2.1 Screen the subsample prepared as detailed in Section 5 over a sieve (screening sieve) equal in aperture size to the maximum particle size to be used in the test.

6.2.2 Break up aggregations of fines or soil clods and remove coatings of fines from the retained material by using the appropriate subsection(s) in Test Method Q101D. Discard the clean aggregate retained on the screening sieve (Note 7.9) and include the material passing the screening sieve with the remainder of the sample.

6.2.3 Process the material passing the screening sieve to ensure that all aggregations of fines or soil clods have been broken up and coatings of fines removed so that, if the subsample was sieved on a 9.50 mm sieve, only discrete uncrushed particles would be retained (Notes 7.10, 7.11 and 7.12).

6.2.4 If necessary, combine all the material passing the screening sieve using the appropriate subsection in Test Method Q101A.

6.2.5 Obtain test subsamples by further splitting or by fractionation as detailed in Test Method Q101B or Q101C respectively.

6.2.6 Place the prepared test subsamples in airtight containers.

6.3 Coarse fraction subsample

Where the test requires subsamples containing uncrushed discrete particles retained on a specified sieve, prepare the subsample as follows:

6.3.1 Screen the subsample prepared as detailed in Section 5 on the specified sieve (screening sieve) and discard the material passing the sieve or keep separate for use in other tests if required.

6.3.2 Break up any aggregations of fines or soil clods retained on the screening sieve using an appropriate subsection in Test Method Q101D.

6.3.3 Re-sieve the material and discard the material passing or include with the passing material from Step 6.3.1.

6.3.4 Reduce the retained material if necessary as detailed in Test Method Q101B.

6.3.5 Wash the subsample (Note 7.13).

6.3.6 Dry the subsample as specified in the appropriate test method.

6.3.7 Reduce the subsample as detailed in Test Method Q101B to obtain the required test subsample(s).

6.3.8 Place the prepared test subsample(s) in an airtight container.
6.4  Fine fraction subsample
Where the test requires subsamples containing uncrushed discrete particles passing a specified sieve, prepare the subsamples as follows:

6.4.1 Screen the subsample prepared as detailed in Section 5 on the specified sieve.
6.4.2 Break up all aggregations of fines and soil clods and remove coatings of fines from the material retained on the sieve using the appropriate subsection in Test Method Q101D.
6.4.3 Re-sieve the material and discard the retained material or keep the retained separate to be used in other tests if required.
6.4.4 Combine the material passing the specified sieve using an appropriate subsection in Test Method Q101A.
6.4.5 Reduce the combined material as detailed in Test Method Q101B to obtain the required test subsample(s).
6.4.6 Place the prepared test subsample(s) in an airtight container.

6.5  Specified fraction subsample
Where the test requires a specified fraction size or a combination of fraction sizes, prepare the subsample as follows:

6.5.1 Screen the subsample prepared as detailed in Section 5 over the smallest sieve specified by the fraction. Discard the passing material or keep separate to be used in other tests if required.
6.5.2 Break up any aggregations of fines retained on the sieve using an appropriate subsection in Test Method Q101D.
6.5.3 Re-sieve the material over the specified sieves and discard the material retained on the largest sieve. Discard the material passing the smallest sieve or include with the passing material from Step 6.5.1.
6.5.4 Wash the fraction(s) (Note 7.13).
6.5.5 Dry the fraction(s) as specified in the appropriate test method.
6.5.6 Reduce the fraction(s) as detailed in Test Method Q101B to obtain the required test subsample(s).
6.5.7 Place the prepared test subsample(s) in an airtight container.

6.6  Crushed subsample
Prepare a crushed subsample as follows:

6.6.1 Crush the subsample prepared as detailed in Section 5 or Sections 5 and 6 to pass the specified sieve using the appropriate subsection in Test Method Q101D (Notes 7.14 and 7.15).
6.6.2 Reduce the subsample as detailed in Test Method Q101B to obtain the required test subsample mass.
6.6.3 Place the prepared test subsample in an airtight container.
7 Notes on method


7.2 Before handling hydrogen peroxide, concentrated hydrochloric acid, sodium hexametaphosphate, anhydrous sodium carbonate, sodium carbonate decahydrate, barium chloride or anhydrous silica gel, the operator must consult the relevant Safety Data Sheet (SDS).

7.3 This solution is unstable and must be freshly prepared approximately once a month with the preparation and expiry dates recorded on the container.

7.4 All foreign matter such as roots and sticks should be removed from the material during processing. The final report should detail any foreign matter found in the sample.

7.5 It is not necessary or desirable to dry the material before commencing preparation. In order to reduce dust nuisance it is preferable that splitting be done on a moist sample. However, the material shall be sufficiently dry to ensure representative subsamples are obtained.

7.6 Prepare test subsamples for determination of moisture content "as received" so as to minimize any moisture loss during the preparation.

7.7 Generally a mortar and pestle is the most suitable method of cleaning and grinding the Winton Sandstone material retained on the 2.36 mm sieve.

7.8 For Winton Sandstone materials pre-treatment is required unless the sample is obtained from a compacted pavement.

7.9 Particular test methods require that the mass of material retained on the screening sieve be recorded and reported. For these methods, the total mass of retained material must be recorded and if required, a representative sample taken for moisture content determination in accordance with Test Method Q102A.

7.10 A sieve other that 9.50 mm may be used. However, an increased sieve aperture will result in an increase in curing time. A decrease in aperture sieve will reduce curing time, but can substantially increase preparation time.

7.11 For Winton Sandstone material a 2.36 mm sieve should be used.

7.12 When preparing moist subsamples which have low to medium plasticity, it is not necessary to remove coatings of fines provided the particles are only lightly coated.

7.13 Most materials may be washed without the addition of a dispersing agent. However, soaking in a solution of sodium hexametaphosphate (Calgon) may be necessary if the sample contains highly plastic fines.

7.14 In order to reduce the preparation time when all of a subsample has been crushed to totally pass a particular sieve listed in Table 1, a further subsample may be taken in accordance with an appropriate subsection in Test Method Q101B. This subsample shall be crushed to pass a smaller sieve in Table 1. This process of progressive crushing and subsampling may be continued until the required particle size is obtained.

7.15 For preparation of subsamples for chemical testing Test Method Q101F should be used.
### Table 1 - Minimum subsample mass

<table>
<thead>
<tr>
<th>Maximum particle size in subsample* (mm)</th>
<th>Minimum mass of subsample (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>125</td>
</tr>
<tr>
<td>100</td>
<td>70</td>
</tr>
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<td>75</td>
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<td>53</td>
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<td>37.5</td>
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<td>26.5</td>
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<tr>
<td>9.50</td>
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<td>4.75</td>
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<td>0.1</td>
</tr>
<tr>
<td>0.425</td>
<td>0.05</td>
</tr>
</tbody>
</table>

*Maximum particle size is identical with the size of the smallest sieve through which the material will pass.
Test Method Q101A: Sample combination and splitting

1 Source

This method was developed in-house using techniques evolved through internal departmental investigations.

2 Scope

Representative subsamples can be obtained by either total sample combination or lot combination. Total sample combination should be employed when the bulk sample as received is 12 containers or less. Lot combination should be employed in all cases where more than 12 containers are received.

3 Apparatus

The following apparatus is required:

3.1 Increment containers, of a size or so configured that their maximum capacity does not exceed approximately 20 kg.

3.2 Labels or tags and marking pens.

3.3 Sample divider (riffle), complying with the requirements of AS 1141.2.

3.4 Rotary cone splitter.

3.5 Cone and quartering equipment:

3.5.1 Quartering cross (optional).

3.5.2 Shovel, flat bottomed scoop or trowel.

3.5.3 Brush.

4 Riffling

4.1 Total sample combination (refer to Figure 1)

4.1.1 Place a portion of the sample in a riffle box ensuring even distribution, hand placing large particles if necessary (Note 7.1).

4.1.2 Split the sample by pouring the material at a uniform rate over the chutes of the riffle, ensuring that no blockages occur and that any oversize particles are divided evenly between the two receiving riffle boxes.

4.1.3 If the two receiving boxes contain sufficient material, temporarily suspend riffling. Set the two receiving riffle boxes aside, place two empty riffle boxes at the collection points and continue riffling.

4.1.4 Repeat Steps 4.1.1 to 4.1.3 until all the material has been split.

4.1.5 Keep all the material accumulated at each of the two collection points separate from each other to form two sample increments.

4.1.6 Using the riffle, split each sample increment to produce two smaller sample increments, one at each collection point. Keep these smaller sample increments separate from each other.

4.1.7 Repeat Step 4.1.6 until such time as the resulting sample increments each comprises only one subsample (that is, one riffle box). The subsamples are now representative (Note 7.1).
4.2 Lot combination
This procedure has the advantage of dividing the bulk sample into manageable lots or groups.

4.2.1 Sort the bulk sample as received into equal lots of similar volume (for example, a bulk sample of 16 containers, 4 lots of 4 containers would be prepared and the containers labelled accordingly).

4.2.2 Combine all of the material within a lot (for example, containers 1 to 4 of lot 1) as detailed in Subsection 4.1.

4.2.3 Place the subsamples produced in the appropriately labelled containers, such that each container contains the same number of sample increments.

4.2.4 Repeat Steps 4.2.2 and 4.2.3 for each of the remaining lots.

4.2.5 Obtain representative subsamples by combining an equal number of containers from each lot as detailed in Subsection 4.1.

5 Rotary cone splitter
This device is suitable for material having a maximum particle size not exceeding 37.5 mm.

5.1 Total sample combination (refer to Figure 2)
5.1.1 Place a portion of the sample in the hopper, taking care to ensure that there is no appreciable segregation of material (Note 7.1).

5.1.2 Place an increment container at each collection point.

5.1.3 Rotate the receivers at a constant speed and allow the hopper to discharge in one operation.

5.1.4 Empty the contents of each receiver into its corresponding increment container.

5.1.5 Split all the material in accordance with Steps 5.1.1, 5.1.3 and 5.1.4. Each sample increment is now representative.

5.1.6 Should smaller subsamples be required, repeat Steps 5.1.1 to 5.1.4 using one or more complete sample increments prepared in Step 5.1.5.

5.2 Lot combination
This procedure has the advantage of dividing the bulk sample into easily managed lots or groups.

5.2.1 Sort the bulk sample as received into equal lots of similar volume (for example, a bulk sample of 48 containers, 4 lots of 12 containers would be prepared and the containers labelled accordingly).

5.2.2 Combine all the material within a lot (for example, containers 1 to 12 of lot 1) as detailed in Subsection 5.1.

5.2.3 Place the sample increments produced in the appropriately labelled containers such that each container contains the same number of whole sample increments.

5.2.4 Repeat Steps 5.2.2 and 5.2.3 for each of the remaining lots.

5.2.5 Obtain representative subsamples by combining an equal number of containers from each lot as detailed in Subsection 5.1.
6 Coning and quartering

Combining samples by coning and quartering should only be used in situations where other procedures are not appropriate.

6.1 Place the material on a clean flat surface and thoroughly mix using a shovel, flat bottomed scoop, trowel or other suitable apparatus.

6.2 Form the material into a cone and then flatten into a circular layer of approximately uniform thickness.

6.3 Divide the material into quarters and then gather the diagonally opposite quarters and mix to form two subsamples. Form each subsample as detailed in Step 6.2.

6.4 Repeat Step 6.3 for each subsample until such time as the resultant subsamples are of the required size.

7 Notes on method

7.1 The minimum mass of material to be split should be such that the quantity of material collected in each riffle box/receiver is equal to the minimum mass required for a representative subsample in accordance with Table 1. However, in the case of materials with a maximum particle size larger than 37.5 mm, this rule cannot always be observed due to capacity of available apparatus.

Table 1 – Minimum subsample mass

<table>
<thead>
<tr>
<th>Maximum particle size in subsample *(mm)</th>
<th>Minimum mass of subsample (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>125</td>
</tr>
<tr>
<td>100</td>
<td>70</td>
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<td>75</td>
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<td>4.75</td>
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<td>2.36</td>
<td>0.1</td>
</tr>
<tr>
<td>0.425</td>
<td>0.05</td>
</tr>
</tbody>
</table>

*Maximum particle size is identical with the size of the smallest sieve through which the material will pass.
Figure 1 – Total sample combination by riffling
**Figure 2 – Total sample combination by rotary cone**

- *Bulk Sample - Twelve Containers*
  - At the completion of Step 5.1.4

- *Subsample approximately one half of a container (all containers)*
  - Rotary Cone Splitter
  - At the completion of Step 5.1.5

- *Subsample approximately two containers (all containers)*
  - Rotary Cone Splitter

**Legend**
- Sample
- Increment Container
  - Rotary Cone Splitter

*Superseded*
Test Method Q101B: Representative sample reduction

1 Source
This method was developed in-house using techniques evolved through internal departmental investigations.

2 Scope
Representative test subsamples of approximate, minimum and specified mass are prepared from representative subsamples, obtained from Test Method Q101A where necessary, by splitting using a riffle or rotary cone splitter.

3 Apparatus
The following apparatus is required:

3.1 Increment containers, of a size or so configured that their maximum capacity does not exceed approximately 20 kg.

3.2 Labels or tags and marking pens.

3.3 Sample divider (riffle), complying with the requirements of AS 1141.2.

3.4 Rotary cone splitter.

4 Riffle

4.1 Approximate/minimum test subsample mass
4.1.1 Place a portion of the representative subsample in a riffle box ensuring even distribution, hand placing large particles if necessary.

4.1.2 Split the sample by pouring the material at a uniform rate over the chutes of the riffle ensuring that no blockages occur. Divide oversize particles evenly between the two riffle boxes.

4.1.3 Repeat Steps 4.1.1 to 4.1.2 until all the material has been split.

4.1.4 Repeat Step 4.1.2 using any combination of representative subsamples until the required number of representative test subsamples of the required approximate or minimum mass have been obtained.

4.2 Specified test subsample mass
4.2.1 Place a portion of the representative subsample in the riffle box ensuring even distribution, hand placing large particles if necessary.

4.2.2 Split the sample by pouring the material at a uniform rate over the chutes of the riffle ensuring that no blockages occur. Divide oversize particles evenly between the two riffle boxes.

4.2.3 Repeat Steps 4.2.1 and 4.2.2 until the material has been split.

4.2.4 Repeat Step 4.2.2 using any combination of representative subsamples until the required number of test subsamples of approximate mass, but less than that specified, have been obtained.

4.2.5 Cone and quarter a representative subsample as detailed in Test Method Q101A. Use this subsample as a stock subsample to increase the mass of the subsamples previously obtained at Step 4.2.4.
4.2.6 Use a flat bottomed scoop to obtain a representative subsample from the stock subsample. Add the scooped material to a subsample obtained in Step 4.2.4 until the specified test subsample mass is obtained (Note 6.1).

4.2.7 Repeat Step 4.2.6 until all the test subsamples have been brought to the specified mass.

5 Rotary cone splitter

This device is suitable for material having a maximum particle size not exceeding 37.5 mm.

5.1 Approximate/minimum test subsample mass

5.1.1 Place a portion of the representative subsample in the hopper taking care to ensure that there is no appreciable segregation of material.

5.1.2 Place an increment container at each collection point.

5.1.3 Rotate the receivers at a constant speed and allow the hopper to discharge in one operation.

5.1.4 Empty the contents of each receiver into its corresponding increment container.

5.1.5 Repeat Steps 5.1.1, 5.1.3 and 5.1.4 until the whole representative subsample has been split.

5.1.6 Repeat Steps 5.1.1 to 5.1.4 using any combination of representative subsamples until the required number of representative test subsamples of the required approximate/minimum mass have been obtained.

5.2 Specified test subsample mass

5.2.1 Place a portion of the representative subsample in the hopper taking care to ensure there is no appreciable segregation of material.

5.2.2 Place an increment container at each collection point.

5.2.3 Rotate the receivers at a constant speed and allow the hopper to discharge in one operation.

5.2.4 Empty the contents of each receiver into its corresponding increment container.

5.2.5 Repeat Steps 5.2.1, 5.2.3 and 5.2.4 until the whole representative subsample has been split.

5.2.6 Repeat Steps 5.2.1 to 5.2.4 using any combination of representative subsamples until the required number of test subsamples of approximate mass, but less than that specified, have been obtained.

5.2.7 Cone and quarter a representative subsample as detailed in Test Method Q101A. Use this subsample as a stock subsample to increase the mass of the subsamples previously obtained at Step 5.2.6.

5.2.8 Use a flat bottomed scoop to obtain a representative subsample from the stock subsample. Add the scooped material to a subsample obtained in Step 5.2.6 until the specified test subsample mass is obtained (Note 6.1).

5.2.9 Repeat Step 5.2.8 until all the test subsamples have been brought to the specified mass.

6 Notes on method

6.1 At no time shall material be added to a test subsample by hand or by pouring from a container.
Test Method Q101C: Fractionation

1 Source
This method was developed in-house using techniques evolved through internal departmental investigations.

2 Scope
Representative test subsamples of specified mass are obtained by fractionation. This procedure has particular application when preparing compaction subsamples and representative subsamples of the total material.

3 Apparatus
The following apparatus is required:

3.1 Sieves, 37.5 mm, 19.0 mm, 9.50 mm and 4.75 mm complying with AS 1152, or mechanical apparatus with perforated plate or woven wire mesh of equivalent apertures.

3.2 Balances:
3.2.1 Balance of suitable capacity, having a resolution of at least 1 g and with a limit of performance within the range of ± 5 g.
3.2.2 Balance of suitable capacity, having a resolution of at least 0.1 g and with a limit of performance within the range of ± 0.5 g.
3.2.3 Balance of suitable capacity, having a resolution of at least 0.01 g and with a limit of performance within the range of ± 0.05 g.

4 Procedure
The procedure shall be as follows:

4.1 Divide the material into predominately single size fractions by sieving. Recommended size fractions for compaction subsamples are contained in Table 1.

4.2 Determine the total mass of each individual fraction \( f_M \).

4.3 Calculate the total mass of all individual fractions to be combined as follows:

\[
M_t = \sum f_M
\]

where
- \( M_t \) = total mass of all individual fractions to be combined (g)
- \( f_M \) = total mass of individual fraction (g)

4.4 Calculate the proportion of each fraction in the subsample as follows:

\[
P_r = \frac{M_r}{M_t}
\]

where
- \( P_r \) = proportion of individual fraction in the subsample
- \( M_r \) = total mass of individual fraction (g)
- \( M_t \) = total mass of all individual fractions to be combined (g)
4.5 Calculate the mass of each individual fraction to be used to produce a test subsample as follows (Notes 5.1 and 5.2):

\[ M_i = M_s P_r \]

where

- \( M_i \) = mass of individual fraction in the subsample (g)
- \( M_s \) = mass of test subsample (g)
- \( P_r \) = proportion of individual fraction in the subsample

4.6 Where necessary combine all individual fractions of the same size.

4.7 Combine the individual subsample fraction masses to form the required test subsample(s) mass (Note 5.3).

5 Notes on method

5.1 When a test subsample has been specified in terms of dry mass, determine the moisture content (hygroscopic) for each individual fraction as detailed in Test Method Q102A. This hygroscopic moisture content is used to calculate the required wet mass of each individual fraction in the test subsample. Calculate the wet mass of each of the individual fractions as follows:

\[ M_i = M_s P_r \left(1 + \frac{w}{100}\right) \]

where

- \( M_i \) = mass of individual fraction in the subsample (g)
- \( M_s \) = mass of test subsample (g)
- \( P_r \) = proportion of individual fraction in the subsample
- \( w \) = hygroscopic moisture content of the individual fraction (%)

5.2 Individual fractions should be retained in airtight containers to prevent contamination and moisture variation during storage. Where the individual fractions have been stored for longer than 48 hours, a moisture content determination should be carried out before calculating the fraction masses for a test subsample.

5.3 The individual fraction masses may be obtained by using an appropriate procedure detailed in Test Method Q101B.

Table 1 – Fraction sizes for compaction subsamples

<table>
<thead>
<tr>
<th>Size fractions (mm)</th>
<th>Passing</th>
<th>Retained</th>
</tr>
</thead>
<tbody>
<tr>
<td>37.5</td>
<td></td>
<td>19.0</td>
</tr>
<tr>
<td>19.0</td>
<td></td>
<td>9.50</td>
</tr>
<tr>
<td>9.50</td>
<td></td>
<td>4.75</td>
</tr>
<tr>
<td>4.75</td>
<td></td>
<td>-</td>
</tr>
</tbody>
</table>
Test Method Q101D: Break-up, cleaning and crushing

1 Source

This method was developed in-house using techniques evolved through internal departmental investigations.

2 Scope

This procedure allows for the breaking up of aggregations of fines and soil clods, and the removal of coatings of fines from aggregate particles.

3 Apparatus

For break-up and cleaning the following apparatus is required:

3.1 Laboratory jaw crusher.
3.2 Soil preparation machine (mulcher).
3.3 Soil preparation machine (shredder).
3.4 Motorised tumbler.
3.5 Mortar and rubber pestle.
3.6 Wire brush and scraping knife.
3.7 Mallet, made of steel, wood or rubber.
3.8 Sieves, complying with AS 1152 of the following sizes:
   3.8.1 For screening materials, 37.5 mm, 19.0 mm, 6.70 mm, 4.75 mm, 2.36 mm and other sieve sizes as required.
   3.8.2 For screening crushed materials, 19.0 mm, 6.70 mm, 0.425 mm, 0.075 mm and other sieve sizes as required.

For crushing the following additional apparatus is required:

3.9 Mini-jaw crusher.
3.10 Motorised mortar and pestle.
3.11 Mortar and pestle, steel or porcelain.
3.12 Vibratory disc mill or ring grinder.

4 Break-up and cleaning

4.1 Laboratory jaw crusher

This apparatus can be used to break up soil clods (Note 6.1):

4.1.1 Inspect the feed box, jaws, discharge chute and sample receiver and clean if necessary.
4.1.2 Set the moving jaw to the required gap. When breaking up soil clods it is sometimes necessary to progressively reduce to the required gap by using a number of jaw settings.
4.1.3 Start the crusher and progressively feed the material.
4.1.4 Stop the crusher and screen the broken-up material over the appropriate sieve. Pass any oversize soil clods back through the crusher.
4.1.5 Repeat Steps 4.1.3 and 4.1.4 until all the soil clods have been broken up.

4.2 Soil preparation machine (mulcher)
This apparatus can be used to break up soil clods containing gravel and aggregations of fines.

4.2.1 Inspect the receiver and clean if necessary.

4.2.2 Start the machine and progressively feed the material.

4.2.3 Take care not to break any discrete rock particles (Note 6.4). If any breakdown of the rock is evident, it may be necessary to break up the material using a method with less impact as detailed in Subsections 4.4, 4.5 or 4.6.

4.2.4 Repeat Steps 4.2.2 to 4.2.3 until such time as clods and aggregations are broken up.

4.3 Soil preparation machine (shredder)
This apparatus can be used to break up soil clods and aggregations of fines (Note 6.2).

4.3.1 Inspect the hopper and receiver and clean if necessary.

4.3.2 Start the machine and progressively feed the material.

4.3.3 Using the lever, press the material against the mesh plate to shred the material.

4.3.4 Repeat Steps 4.3.2 to 4.3.3 until such time as clods and aggregations are broken up.

4.4 Motorised tumbler
This apparatus can be used to break up soil clods and aggregations of fines and to remove coatings of fines from particles.

4.4.1 Inspect the bowl or drum and the charge of steel balls or rods and clean if necessary.

4.4.2 Place the material in the bowl or drum with a small charge if required. The size of the charge will depend on the capacity of the apparatus and the volume and type of material (Note 6.3).

4.4.3 Secure the dust cover or lid in place and start the tumbler.

4.4.4 Take care not to break any discrete rock particles (Note 6.4). If any breakdown of the rock is evident, reduce the size of the charge until such time that no breakdown occurs.

4.4.5 Check the material at frequent intervals and sieve when necessary to prevent an accumulation of fines (Note 6.5).

4.4.6 Repeat Steps 4.4.2 to 4.4.5 until such time as clods and aggregations are broken up and coatings removed.

4.5 Mortar and rubber pestle
The mortar and rubber pestle can be used to break up soil clods and aggregations fines and to remove coatings of fines from particles. The rubber pestle should be used whenever there is any possibility of breaking down low strength discrete particles.

4.5.1 Place sufficient material in the mortar to cover its base.

4.5.2 Grind the sample with the pestle ensuring that any ejected material is returned to the mortar.

4.5.3 Take care not to break any discrete rock particles (Note 6.4). If any breakdown of the rock is evident, reduce the pressure exerted on the pestle. Where there is only a minor proportion of these particles it may be expedient to remove them. The particles should be returned to the sample at the completion of grinding.
4.6 Wire brush and scraping knife

A wire brush and scraping knife can be used to remove coatings of fines from particles (Note 6.4).

4.7 Mallet

A mallet can be used to break up soil clods and aggregations of fines (Notes 6.1 and 6.4).

5 Crushing

5.1 Laboratory jaw crusher or mini-jaw crusher

5.1.1 Inspect the feed box, jaws, discharge chute and sample receiver and clean if necessary.

5.1.2 Set the moving jaw to the required gap (Note 6.6).

5.1.3 Start the crusher and feed the material at a uniform rate so that the hopper is kept almost full.

5.1.4 Stop the crusher, collect the crushed material and screen over the appropriate sieve(s).

5.1.5 Adjust the gap between the jaws if necessary and pass the oversize material through the crusher.

5.1.6 Repeat Steps 5.1.2 to 5.1.5 until all the material has been crushed to the required size(s).

5.2 Motorised mortar and pestle

The motorised mortar and pestle can be used to crush rock fragments.

5.2.1 Inspect the equipment and clean if necessary.

5.2.2 Start the motorised mortar and pestle and feed rock fragments into the mortar.

5.2.3 Check the material at frequent intervals and sieve when necessary to prevent an accumulation of fines (Note 6.5).

5.2.4 Repeat Steps 5.2.2 and 5.2.3 until all the material has been crushed to the required size(s).

5.3 Mortar and pestle

A steel mortar and pestle can be used to crush small rock samples with a maximum particle size of approximately 37.5 mm. The porcelain mortar and pestle can be used to pulverize samples with a maximum particle size of approximately 2.36 mm.

5.3.1 Inspect the mortar and pestle and clean if necessary.

5.3.2 Place sufficient material in the mortar to cover its base. Crush the material ensuring that any ejected material is returned to the mortar.

5.3.3 Sieve the sample frequently during the crushing process to prevent an accumulation of fines (Note 6.5).

5.3.4 Repeat Steps 5.3.2 and 5.3.3 until all the material has been crushed to the required size(s).

5.4 Vibratory disc mill or ring grinder

A vibratory disc mill or ring grinder can be used to crush small rock samples with a maximum particle size of approximately 6.70 mm. They can produce material finer than 0.075 mm.

5.4.1 Inspect the bowl and rings and clean if necessary.

5.4.2 Set the mill/grinder to run for an appropriate time (usually 15 seconds is sufficient).

5.4.3 Place the rings into the bowl and add material to quarter-half fill the bowl.
5.4.4 When the mill/grinder stops, collect the crushed material and screen over the appropriate sieve(s).

5.4.5 Return any oversize material to the mill/grinder (Note 6.7).

5.4.6 Repeat Steps 5.4.3 to 5.4.5 until all the material has been crushed to the required size(s).

6 Notes on method

6.1 This equipment is only suitable for soil clods which are substantially dry and have no appreciable quantity of discrete rock particles which could be crushed and thereby prejudice test results.

6.2 This equipment is only suitable for soil clods which are dry to moist and have no appreciable quantity of discrete rock particles.

6.3 The size of the charge shall be kept as small as possible to prevent break-up of discrete rock particles. It is sometimes unnecessary to use a charge when there is a significant proportion of rock in the material.

6.4 Where difficulty exists ascertaining whether particles are discrete or in fact aggregations of fines, a small number of them shall be placed in water and boiled. If disaggregation occurs, such particles shall be considered as aggregations of fines.

6.5 The production of an excessive quantity of fines will reduce the effectiveness of the process due to their cushioning effect.

6.6 When crushing rock the general rule is to set the moving jaw gap to half the maximum particle size of the rock being crushed.

6.7 If a small quantity of oversize material remains after grinding and screening, the crushing can be completed using the mortar and pestle.
Test Method Q101E: Pre-treatment

1 Source

This method was developed in-house using techniques evolved through internal departmental investigations (Main Roads Barcaldine District, "Pre-Treatment of Decomposed Sandstone" D07-01-1987 and Vanderstaay A.G.B., “Material Sources in Western Queensland", Western Queensland Best Practice Guidelines – WQ33, May 2000).

2 Scope

This pre-treatment procedure is meant to simulate the material breakdown which will occur under construction processes. It would apply to samples taken from prospective or working pits or from material delivered to the roadside, but would not apply to material from the finished pavement. Material from the compacted pavement requires no pre-treatment.

This method was developed for the pre-treatment of Winton Sandstone but may be applicable to other materials.

3 Apparatus

Where appropriate, the working tolerances of particular apparatus are contained in Table 1.

The following apparatus is required:

3.1 Drying oven of suitable capacity, having a temperature of 45-50°C and complying with AS 1289.0.

3.2 Sieve, 37.5 mm complying with AS 1152.

3.3 Compaction mould, a cylindrical metal mould having an internal diameter of 152 mm and an effective height of 132.5 mm, fitted with a detachable baseplate and a removable collar assembly about 60 mm high, both of which can be firmly attached to the mould.

3.4 Steel rammer, or alternatively a mechanical compactor may be used provided that it meets the essential requirements of drop height, mass and energy input (Note 6.1).

3.5 Level rigid foundation on which to compact the specimen, for example, a sound concrete floor about 100 mm or more in thickness or a concrete block of at least 100 kg mass.

3.6 Material height gauge. A flat steel bar, about 250 mm long, 25 mm wide and 1-3 mm thick is satisfactory (Note 6.2).

3.7 Sample extractor, such as a jack, lever frame or other device for extruding compacted specimens from the mould.

4 Material

The following materials are required:

4.1 Mould oil, a light oil such as Caltex Mould Oil 20 (Note 6.3).

5 Procedure

The procedure shall be as follows:

5.1 Prepare the sample as detailed in Preliminary Preparation Section 3 of Test Method Q101 to obtain the required number of representative test subsamples.
5.2 Sieve each test subsample on a 37.5 mm sieve, breaking up aggregations until all material passes the 37.5 mm sieve.

5.3 Moisten the passing 37.5 mm material to approximately optimum moisture content, thoroughly mixing the soil and water (Note 6.4).

5.4 Compact the passing 37.5 mm material in a lightly oiled mould in approximately three equal layers, with 60 blows per layer of the standard compaction rammer (Note 6.5).

5.5 Remove the compacted material from the mould and continue compacting material until all material in each test subsample has been treated.

5.6 Dry the treated material in an oven at a temperature of 45-50°C.

6 Notes on method

6.1 A mechanical form of apparatus may be used provided the essential dimensions are adhered to and the rammer has a free vertical fall of the correct height with blows being uniformly distributed and in keeping with any prescribed cycle of blows. It is also essential that the design of the machine is such that the mould can be attached to a level and rigid support base.

6.2 A material height gauge, which allows monitoring of the height of compacted material relative to the top of the mould, can be made from a steel bar and marked as follows:

6.2.1 Commencing at one end of the bar, measure and mark distances of:
   a) 5.5 mm for the upper range of the third layer
   b) 38.5 mm and 43.5 mm for the acceptable range of the second layer, and
   c) 83.5 mm and 88.5 mm for the acceptable range of the first layer.

6.2.2 Mark the face with the appropriate mould size.

6.3 Before handling oil, the operator must consult the relevant Safety Data Sheet (SDS).

6.4 It is important that the water is thoroughly mixed into and uniformly distributed throughout the material since inadequate mixing gives rise to variable test results. It is desirable to keep the mixed material in a sealed container to allow the water to become more uniformly distributed before compaction.

6.5 During compaction, material can build up on the surface of the rammer. This is particularly evident at moisture contents near to and above optimum moisture content. In order to prevent the cushioning effect caused by this build-up, the rammer face must be inspected and cleaned if necessary during the compaction process.

Table 1 – Dimensions and tolerances for suitable moulds and rammer

<table>
<thead>
<tr>
<th>Apparatus Dimension</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mould: 152 mm diameter</td>
<td>± 1.0 *</td>
</tr>
<tr>
<td>Internal diameter (mm)</td>
<td>152.0</td>
</tr>
<tr>
<td>Effective height (mm)</td>
<td>132.5</td>
</tr>
<tr>
<td>Nominal volume (cm³)</td>
<td>2400</td>
</tr>
</tbody>
</table>

Superseded
### Apparatus Dimension Tolerance

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Dimension</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rammer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter, round foot (mm)</td>
<td>50</td>
<td>± 0.4</td>
</tr>
<tr>
<td>Area of rammer (mm²)</td>
<td>1964</td>
<td>± 31</td>
</tr>
<tr>
<td>Drop (mm)</td>
<td>300</td>
<td>± 2.0 ‡</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>2.7</td>
<td>± 0.01 ‡</td>
</tr>
<tr>
<td>Energy delivered per blow (J)</td>
<td>7.94</td>
<td>± 0.08</td>
</tr>
<tr>
<td>Number of layers</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Number of blows/layer</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Energy input (kJ/m³)</td>
<td>596</td>
<td>± 14</td>
</tr>
</tbody>
</table>

* Either but not both of the tolerances may be exceeded provided that the specified tolerance on volume is not exceeded.

‡ Either but not both of the tolerances may be exceeded provided that the specified tolerance on energy delivered per blow is not exceeded.
Test Method Q101F: Crushing

1 Source
This method was developed in-house using techniques evolved through internal departmental research investigations.

2 Scope
This method describes procedures for crushing samples of soil, rock, aggregates or concrete in preparation for various laboratory chemical test methods. It involves the progressive crushing, drying and dividing of a sample to a final crush finer than a nominated sieve.

3 Apparatus
The following apparatus is required:

3.1 Laboratory jaw crusher.
3.2 Laboratory mini-jaw crusher.
3.3 Vibratory disc mill or ring grinder.
3.4 Sieves, 19.0 mm, 6.70 mm, 0.425 mm, 0.150 mm and 0.075 mm complying with AS 1152.
3.5 Sieve brushes.
3.6 Drying oven of suitable capacity, having a temperature of 105-110°C and complying with AS 1289.0 (if required).
3.7 Drying oven of suitable capacity, having a temperature of 45-50°C and complying with AS 1289.0.
3.8 Sample divider.
3.9 Container, of suitable size for drying subsamples.
3.10 Suitable container for storing crushed test portion.
3.11 Magnet.

4 Procedure
The procedure shall be as follows:

4.1 Coarse crushing
If the sample contains no material larger than 6.70 mm the coarse crushing may be omitted and preparation may commence from Step 4.1.3.

4.1.2 Crush a representative sample of the material to pass the 19.0 mm sieve using the jaw crusher as follows:

a) Inspect the feed box, jaws, discharge chute and sample receiver and clean if necessary.

b) Set the moving jaw to the required gap (Note 5.1).

c) Start the crusher and feed the material at a uniform rate so that the hopper is kept almost full.

d) Stop the crusher, collect the crushed material and screen over the 19.0 mm sieve.
e) Adjust the gap between the jaws if necessary and pass the oversize material back through the crusher.

f) Repeat Steps b) to e) until all the material has been crushed to the required size.

4.1.3 Air or oven dry the subsamples which require drying prior to testing. Use the 45-50°C oven unless otherwise specified in the appropriate test method. Allow the sample to cool to room temperature (Note 5.2).

4.1.4 Mix and reduce the sample for medium crushing to a minimum sample size of 2000 g using a sample divider.

4.2 Medium crushing

4.2.1 If the sample contains no material larger than 4.75 mm the medium crushing may be omitted and preparation may commence from Step 4.2.3.

4.2.2 Crush a representative sample of the material to pass the 6.70 mm sieve using the mini-jaw crusher as follows:

a) Inspect the feed box, jaws, discharge chute and sample receiver and clean if necessary.

b) Set the moving jaw to the required gap (Note 5.1).

c) Start the crusher and feed the material at a uniform rate so that the hopper is kept almost full.

d) Stop the crusher, collect the crushed material and screen over the 6.70 mm sieve.

e) Adjust the gap between the jaws if necessary and pass the oversize material back through the crusher.

f) Repeat Steps b) to e) until all the material has been crushed to the required size.

4.2.3 Air or oven dry the subsamples which require drying prior to testing. Use the 45-50°C oven unless otherwise specified in the appropriate test method. Allow the sample to cool to room temperature (Note 5.2).

4.2.4 Mix and reduce the sample for fine crushing to a minimum sample size of 750 g using a sample divider.

4.2.5 Remove any iron filings produced during the crushing process by passing a magnet over the sample (Note 5.3).

4.3 Fine crushing

4.3.1 Select the appropriate fine screening sieve from Table 1 or as otherwise specified in the relevant test method.

4.3.2 Crush the reduced sample to pass the fine screening sieve using a vibratory disc mill or ring grinder as follows:

a) Inspect the bowl and crushing rings and clean if necessary.

b) Set the crushing time (usually 15 seconds is sufficient).

c) Push the crushing rings to one side of the bowl and place no more than 100 g of material in gap between the bowl and the crushing rings.

d) Start the mill or grinder and allow to run for the programmed time.

e) Collect the crushed material and screen over the fine screening sieve.
f) Repeat Steps c) to e) until all the material passes the fine screening sieve.

4.3.3 Remove any iron filings produced during the crushing process by passing a magnet over the sample (Note 5.3).

4.3.4 Air or oven dry the subsamples which require drying prior to testing. Use the 45-50°C oven unless otherwise specified in the appropriate test method. Allow the sample to cool to room temperature (Note 5.2).

4.3.5 Store the sample in a sealed container.

5 Notes on method

5.1 When crushing rock the general rule is to set the moving jaw gap to half the maximum particle size of the rock being crushed.

5.2 Where oven drying to constant mass is specified using a 105-110°C oven, the sample is considered to have reached a constant mass when the difference between successive weighings, after a further 1 hour drying at 105-110°C, is not more than 1 percent of the total of the previous moisture losses. Where a 45-50°C oven is specified the sample is considered to have reached a constant mass when the difference between successive weighings, after a further 4 hours drying at 45-50°C, is not more than 1 percent of the total of the previous moisture losses.

5.3 This step may be omitted where crushing apparatus with zirconium oxide faces is used.

Table 1 – Fine screen size

<table>
<thead>
<tr>
<th>Test method</th>
<th>Sieve size (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q129</td>
<td>0.075</td>
</tr>
<tr>
<td>Q130A</td>
<td>0.425</td>
</tr>
<tr>
<td>Q456, Q457A, Q457B</td>
<td>0.150</td>
</tr>
</tbody>
</table>
Test Method Q102A: Standard moisture content of soil – oven drying

1 Source
This method applies the principles of AS 1289.2.1.1: Determination of the moisture content of a soil – Oven drying method (standard method). It differs from this Australian Standard in that the sample sizes required are larger and differences also occur in cross-referenced test methods.

2 Scope
This method describes the procedure for the determination of the moisture content of fine-grained, medium-grained and coarse-grained soils as a percentage of dry mass using a drying oven. This method is the standard method for determining moisture content and it may be used to establish relationships with subsidiary methods of moisture content measurement.

This method may also be used to determine the moisture content of other materials such as aggregates.

3 Apparatus
The following apparatus is required:

3.1 Drying oven of suitable capacity, having a temperature of 105-110°C and complying with AS 1289.0.

3.2 Heat and corrosion resistant container of adequate capacity. For fine-grained material a close fitting lid will be required.

3.3 Balance of suitable capacity, with a resolution and limit of performance as specified in Table 1.

3.4 Desiccator containing anhydrous silica gel (for fine-grained material only).

4 Procedure
The procedure shall be as follows:

4.1 Obtain a representative test portion of at least the mass listed in Table 1. Where moisture content of soil as received in the laboratory is required, obtain a representative test portion as detailed in Test Method Q101.

4.2 Determine the mass of the container (m_1).

4.3 Place the test portion in the container. Crumble any large aggregations or slice any soil clods to assist drying taking care to avoid any loss of soil. Determine the mass of the container and soil (m_2).

4.4 Dry the test portion in the oven at 105-110°C (Notes 7.1 and 7.2).

4.5 Remove the container from the oven and allow the container to cool as follows:

a) until it is warm to touch for medium and coarse-grained soils, or

b) until it is cooled to room temperature in a desiccator for fine-grained soils.

4.6 Determine the mass of the container and soil (m_3).

4.7 Place the container and soil in the oven. Dry the soil for at least another hour after the temperature recovers to 105-110°C.
4.8 Repeat Steps 4.5 to 4.7 until such time that the difference between successive weighings, after a further one hour drying, is not more than 1 percent of the total of the previous moisture losses (Note 7.3).

5 Calculations

5.1 Calculate the moisture content of the test portion as follows:

$$w = \frac{m_2 - m_1}{m_3 - m_1} \times 100$$

where

- $w$ = moisture content of the material (%)
- $m_2$ = mass of container and wet soil (g)
- $m_3$ = mass of container and dry soil (g)
- $m_1$ = mass of container (g)

6 Reporting

Report the following:

6.1 The moisture content of the test portion as the moisture content of the material (refer to Table 2).

6.2 Drying temperature (if required) to the nearest 1°C.

7 Notes on method

7.1 A drying time of 16 to 24 hours is usually sufficient for most soils, but certain soil types and large or very wet samples may require longer. The drying time will also depend on the total amount of material in the oven.

7.2 Gypsum loses water of crystallisation on heating, and drying at 105-110°C will result in an approximate 0.2 percent increase in moisture content for each 1 percent gypsum. Soils containing gypsum should be dried at a temperature of not more than 80°C and the drying temperature reported.

7.3 The soil is considered to be dry when this requirement is first achieved. The confirmed mass ($m_3$), that is, the penultimate weighing, shall be used in the calculation of moisture content.

Table 1 – Test portion and balance requirements

<table>
<thead>
<tr>
<th>Soil size</th>
<th>Minimum test portion mass (g)</th>
<th>Balance resolution (g)</th>
<th>Balance limit of performance (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fine-grained</td>
<td>100</td>
<td>0.01</td>
<td>± 0.05</td>
</tr>
<tr>
<td>(0-20% retained 2.36 mm sieve)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium-grained</td>
<td>1000</td>
<td>0.1</td>
<td>± 0.5</td>
</tr>
<tr>
<td>(0-20% retained 19.0 mm sieve)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coarse-grained</td>
<td>5000</td>
<td>1</td>
<td>± 5</td>
</tr>
<tr>
<td>(0-20% retained 37.5 mm sieve)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Superseded
### Table 2 – Reporting intervals for moisture content

<table>
<thead>
<tr>
<th>Moisture content (%)</th>
<th>Reporting interval (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 50</td>
<td>0.1</td>
</tr>
<tr>
<td>50 to 100</td>
<td>0.5</td>
</tr>
<tr>
<td>&gt;100</td>
<td>1</td>
</tr>
</tbody>
</table>
Test Method Q102B: Subsidiary moisture content of soil – microwave oven drying

1 Source
This method applies the principles of AS 1289.2.1.4: Determination of the moisture content of the soil – Microwave-oven drying method (subsidiary method). It differs from this Australian Standard in that the sample sizes required are larger and differences also occur in cross-referenced test methods.

2 Scope
This method describes the procedure for the rapid determination of the moisture content of fine-grained, medium grained and coarse-grained soils as a percentage of dry mass using a microwave oven.

The method is presumed to be less accurate than the standard method and results obtained using this procedure must be corrected to the standard method using the relationship established in accordance with Test Method Q010.

This method is not suitable for soils containing gypsum, ironstone, calcareous material or organic matter.

3 Apparatus
The following apparatus is required:

3.1 Microwave oven.

3.2 Heat resistant, non-absorbent and non-metallic container of suitable capacity. A perforated, heat resistant, non-metallic cover may be required.

3.3 Desiccator containing anhydrous silica gel (for fine-grained material only).

3.4 Balance of suitable capacity with a resolution and limit of performance as specified in Table 1.

4 Procedure
The procedure shall be as follows:

4.1 Obtain a representative test portion of at least the mass listed in Table 1. Where moisture content of soil as received in the laboratory is required, obtain a representative test portion as detailed in Test Method Q101.

4.2 Determine the mass of the container (m₁).

4.3 Place the test portion in the container. Crumble any large aggregations or slice any soil clods to assist drying taking care to avoid any loss of soil. Determine the mass of the container soil (m₂).

4.4 Dry the test portion in the oven for a suitable period (Notes 7.1 and 7.2).

4.5 Remove the container from the oven and allow the container to cool as follows:
   a) until it is warm to touch for medium and coarse-grained soils, or
   b) until it is cooled to room temperature in a desiccator for fine grained soils.

4.6 Determine the mass of the container and soil (m₃).
4.7 Repeat Steps 4.4 to 4.6 until such a time as the difference between successive weighings after a further drying time equal to a quarter of the original time, is not more than 1 percent of the total of the previous moisture losses (Note 7.3).

5 **Calculations**

Calculate the moisture content as follows:

5.1 Calculate the estimated moisture content of the test portion as follows:

\[ w_e = \frac{m_2 - m_1}{m_3 - m_1} \times 100 \]

where

- \( w_e \) = estimated moisture content (%)
- \( m_2 \) = mass of container and wet soil (g)
- \( m_3 \) = mass of container and dry soil (g)
- \( m_1 \) = mass of container (g)

5.2 Correct the estimated moisture content using the relationship established in Test Method Q010 as follows:

\[ w = bw_e + a \]

where

- \( w \) = moisture content of the material (%)
- \( b \) = slope of linear relationship obtained from Q010
- \( w_e \) = estimated moisture content (%)
- \( a \) = y intercept of linear relationship obtained from Q010

6 **Reporting**

Report the following:

6.1 The moisture content of the material (refer to Table 2).

6.2 The estimated moisture content of the test portion (refer to Table 2), if required.

7 **Notes on method**

7.1 The drying time is dependent on the sample size, its moisture condition and the energy used.

7.2 Microwave drying at high energies may result in cracking of some rock particles, disintegration of soil aggregations or violent boiling of fine particles. These phenomena are more prevalent in soils with high moisture content and can result in the ejection of material from the container. Ejection can be eliminated by using a lower drying energy or by placing a perforated, heat resistant and non-metallic cover over the container.

7.3 The soil is considered to be dry when this requirement is first achieved. The confirmed mass (\( m_3 \)), the penultimate weighing, shall be used in the calculation of moisture content.
Table 1 – Test portion and balance requirements

<table>
<thead>
<tr>
<th>Soil size</th>
<th>Minimum test portion mass (g)</th>
<th>Balance resolution (g)</th>
<th>Balance limit of performance (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fine-grained (0-20% retained 2.36 mm sieve)</td>
<td>100</td>
<td>0.01</td>
<td>± 0.05</td>
</tr>
<tr>
<td>Medium-grained (0-20% retained 19.0 mm sieve)</td>
<td>1000</td>
<td>0.1</td>
<td>± 0.5</td>
</tr>
<tr>
<td>Coarse-grained (0-20% retained 37.5 mm sieve)</td>
<td>5000</td>
<td>1</td>
<td>± 5</td>
</tr>
</tbody>
</table>

Table 2 – Reporting intervals for moisture content

<table>
<thead>
<tr>
<th>Moisture content (%)</th>
<th>Reporting interval (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 50</td>
<td>0.1</td>
</tr>
<tr>
<td>50 to 100</td>
<td>0.5</td>
</tr>
<tr>
<td>&gt;100</td>
<td></td>
</tr>
</tbody>
</table>
Test Method Q102D: Subsidiary moisture content of soil – hotplate drying

1 Source

This method applies the principles of AS 1289.2.1.2: Determination of the moisture content of the soil – Hotplate drying method (subsidiary method). It differs from this Australian Standard in that the sample sizes required are larger and differences also occur in cross-referenced test methods.

2 Scope

This method describes the procedure for the rapid determination of the moisture content of fine-grained, medium-grained and coarse-grained soils as a percentage of dry mass using a hotplate. The method is presumed to be less accurate than the standard method and results obtained using this procedure must be corrected to the standard method using the relationship established in accordance with Test Method Q010.

This method is not suitable for soils containing a significant percentage of clay material, gypsum, calcareous material or organic matter.

3 Apparatus

The following apparatus is required:

3.1 Heating device such as an electric hotplate, frypan or gas stove.

3.2 Heat tolerant and corrosion resistant container of adequate capacity. For fine-grained material a close fitting lid will be required.

3.3 Balance of suitable capacity with a resolution and limit of performance within the range as shown in Table 1.

3.4 A spatula or other suitable stirring device.

4 Procedure

The procedure shall be as follows:

4.1 Obtain a representative test portion of at least the mass listed in Table 1. Where moisture content of soil as received in the laboratory is required, obtain a representative test portion as detailed in Test Method Q101.

4.2 Determine the mass of the container (m₁).

4.3 Place the test portion in the container. Crumble any large aggregations or slice any soil clods to assist drying taking care to avoid any loss of soil. Determine the mass of the container and soil (m₂).

4.4 Dry the test portion on the heating device for a suitable period (Note 7.1). Stir the soil frequently to facilitate drying and to ensure that the soil immediately above the heat source is not overheated.

4.5 Remove the container from the heating device, and allow the container to cool until it is warm to touch. Determine the mass of the container and soil (m₃).

4.6 Repeat Steps 4.4 and 4.5 until such time as the difference between successive weighings after a further 15 minutes drying is not more than 1 percent of the total of the previous moisture losses (Note 7.2).
5 Calculations

Calculate the moisture content as follows:

5.1 Calculate the estimated moisture content of the test portion as follows:

$$w_e = \frac{m_2 - m_3}{m_3 - m_1} \times 100$$

where
- $w_e$ = estimated moisture content (%)
- $m_2$ = mass of container and wet soil (g)
- $m_3$ = mass of container and dry soil (g)
- $m_1$ = mass of container (g)

5.2 Correct the estimated moisture content using the relationship established in Test Method Q010 as follows:

$$w = bw_e + a$$

where
- $w$ = moisture content of the material (%)
- $b$ = slope of linear relationship obtained from Q010
- $w_e$ = estimated moisture content (%)
- $a$ = y intercept of linear relationship obtained from Q010

6 Reporting

Report the following:

6.1 The moisture content of the material (refer to Table 2).

6.2 The estimated moisture content of the test portion (refer to Table 2), if required.

7 Notes on method

7.1 The drying time is dependent on the sample size, its moisture condition and the heating device used.

7.2 The soil is considered to be dry when this requirement is first achieved. The confirmed mass ($m_3$), that is, the penultimate weighing, shall be used in the calculation of moisture content.

Table 1 – Test portion and balance requirements

<table>
<thead>
<tr>
<th>Soil size</th>
<th>Minimum test portion mass (g)</th>
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<th>Balance limit of performance (g)</th>
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<td>Fine-grained</td>
<td>100</td>
<td>0.01</td>
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</tr>
<tr>
<td>(0-20% retained 2.36 mm sieve)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium-grained</td>
<td>1000</td>
<td>0.1</td>
<td>± 0.5</td>
</tr>
<tr>
<td>(0-20% retained 19.0 mm sieve)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coarse-grained</td>
<td>5000</td>
<td>1</td>
<td>± 5</td>
</tr>
<tr>
<td>(0-20% retained 37.5 mm sieve)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table 2 – Reporting intervals for moisture content

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<thead>
<tr>
<th>Moisture content (%)</th>
<th>Reporting interval (%)</th>
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</thead>
<tbody>
<tr>
<td>&lt; 50</td>
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</tr>
<tr>
<td>50 to 100</td>
<td>0.5</td>
</tr>
<tr>
<td>&gt;100</td>
<td>1</td>
</tr>
</tbody>
</table>
Test Method Q103A: Particle size distribution of soil - wet sieving

1 Source
This method applies the principles of AS 1289.3.6.1: Determination of the particle size distribution of a soil – Standard method of analysis by sieving. It differs from this Australian Standard in that only oven dry material is sieved, the passing 2.36 mm portion is washed and differences also occur in reporting requirements and cross-referenced test methods.

2 Scope
This method describes the procedure for determining the particle size distribution of soil or crushed rock material, down to the 0.075 mm sieve. The method uses a dry sieving technique in association with washing the passing 2.36 mm material prior to dry sieving.

The method also includes the calculation of properties such as fines ratio ($F_R$), coefficient of uniformity ($C_u$), coefficient of curvature ($C_c$) and grading coefficient ($G_G$) (Note 9.1).

3 Apparatus
The following apparatus is required:

3.1 Balance of suitable capacity, having a resolution and a limit of performance as detailed in Table 1 (Note 9.1).

3.2 Sieves complying with AS 1152 as follows:

3.2.1 Dry sieving; commonly used sieves include 75.0 mm, 53.0 mm, 37.5 mm, 26.5 mm, 19.0 mm, 9.50 mm, 4.75 mm, 2.36 mm, 0.425 mm and 0.075 mm sieves. Other sieve sizes such as 63.0 mm, 6.70 mm, 2.00 mm, 1.18 mm, 0.600 mm, 0.300 mm and 0.150 mm may be included to furnish the information required on the material to be tested.

3.2.2 Wet sieving; reinforced 0.075 mm sieve (Note 9.3).

3.3 Mechanical sieve shaker (optional).

3.4 Sieve brushes and a wire or other stiff bristle brush.

3.5 Rubber pestle and steel or ceramic mortar.

3.6 Drying oven of suitable capacity, having a temperature of 105 - 110°C and complying with AS 1289.0.

3.7 Containers, of suitable size for drying and washing the material.

4 Materials
The following materials are required:

4.1 Dispersing agent
- Prepare by dissolving 33 g of sodium hexametaphosphate (LR Grade) and 7 g of anhydrous sodium carbonate (LR Grade) or 18.9 g of sodium carbonate decahydrate (LR Grade) in one litre of water (Notes 9.4 and 9.5).
5 Preparation

The sample shall be prepared as follows:

5.1 Determine the maximum particle size of the material by assessing the sieve through which all of the material will just pass. Prepare the sample as detailed in Section 5 of Test Method Q101 to obtain a test portion which, when dry, will comply with the minimum mass requirements of Table 1.

5.2 Determine the mass of the container ($m_1$).

5.3 Place the test portion in the container and dry in the oven to a constant mass ($m_2$) (Note 9.6).

6 Procedure

The sample shall be sieved as follows:

6.1 Coarse sieving (particles larger than 19.0 mm)

6.1.1 Sieve the test portion through sieves in order of decreasing aperture size down to and including 19.0 mm, using as the largest sieve a size through which all the material just passes and ensuring no sieve is overloaded (Note 9.7).

6.1.2 Clean the rock particles retained initially on the largest sieve in this coarse sieve series, using the stiff bristle brush to remove coatings of fines and also break up soil clods and aggregations of fines using the pestle and mortar (Note 9.8). Ensure that the resulting fines are passed through the sieve.

6.1.3 Sieve the cleaned rock particles by either hand or mechanical shaker (Notes 9.9, 9.10, 9.11).

6.1.4 Determine the mass of the particles retained on the sieve ($m_i$).

6.1.5 Repeat Steps 6.1.2 to 6.1.4 for each sieve in the coarse series, in order of decreasing size down to and including the 19.0 mm and determine the mass retained on each sieve ($m_i$).

6.2 Intermediate Sieving (particles between 19.0 mm and 2.36 mm)

6.2.1 Where the test portion has already been coarse sieved as detailed in Steps 6.1.1 to 6.1.5, subsample the material passing 19.0 mm, observing the minimum mass requirements of Table 1. Place the test portion subsample into a suitable container of known mass ($m_3$).

Determine the mass of the test portion and container ($m_4$).

6.2.2 Sieve the test portion through the nominated sieves in order of decreasing aperture size down to and including 2.36 mm ensuring no sieve is overloaded (Note 9.7).

6.2.3 Clean the rock particles retained on the largest sieve in this intermediate sieve series, using the rubber pestle and mortar to remove coatings of fines and break up soil clods and aggregations of fines (Note 9.8). Ensure the resulting fines collected in the mortar are passed over the sieve.

6.2.4 Sieve the cleaned rock particles by either hand or mechanical shaker (Notes 9.9, 9.10, 9.11).

6.2.5 Determine the mass of the particles retained on the sieve ($m_i$).

6.2.6 Repeat Steps 6.2.3 to 6.2.5 for each sieve in the intermediate series, in order of decreasing size down to and including the 2.36 mm and determine the mass retained on each sieve ($m_i$).
6.3 **Fine Sieving (particles smaller than 2.36 mm)**

6.3.1 Where the test portion has already been intermediate sieved as detailed in Steps 6.2.1 to 6.2.6, subsample the material passing 2.36 mm, observing the minimum mass requirements of Table 1. Place the test portion subsample into a suitable container of known mass \( m_c \).

Determine the mass of the test portion and container \( m_{t+c} \).

6.3.2 Fill the container with dispersing solution until the test portion is covered. Stir to wet the material and allow it to soak for at least two hours (Note 9.12).

6.3.3 After soaking, agitate the contents of the container and pour the suspension into the 0.075 mm reinforced sieve, taking care to prevent overflowing and loss of fines.

6.3.4 Wash the material retained on the 0.075 mm sieve until the wash water becomes clear. Allow the passing 0.075 mm material to run to waste.

6.3.5 Add fresh water to the container as required and repeat Steps 6.3.3 and 6.3.4 until the material in the container and that retained on the 0.075 mm is clean.

6.3.6 Return all the washed retained 0.075 mm material to the container and decant excess water.

6.3.7 Place the container in the oven and dry until the material has reached constant mass (Note 9.6).

6.3.8 Sieve the washed test portion through the nominated sieves in order of decreasing aperture size down to and including the 0.075 mm by either hand or mechanical shaker (Notes 9.9, 9.10, 9.11, 9.13).

6.3.9 Determine the mass of the particles retained on each sieve in the fine series \( m_f \).

7 **Calculations**

7.1 **Coarse Sieving**

7.1.1 Calculate the cumulative mass retained on each coarse sieve as follows:

\[
M_c = \sum m_c
\]

where

- \( M_c \) = cumulative mass retained on a particular coarse sieve (g)
- \( m_c \) = individual mass retained on each coarse sieve with aperture size larger than or equal to the particular sieve (g)

7.1.2 Calculate the cumulative percent retained on each coarse sieve as follows:

\[
P_r = \frac{100M_c}{m_2 - m_1}
\]

where

- \( P_r \) = cumulative percent retained on a particular sieve
- \( M_c \) = cumulative mass retained on the particular sieve (g)
- \( m_1 \) = mass of container (g)
- \( m_2 \) = mass of container and test portion (g)
7.1.3 Calculate the percent passing each sieve as follows:

\[ P_p = 100 - P_r \]

where

\( P_p \) = percent passing a particular sieve

\( P_r \) = cumulative percent retained on the particular sieve

7.2 Intermediate sieving

7.2.1 Calculate the cumulative mass retained on each intermediate sieve as follows:

\[ M_i = \sum m_i \]

where

\( M_i \) = cumulative mass retained on a particular intermediate sieve (g)

\( m_i \) = individual mass retained on each intermediate sieve with aperture size larger than or equal to the particular sieve (g)

7.2.2 Where the test portion has been previously coarse sieved and the passing 19.0 mm material subsampled, calculate the cumulative percent retained on each intermediate sieve as follows:

\[ P_r = \frac{M_i P_{19}}{m_4 - m_3} \]

where

\( P_r \) = cumulative percent retained on a particular sieve

\( M_i \) = cumulative mass retained on the particular sieve (g)

\( m_3 \) = mass of container (g)

\( m_4 \) = mass of container and test portion subsample (g)

\( P_{19} \) = percent passing the 19.0 mm sieve

7.2.3 Where the test portion has not been coarse sieved or the passing 19.0 mm material has not been subsampled, calculate the cumulative percent retained on each intermediate sieve as follows:

\[ P_r = \frac{100 M_i}{m_2 - m_1} \]

where

\( P_r \) = cumulative percent retained on a particular sieve

\( M_i \) = cumulative mass retained on the particular sieve (g) (Note 9.14)

\( m_1 \) = mass of container (g)

\( m_2 \) = mass of container and test portion (g)
7.2.4 Where the test portion has been previously coarse sieved and the passing 19.0 mm material subsampled, calculate the percent passing each sieve as follows:

\[
P_p = P_{19} - P_r
\]

where

- \( P_p \) = percent passing a particular sieve
- \( P_{19} \) = percent passing the 19.0 mm sieve
- \( P_r \) = cumulative percent retained on the particular sieve (g)

7.2.5 Where the test portion has not been coarse sieved or the passing 19.0 mm material has not been subsampled, calculate the percent passing each sieve as follows:

\[
P_p = 100 - P_r
\]

where

- \( P_p \) = percent passing a particular sieve
- \( P_r \) = cumulative percent retained on the particular sieve (g)

7.3 Fine sieving

7.3.1 Calculate the cumulative mass retained on each fine sieve as follows:

\[
M_f = \sum m_r
\]

where

- \( M_f \) = cumulative mass retained on a particular fine sieve (g)
- \( m_r \) = cumulative mass retained on each fine sieve with aperture size larger than or equal to the particular sieve (g)

7.3.2 Where the test portion has been previously intermediate sieved and the passing 2.36 mm material subsampled, calculate the cumulative percent retained on each fine sieve as follows:

\[
P_r = \frac{M_f P_{2.36}}{m_6 - m_5}
\]

where

- \( P_r \) = cumulative percent retained on a particular sieve
- \( M_f \) = cumulative mass retained on the particular sieve (g)
- \( m_5 \) = mass of tray (g)
- \( m_6 \) = mass of tray and test portion subsample (g)
- \( P_{2.36} \) = percent passing the 2.36 mm sieve
7.3.3 Where the test portion has not been intermediate sieved or the passing 2.36 mm material has not been subsampled, calculate the cumulative percent retained on each fine sieve as follows:

\[ P_r = \frac{100M_r}{m_2 - m_1} \]

where
- \( P_r \) = cumulative percent retained on a particular sieve
- \( M_r \) = cumulative mass retained on the particular sieve (g) (Note 9.15)
- \( m_1 \) = mass of container (g)
- \( m_2 \) = mass of container and test portion (g)

7.3.4 Where the test portion has been previously intermediate sieved and the passing 2.36 mm material subsampled, calculate the percent passing each sieve as follows:

\[ P_p = P_{2.36} - P_r \]

where
- \( P_p \) = percent passing a particular sieve
- \( P_{2.36} \) = percent passing the 2.36 mm sieve
- \( P_r \) = cumulative percent retained on the particular sieve (g)

7.3.5 Where the test portion has not been intermediate sieved or the passing 2.36 mm material has not been subsampled, calculate the percent passing each sieve as follows:

\[ P_p = 100 - P_r \]

where
- \( P_p \) = percent passing a particular sieve
- \( P_r \) = cumulative percent retained on the particular sieve (g)

7.4 Other properties

7.4.1 If required, calculate the fines ratio as follows:

\[ FR = \frac{P_{0.075}}{P_{0.425}} \]

where
- \( FR \) = fines ratio
- \( P_{0.075} \) = percent passing the 0.075 mm sieve
- \( P_{0.425} \) = percent passing the 0.425 mm sieve
7.4.2 If the coefficient of uniformity or the coefficient of curvature are required, calculate the following particle size values:

a) Calculate the particle size where 60% of particles are smaller as follows:

\[ D_{60} = 10^{\log_{10} \left( \frac{\log_{10} D_2 - \log_{10} D_1}{P_2 - P_1} \right) - \log_{10} D_2} \]

where
- \( D_{60} \) = particle size where 60% of particles are smaller (mm)
- \( \log \) = logarithm to base 10
- \( D_2 \) = largest sieve with less than 60% passing (mm)
- \( P_2 \) = percent passing \( D_2 \)
- \( D_1 \) = smallest sieve with more than 60% passing (mm)
- \( P_1 \) = percent passing \( D_1 \)

b) Calculate the particle size where 10% of particles are smaller as follows:

\[ D_{10} = 10^{\log_{10} \left( \frac{\log_{10} D_2 - \log_{10} D_1}{P_2 - P_1} \right) - \log_{10} D_2} \]

where
- \( D_{10} \) = particle size where 10% of particles are smaller (mm)
- \( \log \) = logarithm to base 10
- \( D_2 \) = largest sieve with less than 10% passing (mm)
- \( P_2 \) = percent passing \( D_2 \)
- \( D_1 \) = smallest sieve with more than 10% passing (mm)
- \( P_1 \) = percent passing \( D_1 \)

c) Calculate the particle size where 30% of particles are smaller as follows:

\[ D_{30} = 10^{\log_{10} \left( \frac{\log_{10} D_2 - \log_{10} D_1}{P_2 - P_1} \right) - \log_{10} D_2} \]

where
- \( D_{30} \) = particle size where 30% of particles are smaller (mm)
- \( \log \) = logarithm to base 10
- \( D_2 \) = largest sieve with less than 30% passing (mm)
- \( P_2 \) = percent passing \( D_2 \)
- \( D_1 \) = smallest sieve with more than 30% passing (mm)
\[ P_1 = \text{percent passing } D_1 \]

7.4.3 If required, calculate the coefficient of uniformity as follows:

\[ C_u = \frac{D_{60}}{D_{10}} \]

where \( C_u \) = coefficient of uniformity
\( D_{60} \) = particle size where 60% of particles are smaller
\( D_{10} \) = particle size where 10% of particles are smaller

7.4.4 If required, calculate the coefficient of curvature as follows:

\[ C_c = \frac{D_{30}^2}{D_{10}D_{60}} \]

where \( C_c \) = coefficient of curvature
\( D_{30} \) = particle size where 30% of particles are smaller
\( D_{10} \) = particle size where 10% of particles are smaller
\( D_{60} \) = particle size where 60% of particles are smaller

7.4.5 If required, calculate the grading coefficient as follows:

\[ G_c = \frac{(P_{26.5} - P_{2.00})P_{4.75}}{100} \]

where \( G_c \) = grading coefficient (Note 9.1)
\( P_{26.5} \) = percent passing the 26.5 mm sieve
\( P_{2.00} \) = percent passing the 2.00 mm sieve
\( P_{4.75} \) = percent passing the 4.75 mm sieve

8 Reporting

Report the following:

8.1 Percent passing each sieve to the nearest 1% for results 10% or greater, and to the nearest 0.1% for results less than 10%.

8.2 If required, a semi-logarithmic graph of the sieve size versus the percent passing each sieve.

8.3 Fines ratio to the nearest 0.01 units (if required).

8.4 Coefficient of uniformity to the nearest 0.1 for results 1 or greater and to the nearest 0.01 for results less than 1 (if required).
8.5 Coefficient of curvature to the nearest 0.1 for results 1 or greater and to the nearest 0.01 for results less than 1 (if required).

8.6 Grading coefficient to the nearest 0.1 units (if required).

9 Notes on method


9.2 The balance used in the procedure is dependent on the maximum particle size of the test portion or test portion subsample.

9.3 Because of the ease with which a 0.075 mm sieve can be damaged, the use of a special washing sieve, in which the sieve cloth is reinforced underneath with a coarser sieve or punched plate screen, is recommended.

9.4 Before handling sodium hexametaphosphate, anhydrous sodium carbonate or sodium carbonate decahydrate, the operator must consult the relevant Safety Data Sheet (SDS).

9.5 This solution is unstable and must be freshly prepared approximately once a month with the preparation and expiry dates being recorded on the container.

9.6 The material is considered to have reached a constant mass when the difference between successive weighings, after a further 1 hour drying at 105-110 °C, is not more than 1 percent of the total of the previous moisture losses.

9.7 Overloading of sieves may affect the accuracy of results and damage the sieves. The recommended maximum loads on sieves at completion of sieving are set out in Table 2. To prevent overloading:

- use sieves with a larger diameter, or
- use additional sieves, or
- divide the mass retained on the sieve into two or more portions of a mass less than the recommended loading in Table 2 and pass the separate portions through the sieve.

9.8 Where difficulty exists ascertaining whether particles are discrete or in fact aggregations of fines, obtain some similar particles from the remaining bulk sample. Place these particles in water and bring the water to the boil. If disaggregation occurs, such particles are considered to be an aggregation of fines and those in the test portion should be treated accordingly.

9.9 When sieving is conducted by hand, a lateral and vertical motion shall be employed accompanied by a slight jarring action to keep the sample moving continuously over the sieve. Particles 19.0 mm or larger may be placed by hand to pass the sieves.

9.10 When sieving is conducted using a mechanical sieve shaker, sieving shall be carried out for such time as will give a comparable result to hand sieving, which is generally 12-15 minutes.

9.11 At the end of sieving, hand sieve each portion retained until the mass passing each sieve in one minute is less than 1% of the mass of material retained on that sieve.

9.12 Clean granular materials may be washed without the addition of a dispersing agent while cohesive clays may need to be soaked in dispersing solution for several hours.

9.13 Care shall be taken not to apply pressure to the surface of the sieve. Brushes with stiff or worn-down bristles must not be used.
9.14 Where subsampling of the test portion is omitted following the coarse sieving stage, add the total cumulative mass retained from the coarse sieving stage to each value of $M_i$.

9.15 Where subsampling of the test portion is omitted following both the coarse sieving stage and intermediate sieving stage, add the total cumulative mass retained from the coarse sieving stage and the intermediate sieving stage to each value of $M_i$.

### Table 1 - Test portion and balance requirements

<table>
<thead>
<tr>
<th>Maximum particle size (mm)</th>
<th>Minimum test portion mass (g)</th>
<th>Balance resolution (g)</th>
<th>Balance limit of performance range (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>70000</td>
<td>10</td>
<td>± 50</td>
</tr>
<tr>
<td>75.0</td>
<td>40000</td>
<td>10</td>
<td>± 50</td>
</tr>
<tr>
<td>53.0</td>
<td>25000</td>
<td>10</td>
<td>± 50</td>
</tr>
<tr>
<td>37.5</td>
<td>15000</td>
<td>10</td>
<td>± 50</td>
</tr>
<tr>
<td>26.5</td>
<td>5000</td>
<td>1</td>
<td>± 5</td>
</tr>
<tr>
<td>19.0</td>
<td>2000</td>
<td>1</td>
<td>± 5</td>
</tr>
<tr>
<td>9.50</td>
<td>500</td>
<td>0.1</td>
<td>± 0.5</td>
</tr>
<tr>
<td>4.75</td>
<td>200</td>
<td>0.1</td>
<td>± 0.5</td>
</tr>
<tr>
<td>2.36</td>
<td>100</td>
<td>0.1</td>
<td>± 0.5</td>
</tr>
<tr>
<td>0.425</td>
<td>50</td>
<td>0.01</td>
<td>± 0.05</td>
</tr>
</tbody>
</table>

### Table 2 - Recommended maximum sieve loadings

<table>
<thead>
<tr>
<th>Aperture size (mm)</th>
<th>200 mm diameter (g)</th>
<th>300 mm diameter (g)</th>
<th>450 mm diameter (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>3750</td>
<td>7500</td>
<td></td>
</tr>
<tr>
<td>75.0</td>
<td>3000</td>
<td>6000</td>
<td></td>
</tr>
<tr>
<td>37.5</td>
<td>2200</td>
<td>5000</td>
<td></td>
</tr>
<tr>
<td>26.5</td>
<td>1800</td>
<td>4000</td>
<td></td>
</tr>
<tr>
<td>19.0</td>
<td>1200</td>
<td>3000</td>
<td></td>
</tr>
<tr>
<td>13.2</td>
<td>900</td>
<td>4000</td>
<td></td>
</tr>
<tr>
<td>9.5</td>
<td>600</td>
<td>1500</td>
<td></td>
</tr>
<tr>
<td>6.70</td>
<td>500</td>
<td>1250</td>
<td></td>
</tr>
<tr>
<td>4.75</td>
<td>400</td>
<td>1000</td>
<td></td>
</tr>
<tr>
<td>2.36</td>
<td>300</td>
<td>600</td>
<td></td>
</tr>
<tr>
<td>1.18</td>
<td>200</td>
<td>400</td>
<td></td>
</tr>
<tr>
<td>0.600</td>
<td>150</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>0.425</td>
<td>120</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>0.300</td>
<td>100</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>0.150</td>
<td>80</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>0.075</td>
<td>50</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>
Test Method Q103B: Particle size distribution of aggregate - dry sieving

1 Source

This method applies the principles of AS 1141.11.1 : Particle size distribution - Sieving method. It differs from this Australian Standard in that it also provides for the sieving of dried precoated aggregates and includes a finer reporting interval.

2 Scope

This method describes the procedure for determining the particle size distribution of coarse aggregate, fine aggregates, fillers and precoated aggregate using a dry sieving technique. For precoated aggregate, the method does not require the precoating agent to be removed prior to sieving.

3 Apparatus

The following apparatus is required:

3.1 Balance of suitable capacity, having a resolution and with a limit of performance as detailed in Table 1 (Note 8.1).

3.2 Sieves, 26.5 mm, 19.0 mm, 16.0 mm, 13.2 mm, 9.50 mm, 6.70 mm, 4.75 mm, 2.36 mm, 1.18 mm, 0.600 mm, 0.300 mm, 0.150 mm and 0.075 mm as required, complying with AS 1152.

3.3 Mechanical sieve shaker (optional).

3.4 Sieve brushes (Note 8.2).

3.5 Drying oven of suitable capacity, having a temperature of 105-110°C and complying with AS 1289.0.

3.6 Container, of suitable size for drying.

4 Procedure

The procedure shall be as follows:

4.1 Determine the nominal size of the aggregate by assessing the sieve size at which not more than 10 percent of the particles are larger. Prepare the sample as detailed in Section 5 of Test Method Q101 to obtain a test portion which, when dry, will comply with the minimum mass requirement of Table 1.

4.2 Determine the mass of the container (\( m_1 \)).

4.3 Place the test portion in the container and dry in the oven to constant mass (Notes 8.3, 8.4).

4.4 Determine the mass of the container and test portion (\( m_2 \)).

4.5 Sieve the subsample by hand or with a mechanical shaker through the sieves appropriate to the aggregate nominal size, ensuring no sieve is overloaded (Notes 8.2, 8.5, 8.6, 8.7 and 8.8).

4.6 Determine the mass of aggregate on each sieve (\( m_i \)).
5 Calculations

5.1 Calculate the cumulative mass retained on each sieve as follows:

\[ M = \sum m_r \]

where

- \( M \) = cumulative mass retained on a particular sieve (g)
- \( m_r \) = individual mass retained on each sieve with aperture size larger than or equal to the particular sieve (g)

5.2 Calculate the cumulative percent retained on each sieve as follows:

\[ P_r = \frac{100M}{m_2-m_1} \]

where

- \( P_r \) = cumulative percent retained on a particular sieve
- \( M \) = cumulative mass retained on the particular sieve (g)
- \( m_1 \) = mass of container (g)
- \( m_2 \) = mass of container and dry aggregate (g)

5.3 Calculate the percent passing each sieve as follows:

\[ p_P = 100 - P_r \]

where

- \( p_P \) = percent passing a particular sieve
- \( P_r \) = cumulative percent retained on the particular sieve (g)

6 Reporting

Report the following values and general information:

6.1 Percent passing each sieve to the nearest 1% for results 10% or greater, and to the nearest 0.1% for results less than 10%.

6.2 If required, a semi-logarithmic graph of the sieve size versus the percent passing each sieve.

7 Precision

The following criteria should be used to judge the acceptability of results:

7.1 Repeatability

The results for duplicate tests by the same operator are acceptable if they do not differ by more than 0.05 of the mean value.

8 Notes on method

8.1 The balance used in the procedure is dependent on the nominal size of the aggregate with the same balance being used throughout.

8.2 When sieving fine materials such as fillers, the underside of the sieves may be lightly brushed with a soft fine brush to prevent aggregation of particles (balling) and blinding of the apertures. With some materials such as hydrated lime, balling can only be overcome by lightly brushing
the top surface of the sieves. Care shall be taken not to apply pressure to the surface of the sieve. Brushes with stiff or worn-down bristles must not be used.

8.3 The material is considered to have reached a constant mass when the difference between successive weighings, after a further 1 hour drying at 105-110°C, is not more than 1 percent of the total of the previous moisture losses.

8.4 For precoated aggregate, longer drying times may be necessary to remove all volatiles from the aggregate prior to testing.

8.5 Overloading of sieves may affect the accuracy of results and damage the sieves. The recommended maximum loads on sieves at completion of sieving are set out in Table 2. To prevent overloading:
- use sieves with a larger diameter, or
- use additional sieves, or
- divide the mass retained on the sieve into two or more portions of a mass less than the recommended loading in Table 2 and pass the separate portions through the sieve.

8.6 When sieving is conducted by hand, a lateral and vertical motion shall be employed accompanied by a slight jarring action to keep the sample moving continuously over the sieve. Particles 19.0 mm or larger may be placed by hand to pass the sieves.

8.7 When using a mechanical sieve shaker, sieving shall be carried out for such time as will give a comparable result to hand sieving, which is generally 12-15 minutes.

8.8 At the end of sieving, hand sieve each portion retained until the mass passing each sieve in one minute is less than 1% of the mass of material retained on that sieve.

**Table 1 – Test portion and balance requirements**

<table>
<thead>
<tr>
<th>Aggregate nominal size (mm)</th>
<th>Minimum test portion mass (g)</th>
<th>Balance resolution (g)</th>
<th>Balance limit of performance range (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td>10000</td>
<td>10</td>
<td>± 50</td>
</tr>
<tr>
<td>20</td>
<td>5000</td>
<td>1</td>
<td>± 5</td>
</tr>
<tr>
<td>16</td>
<td>3000</td>
<td>1</td>
<td>± 5</td>
</tr>
<tr>
<td>14</td>
<td>2500</td>
<td>1</td>
<td>± 5</td>
</tr>
<tr>
<td>10</td>
<td>1000</td>
<td>1</td>
<td>± 5</td>
</tr>
<tr>
<td>7</td>
<td>600</td>
<td>0.1</td>
<td>± 0.5</td>
</tr>
<tr>
<td>5</td>
<td>500</td>
<td>0.1</td>
<td>± 0.5</td>
</tr>
<tr>
<td>Fine Aggregate</td>
<td>100</td>
<td>0.1</td>
<td>± 0.05</td>
</tr>
<tr>
<td>Filler</td>
<td>50</td>
<td>0.01</td>
<td>± 0.05</td>
</tr>
</tbody>
</table>

**Table 2 – Recommended maximum sieve loadings**

<table>
<thead>
<tr>
<th>Aperture size (mm)</th>
<th>200 mm diameter (g)</th>
<th>300 mm Diameter (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>26.5</td>
<td>800</td>
<td>1800</td>
</tr>
<tr>
<td>19.0</td>
<td>600</td>
<td>1200</td>
</tr>
<tr>
<td>Aperture size (mm)</td>
<td>200 mm diameter (g)</td>
<td>300 mm Diameter (g)</td>
</tr>
<tr>
<td>-------------------</td>
<td>---------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>16.0</td>
<td>500</td>
<td>1050</td>
</tr>
<tr>
<td>13.2</td>
<td>400</td>
<td>900</td>
</tr>
<tr>
<td>9.50</td>
<td>250</td>
<td>600</td>
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<tr>
<td>6.70</td>
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<td>4.75</td>
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<td>2.36</td>
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<td>300</td>
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<td>1.18</td>
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<td>200</td>
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<td>0.600</td>
<td>75</td>
<td>150</td>
</tr>
<tr>
<td>0.300</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>0.150</td>
<td>40</td>
<td>80</td>
</tr>
<tr>
<td>0.075</td>
<td>25</td>
<td>50</td>
</tr>
</tbody>
</table>
Test Method Q103C: Particle size distribution of soil - hydrometer

1 Source
This method applies the principles of AS 1289.3.6.3: Determination of the particle size distribution of a soil – Standard method of fine analysis using a hydrometer. It differs from this Australian Standard with minor variations in operational techniques; the treatment of various corrections used to determine the test results and the addition of calculations for fines ratio, coefficient of uniformity and the coefficient of curvature.

2 Scope
This method sets out the procedure for the quantitative determination of the particle size distribution of the fine fraction of a soil (passing the 2.36 mm sieve), using a hydrometer for particles finer than 0.075 mm (Note 10.1). The method as described is not applicable if less than 10 percent of the material passes the 0.075 mm sieve as measured in Test Method Q103A.

3 Apparatus
The following apparatus is required:

3.1 Hydrometer complying with the general specifications of AS 2026 and with the following features:
3.1.1 The glass used for the bulb and stem is as free as possible from visible defects.
3.1.2 The stem and bulb are circular in cross-section and symmetrical about the longitudinal axis, with no abrupt changes in cross-section which may trap air bubbles or hinder cleaning or drying.
3.1.3 The basis of the scale is grams per litre (g/L) of colloid in suspension at 20°C, graduated from -2 to +60, with graduation lines at every g/L. The scale is based on an apparent particle density of 2.65 t/m³, refer to Subsection 6.2.

3.2 Sedimentations cylinders, two 1 L capacity parallel sided graduated glass measuring cylinders, about 60 mm internal diameter and 450 mm high, marked at 1 L volume.

3.3 Thermometer, a partial or total immersion thermometer or other suitable temperature measuring device with a temperature range of at least 0-50°C and graduated to 1°C or less with an uncertainty of no more than 0.5°C.

3.4 Mechanical dispersion device (Note 10.2).
3.4.1 Mechanical mixer, for example an electrically driven mixer with a cup to fit, equipped with a wire baffle, the cup and baffle being of material resistant to chemical attack from the reagents used. (Many types of paddle or agitator mixers are suitable provided they cause thorough mixing without crushing particles or splashing. A low peripheral speed of the rotor tips is desirable, provided it is compatible with thorough mixing).
3.4.2 Air-jet dispersion cup complying with ASTM D422 (optional).

3.5 Sieves complying with AS 1152 as follows:
3.5.1 Dry sieving; 2.36 mm, 1.18 mm, 0.600 mm, 0.300 mm, 0.150 mm and 0.075 mm.
3.5.2 Wet sieving; reinforced 0.075 mm sieve.

3.6 Mechanical sieve shaker (optional).
3.7 Balance of suitable capacity, having a resolution of at least 0.01 g and with a limit of
performance within the range ± 0.05 g.
3.8 Oven of suitable capacity, having a temperature of 105-110°C and complying with AS 1289.0.
3.9 Timer.
3.10 Calliper, with a resolution of 0.01 mm and complying with AS 1984 or JIS 7507.
3.11 Steel rule with a resolution of 1 mm.
3.12 Evaporation dishes, porcelain evaporating dishes of suitable capacity and about 150 mm
diameter.
3.13 Beaker, glass beaker of about 600 mL capacity with a cover glass.
3.14 Buchner funnel and filter flask, about 500 mL capacity.
3.15 Cylinder, glass measuring cylinder of 100 mL capacity.
3.16 Plastic wash bottle.
3.17 Glass rod, about 200 mm long and 5 mm diameter.
3.18 Hot plate.
3.19 Desiccator.
3.20 Constant temperature environment (that is room, bath or cabinet) capable of maintaining the
soil suspension at a constant temperature (± 2.0°C) and free from vibration during
sedimentation.
3.21 Sieve brush.

4 Reagents
The following reagents of recognised analytical reagent quality are required:
4.1 Hydrogen peroxide 20-volume solution.
   - Prepare by diluting 30 mL of 100 volume hydrogen peroxide (30% w/v) with distilled water
to make 150 mL of solution (Note 10.3).
4.2 Hydrochloric acid 1M solution.
   - Prepare by diluting 89 mL of concentrated hydrochloric acid with distilled water to make
   1 L of solution (Note 10.3).
4.3 Barium chloride solution.
   - Prepare by dissolving 50 g of barium chloride in 1 L of distilled water (Note 10.3).

5 Materials
The following materials are required:
5.1 Dispersing agent
   - Prepare by dissolving 33 g of sodium hexametaphosphate (LR Grade) and 7 g of
   anhydrous sodium carbonate (LR Grade) or 18.9 g of sodium carbonate decahydrate
   (LR Grade) in one litre of water (Notes 10.3 and 10.4).
5.2 Filter papers (Whatman No. 50 or similar grade) to fit the Buchner funnel.
5.3 Litmus paper (blue) or suitable universal pH indicator papers.
5.4 Distilled water.
5.5 Anhydrous silica gel for desiccator.

6 Calibration of hydrometer

The hydrometer shall be calibrated as follows:

6.1 Effective depth of Hydrometer

6.1.1 Choose two major graduation marks on the sedimentation cylinder to be used in the test (for example 100 mL and 900 mL), and record the values (\( V_{c1} \), \( V_{c2} \)).

6.1.2 Using the steel rule determine the distance between the marks on the cylinder (\( d \)).

6.1.3 Determine the mass of the hydrometer (\( m \)) and record this mass as the volume of the hydrometer bulb and stem below the 0 g/L graduation mark (\( v \)).

6.1.4 Using the calliper determine the following:
   a) Determine the distance from the graduation mark nearest to the neck on the stem of the hydrometer to each of the other major graduation marks (\( d \)).
   b) Determine the distance from the neck of the bulb to the nearest graduation mark (\( r \)) to the nearest 0.1 mm.
   c) Determine the height of the bulb from the neck to the bottom of the bulb. If the bulb is symmetrical record this distance as equal to twice the length from the neck of the bulb to its centre of volume. If the bulb is not symmetrical, estimate the position of its centre of volume by any suitable means (Note 10.5) and record twice the distance from the neck to the centre of volume (\( h \)) as an equivalent value of 1.

6.1.5 Calculate the effective depth values corresponding to each major graduation mark as follows (Note 10.6):
   a) When the hydrometer remains in the suspension from the start of the test:

\[
H_{\text{r1}} = d + r + \frac{h}{2}
\]

where
\( H_{\text{r1}} \) = effective depth of hydrometer (mm)
\( d \) = distance from the graduation mark nearest to the neck on the stem to each major graduation mark (mm)
\( r \) = distance from the neck of the bulb to the nearest graduation mark (mm)
\( h \) = twice the distance from the neck of the bulb to its centre of volume (mm)

b) When the hydrometer is inserted to take a single reading:

\[
H_{\text{r2}} = d + r + \frac{1}{2} \left[ h - \frac{1000vd}{V_{c2} - V_{c1}} \right] A
\]
Test Method Q103C: Particle size distribution of soil - hydrometer

where \( H_{R2} \) = effective depth of hydrometer (mm)

\( d \) = distance from the graduation mark nearest to the neck on the stem to each major graduation mark (mm)

\( r \) = distance from the neck of the bulb to the nearest graduation mark (mm)

\( h \) = twice the distance from the neck of the bulb to its centre of volume (mm)

\( v \) = volume of the hydrometer bulb (mL)

\( d_c \) = distance between chosen graduation marks on the sedimentation cylinder to be used in the test (mm)

\( V_{c1}, V_{c2} \) = value of chosen graduation marks on the sedimentation cylinder (\( V_{c1} \) being the lesser) (mL)

\( A \) = mean cross-sectional area of the hydrometer stem (mm\(^2\)) (refer to Step 6.2.5).

6.1.6 For each set of calculated effective depth values, determine the relationship between hydrometer reading and effective depth by either of the following:

a) For each major graduation mark, plot the value of effective depth against the corresponding hydrometer reading on linear graph paper and draw the straight line of best fit through the data points.

b) Calculate the linear regression equation for the relationship in the form:

\[ H_R = mR_2 + c \]

where \( H_R \) = effective depth value (mm)

\( R_2 \) = corresponding hydrometer reading (g/L)

\( m, c \) = linear regression constants

6.2 Calibration of hydrometer scale

6.2.1 Immerse the hydrometer in distilled water at 20 ± 0.5°C and record the hydrometer reading at the bottom of the meniscus as the base reference mark to the nearest 0.2 g/L.

6.2.2 Determine the mass of the hydrometer in air (\( m \)).

6.2.3 Using callipers, determine the diameter of the stem at each major graduation mark (\( D \)).

6.2.4 Determine the distance between the base reference mark and each of the major graduations marks (\( d \)).

6.2.5 Calculate the mean cross-sectional area of the hydrometer stem as follows:

\[ A = \pi \left( \frac{\sum D^2}{2n} \right) \]

where \( A \) = mean cross-sectional area of the hydrometer stem (mm\(^2\))

\( D \) = diameter of the stem at each major graduation mark (mm)
Test Method Q103C: Particle size distribution of soil - hydrometer

n = number of graduation marks at which the stem diameter was recorded

6.2.6 For each major graduation mark, calculate and record the corrected hydrometer reading as follows:

\[ R_c = \frac{0.9982}{\frac{1000m - 1}{0.9982Ad} \cdot 6.233 \times 10^{-4}} \]

where
- \( R_c \) = corrected hydrometer reading at each graduation mark (g/L)
- \( m \) = mass of hydrometer (g)
- \( A \) = mean cross-sectional area of the hydrometer stem (mm²)
- \( d \) = distance between the base reference mark and each major graduation mark (mm)

6.2.7 Report the hydrometer calibration data in tabular form, showing the following:

a) The base reference mark and corresponding corrected hydrometer reading to the nearest 0.1 g/L.

b) For each major graduation mark, the hydrometer reading and corresponding corrected hydrometer reading to the nearest 0.1 g/L (Note 10.7).

7 Procedure

The procedure shall be as follows:

7.1 Sample preparation

7.1.1 Obtain a representative subsample of approximately 350 g passing the 2.36 mm sieve from material used in Test Method Q103A.

7.1.2 From the subsample obtain the following test portions:

a) Moisture content test portion
   - Determine the moisture content (\( w_1 \)) as detailed in Test Method Q102A.

b) Sedimentation test portion
   - The size of the sample depends on the soil type, for example 50 g for a clayey soil and 100 g for a sandy soil (Note 10.8).

c) Apparent particle density test portion
   - The sample size depends on the quantity of impurities, however, 100 g is usually sufficient.

d) Impurities test portion
   - Approximately 30 g is required to allow spot tests to be performed to test for the presence of organics and carbonates.
7.2 Preparation of sedimentation test portion

7.2.1 Calculate the mass of soil required to produce a dry mass of 20 g passing the 0.075 mm sieve in the sedimentation test portion as follows:

\[
M_i = \frac{20(100 + w_i)}{P_{0.075}}
\]

where

- \( M_i \) = mass of wet material in sedimentation test portion (g)
- \( w_i \) = hygroscopic moisture content of sedimentation test portion (g)
- \( P_{0.075} \) = percentage passing the 0.075 mm sieve, obtained from Test Method Q103A.

7.2.2 Determine the mass of the beaker (\( m_i \)).

7.2.3 Prepare the test portion having the mass as calculated in Step 7.2.1, using the procedure detailed in Subsection 6.4 of Test Method Q101 for fine fraction subsamples. Place the portion in the beaker and determine the mass of the beaker and soil (\( m_2 \)).

7.3 Pre-treatment

7.3.1 Organic matter

Check the soil for the presence of any significant quantity of organic matter by adding a few drops of hydrogen peroxide solution to a few grams of soil from the impurities test portion. If no effervescence occurs omit the pre-treatment, otherwise, proceed as follows:

a) Add 150 mL of hydrogen peroxide solution to the sedimentation test portion in the beaker and stir the mixture gently with a glass rod for a few minutes. Cover the beaker with the glass cover and leave it to stand for about 12 hours (Note 10.9).

b) When effervescence has stopped, heat gently, avoiding frothing over and stir the contents periodically. When vigorous frothing has subsided, reduce the volume to about 50 mL by boiling.

7.3.2 Carbonates

Check the soil for the presence of carbonates by adding hydrochloric acid solution to a few grams of soil from the impurities test portion. If no effervescence occurs omit the pre-treatment, otherwise, proceed as follows (Note 10.10):

a) Add 100 mL of hydrochloric acid solution to the sedimentation test portion in the beaker, stir for a few minutes and leave it to stand for about 1 hour (Note 10.11). The pre-treatment is complete when the solution has an acid reaction to litmus paper.

b) Filter the mixture on the Buchner funnel and wash with warm water until the filtrate shows no acid reaction to litmus paper. Return all of the soil on the filter paper and the funnel to the beaker.

7.3.3 Soluble salts

Remove any soluble salts from saline soils as follows:

a) Add distilled water to the sedimentation test portion in the beaker to the 150 mL mark and stir the mixture.
b) Filter the mixture on the Buchner funnel and wash with warm water until the filtrate shows no precipitation with the barium chloride solution (Note 10.12). Return all of the soil on the filter paper and the funnel to the beaker.

7.4 Apparent particle density determination

7.4.1 If pre-treatment of the soil is required for the hydrometer analysis, pre-treat the apparent particle density test portion in the same manner.

7.4.2 Determine the apparent particle density of the test portion as detailed in Test Method Q109A.

7.5 Dispersion of soils

Sodium hexametaphosphate is the recommended dispersing agent (Note 10.13).

7.5.1 Prepare the sedimentary test portion for dispersion by adding 100 mL of dispersing agent. Where pre-treatment has been omitted, cover the beaker with the glass cover and leave it to stand for about 12 hours.

7.5.2 Warm the mixture on a hotplate using a low heat for about 10 minutes.

7.5.3 Transfer all the mixture to the mechanical dispersion device (Note 10.2) using distilled water from the wash bottle to clean the beaker, but taking care that the dispersion container is not more than half filled.

7.5.4 Fit the baffle to the container and operate the dispersion device for 15 minutes.

7.5.5 Transfer the suspension to the 1 L sedimentation cylinder using distilled water from the wash bottle to clean the dispersion container and baffle. Make up to 1 L with distilled water. Fill the second sedimentation cylinder with up to 1 L with distilled water.

7.6 Sedimentation

7.6.1 Immerse the hydrometer in the 1 L sedimentation cylinder containing distilled water. Place the sedimentation cylinder in the constant temperature environment.

7.6.2 Place the 1 L cylinder, containing the suspension, in the constant temperature environment and leave it to stand until it has attained the ambient temperature. Close the mouth of the cylinder with the palm of the hand, or with a suitable watertight stopper, and bring all the contents into suspension by shaking and turning the cylinder end to end for at least one minute.

7.6.3 Immediately place the cylinder on a firm, level, vibration free position in the constant temperature environment.

7.6.4 Immediately start the timer and record the time of commencement of the test.

7.6.5 Record the sedimentation measurements as follows:

a) Carefully immerse the hydrometer to a depth slightly below its floating position (taking at least 10 seconds for this operation) and allow it to float freely.

b) Read and record the hydrometer reading at the top of the meniscus to the nearest 0.2 g/L, after the following periods: 1, 2, 4, 8, 15 and 30 minutes, and 1, 2 and 4 hours. Take further readings as required up to 48 hours after dispersion.

c) Determine the temperature of the suspension once during the first 15 min of sedimentation and then after every subsequent reading (tₜ) (Notes 10.16 and 10.17).

d) At the completion of the reading, remove the hydrometer from the suspension (Notes 10.14 and 10.15).
7.6.6 After the final sedimentation measurement, close the mouth of the cylinder with the palm of the hand, or with a suitable watertight stopper and bring all the contents into suspension.

7.6.7 Transfer the contents of the cylinder to the 0.075 mm sieve placed on the sieve pan. Use water from the wash bottle to clean the measuring cylinder and the retained 0.075 mm material. Where pre-treatment has been omitted allow the passing 0.075 mm material to run to waste.

7.6.8 Transfer all the washed retained 0.075 mm material to a suitable container and decant excess water.

7.6.9 Place the container in the oven and dry until the material has reached constant mass (Note 10.18).

7.6.10 Dry sieve the washed test portion by hand through the nominated sieves in order of decreasing aperture size down to and including 0.075 mm (Note 10.19).

7.6.11 Determine the mass of the particles retained on each sieve ($m_i$).

7.6.12 Where the test portion has been pre-treated, determine the mass of the passing 0.075 mm fraction as follows:
   a) Add any passing 0.075 mm material from the dry sieving in Step 7.6.10 to the wash water collected in the sieve pan at Step 7.6.7.
   b) Transfer the contents of the pan to a container of known mass ($m_4$) and dry in the oven. When the test portion has reached a constant mass, determine the mass of the container and contents ($m_5$) (Note 10.18).

7.7 Adjustments

7.7.1 Dispersing agent
   a) Place 100 mL of the dispersing agent in an evaporating dish of known mass ($m_6$) and dry in the oven until a constant mass is reached (Note 10.18).
   b) Allow the evaporating dish and contents to cool in a dessicator and determine the mass ($m_7$).

7.7.2 Meniscus
   a) Insert the hydrometer in a 1 L graduated cylinder containing about 700 mL of distilled water.
   b) Align the eye slightly below the plane of the surface of the liquid and raise the eye slowly until the surface, seen as an ellipse, becomes a straight line.
   c) Record the hydrometer reading ($R_{m1}$), where the straight line intersects the hydrometer scale to the nearest 0.2 g/L.
   d) Record the hydrometer reading ($R_{m2}$), where the upper limit of the meniscus intersects the hydrometer scale to the nearest 0.2 g/L.
8 Calculations

8.1 Calculate the cumulative mass retained on each sieve as follows:

\[ M = \sum m_r \]

where
- \( M \) = cumulative mass retained on a particular sieve (g)
- \( m_r \) = individual mass retained on each sieve with aperture size larger than or equal to the particular sieve (g)

8.2 Calculate the dry mass of the test portion with no pre-treatment as follows:

\[ m_8 = \frac{(m_2 - m_i)100}{100 + w} \]

where
- \( m_8 \) = mass of test portion with no pre-treatment (g)
- \( m_2 \) = mass of beaker and air dry test portion (g)
- \( m_i \) = mass of beaker (g)
- \( w \) = moisture content of the air dry test portion (g)

8.3 Calculate the dry mass remaining after pre-treatment as follows:

\[ m_9 = (m_5 - m_4) + M_{0.075} \]

where
- \( m_9 \) = mass of pre-treated test portion (g)
- \( m_5 \) = mass of container and passing 0.075 mm material (g)
- \( m_4 \) = mass of container (g)
- \( m_7 \) = mass of evaporating dish and residual dispersing agent (g)
- \( m_8 \) = mass of evaporating dish (g)
- \( M_{0.075} \) = cumulative mass retained on the 0.075 mm sieve (g)

8.4 Calculate any loss due to pre-treatment as follows:

\[ p = \left( \frac{m_8 - m_9}{m_8} \right) \times 100 \]

where
- \( p \) = loss due to pre-treatment (%)
- \( m_8 \) = mass of test portion with no pre-treatment (g)
- \( m_9 \) = mass of pre-treated test portion (g)

8.5 Calculate the dispersing agent adjustment as follows:

\[ R_a = m_7 - m_6 \]

where
- \( R_a \) = dispersing agent adjustment (g)
8.6 Calculate the meniscus adjustment to hydrometer readings as follows:

\[ R_m = R_{m1} - R_{m2} \]

where 
- \( R_m \) = meniscus adjustment (g/L)
- \( R_{m1} \) = hydrometer reading at the bottom of the meniscus (g/L)
- \( R_{m2} \) = hydrometer reading at the top of the meniscus (g/L)

8.7 Adjust each hydrometer reading for meniscus and dispersing agent adjustment as follows:

\[ R_2 = R_1 + R_m - R_a \]

where 
- \( R_2 \) = adjusted hydrometer reading (g/L)
- \( R_1 \) = test hydrometer reading (g/L)
- \( R_m \) = meniscus adjustment (g/L)
- \( R_a \) = dispersing agent adjustment (g)

8.8 Determine the effective depth (\( H_R \)) for each adjusted hydrometer reading, in accordance with the appropriate hydrometer reading/effective depth relationship determined in Subsection 6.1.

8.9 Calculate the particle diameter as follows:

\[ D = \frac{5.5300 \left( \sqrt{\frac{H_R}{t}} \sqrt{\frac{\nu}{\rho_s - \rho_w}} \right)}{1000} \]

where 
- \( D \) = particle diameter (mm)
- \( H_R \) = effective depth corresponding to the adjusted hydrometer reading (mm)
- \( t \) = elapsed time (mins)
- \( \nu \) = dynamic viscosity of water (mPa.s) (Refer to Table 1)
- \( \rho_s \) = apparent particle density of the soil sample (t/m³)
- \( \rho_w \) = density of water (t/m³) (Refer to Table 2)

8.10 Correct the adjusted hydrometer reading using the appropriate calibration information determined in Subsection 6.2.

8.11 Calculate the temperature adjustment for temperature of the suspension as follows:

\[ R_t = 0.0086t_s^2 - 0.0588t_s - 2.2657 \]

where 
- \( R_t \) = temperature adjustment (g/L) (Note 10.20)
8.12 Calculate the percent by mass of particles finer than the corresponding particle diameter from the appropriate calculation as follows:

8.12.1 If the pre-treatment of the subsample was omitted:

\[ P_D = \frac{(R_c + R_t) \cdot 0.623 \cdot \rho_s}{m_s (\rho_s - 1)} \times 100 \]

where
- \( P_D \) = percent by mass of particles finer than the corresponding particle diameter (%)
- \( R_c \) = corrected hydrometer reading (from Step 8.10) (g/L)
- \( R_t \) = temperature adjustment (from Step 8.11) (g/L)
- \( \rho_s \) = apparent particle density of the soil sample (t/m³)
- \( m_s \) = mass of test portion with no pre-treatment (g)

8.12.2 If the subsample was pre-treated:

\[ P_D = \frac{(R_c + R_t) \cdot 0.623 \cdot \rho_s}{m_o (\rho_s - 1)} \times 100 \]

where
- \( P_D \) = percent by mass of particles finer than the corresponding particle diameter (%)
- \( R_c \) = corrected hydrometer reading (from Step 8.10) (g/L)
- \( R_t \) = temperature adjustment (from Step 8.11) (g/L)
- \( \rho_s \) = apparent particle density of the soil sample (t/m³)
- \( m_o \) = mass of pre-treated test portion (g)

8.13 Other material properties

If required, calculate other material properties using necessary results from the sample tested as detailed in Test Method Q103A as follows:

8.13.1 Calculate the particle size where 60% of particles are smaller as follows:

\[ D_{60} = 10^{\left(\frac{\log D_2 - (60 - P_2) \cdot \log D_1}{\log D_2 - \log D_1}\right)} \]

where
- \( D_{60} \) = particle size where 60% of particles are smaller (mm)
- \( \log \) = logarithm to base 10
- \( D_2 \) = largest sieve or particle diameter with less than 60% passing (mm)
- \( P_2 \) = percent passing \( D_2 \)
- \( D_1 \) = smallest sieve or particle diameter with more than 60% passing (mm)
- \( P_1 \) = percent passing \( D_1 \)
8.13.2 Calculate the particle size where 10% of particles are smaller as follows:

\[ D_{10} = 10^{\left(\frac{\log_{10} D_2 - (10-P_1) \log_{10} D_2 - (10-P_2)}{P_1 - P_2}\right)} \]

where

- \( D_{10} \) = particle size where 10% of particles are smaller (mm)
- \( \log \) = logarithm to base 10
- \( D_2 \) = largest sieve or particle diameter with less than 10% passing (mm)
- \( P_2 \) = percent passing \( D_2 \)
- \( D_1 \) = smallest sieve or particle diameter with more than 10% passing (mm)
- \( P_1 \) = percent passing \( D_1 \)

8.13.3 Calculate the particle size where 30% of particles are smaller as follows:

\[ D_{30} = 10^{\left(\frac{\log_{10} D_2 - (30-P_1) \log_{10} D_2 - (30-P_2)}{P_1 - P_2}\right)} \]

where

- \( D_{30} \) = particle size where 30% of particles are smaller (mm)
- \( \log \) = logarithm to base 10
- \( D_2 \) = largest sieve or particle diameter with less than 30% passing (mm)
- \( P_2 \) = percent passing \( D_2 \)
- \( D_1 \) = smallest sieve or particle diameter with more than 30% passing (mm)
- \( P_1 \) = percent passing \( D_1 \)

8.13.4 Calculate the coefficient of uniformity as follows:

\[ C_u = \frac{D_{60}}{D_{10}} \]

where

- \( C_u \) = coefficient of uniformity
- \( D_{60} \) = particle size where 60% of particles are smaller (mm)
- \( D_{10} \) = particle size where 10% of particles are smaller (mm)

8.13.5 Calculate the coefficient of curvature as follows:

\[ C_c = \frac{D_{30}^2}{D_{10}D_{60}} \]

where

- \( C_c \) = coefficient of curvature
- \( D_{30} \) = particle size where 30% of particles are smaller (mm)
- \( D_{10} \) = particle size where 10% of particles are smaller (mm)
\[ D_{60} = \text{particle size where 60\% of particles are smaller (mm)} \]

9 Reporting

Report the following values:

9.1 For each sedimentation reading, the particle diameter to the nearest 0.0001 mm and the percentage of material finer than each particle diameter to the nearest 1%.

9.2 The loss in pre-treatment as a percentage of the fraction passing the 2.36 mm sieve to the nearest 1%.

Report the following additional information, if required:

9.3 If required, a semi-logarithmic graph of the percent passing versus sieve size/particle diameter.

9.4 Coefficient of uniformity to the nearest 0.1 for results 1 or greater and to the nearest 0.01 for results less than 1 (if required).

9.5 Coefficient of curvature to the nearest 0.1 for results 1 or greater and to the nearest 0.01 for results less than 1 (if required).

10 Notes on method

10.1 The hydrometer method is relatively simple to perform and requires only inexpensive apparatus. The accuracy of the results obtained is adequate for engineering purposes.

10.2 The choice of dispersion device is dependent on the soil under test. Some soils particularly residual soils of igneous origin suffer severe structural breakdown when subjected to mechanical mixing. The air-jet dispersion cup is to be used for these soils.

10.3 Before handling hydrogen peroxide, concentrated hydrochloric acid, sodium hexametaphosphate, anhydrous sodium carbonate, sodium carbonate decahydrate, barium chloride or anhydrous silica gel, the operator must consult the relevant Safety Data Sheet (SDS).

10.4 This solution is unstable and must be freshly prepared approximately once a month with the preparation and expiry dates recorded on the container.

10.5 The distance h/2 shown on AS 1289.3.6.3 Figure 1 locates the centre of volume of a symmetrical bulb (that is circular in cross-section and symmetrical about the longitudinal axis). If a symmetrical bulb is used, determine the centre of volume with sufficient accuracy by projecting the shape of the bulb on to a sheet of paper and locating the centre of gravity of the projected area.

10.6 The relationships give the effective depth of the suspension referred to any given hydrometer reading, allowing for the rise of liquid in the graduated cylinder. It is desirable to pair a hydrometer with a calibrated cylinder so that values of effective depth only need to be calculated once, when the hydrometer is first calibrated. Further simplification can be obtained by using hydrometers and cylinders manufactured to closely tolerated standard dimensions.

10.7 In order to apply corrections to hydrometer readings which fall between major graduation marks, determine the corrected hydrometer reading using linear interpolation between the calibration data at the adjacent major graduation marks.

10.8 Stoke’s Law was derived for a single sphere falling in a large body of liquid. It is not applicable to a highly concentrated suspension in which the particles are close enough to influence each
other, but if the mass of solid matter in the suspension is not too large, the deviation from Stoke’s Law is negligible. For some heavy clays, however, it may be necessary to limit the suspension to not more than 20 g/L to avoid interference.

10.9 With highly organic soils (greater than 15 percent), additional peroxide may be required to complete the oxidation process.

10.10 Certain types of predominantly chalky soils should not be pretreated with acids as this would result in a dissolution of particles. In such cases try other suitable methods for breaking up agglomerations of particles, such as prolonged stirring or rubbing. Agglomerations of solid particles bonded with iron oxides are of a more permanent nature and acid pre-treatment is not carried out.

10.11 If the soil contains a considerable amount of calcium salts, add more acid as required.

10.12 Slightly soluble salts, notably calcium sulfate, will require larger quantities of water for complete dissolution. Considerable time may be saved by repeated washing in the flask or beaker, rather than washing the sample on the filter. Completion of the treatment is indicated by the absence of sulfate ions in the wash water.

10.13 After pre-treatment, the majority of soils will disperse easily but certain very heavily flocculated soils may not be dispersed completely. Incomplete dispersion is indicated by the formation of relatively large crumbs or “flocs” of soils which fall rapidly through the water, leaving a sharply defined clear layer above the suspension. Such a case may require an additional quantity of the dispersing agent or a different agent. For example, latitic soils cannot be dispersed adequately with sodium hexametaphosphate and the use of sodium phosphate is advised.

10.14 If a calibrated hydrometer is not available for each concurrent test, carefully remove the hydrometer after the 4 minute reading (taking at least 10 seconds for this operation), rinse it in distilled water and place it in a sedimentations cylinder of distilled water which is at the same temperature as that of the suspension.

Re-insert the hydrometer in the suspension just prior to taking each subsequent reading, take the reading, remove the hydrometer, rinse it and replace it in the cylinder of distilled water (taking at least 10 seconds for each insertion/removal operation).

10.15 Keep the hydrometer stem perfectly clean to obtain a fully developed meniscus around the stem.

10.16 For an error in particle size of not more than 2 percent, the temperature of the suspension should not differ from the mean temperature by more than 2°C over the period of the test. This condition is usually satisfied if the range in room temperatures is not greater than about 8°C.

10.17 To avoid convection currents during the sedimentation process, keep the suspension out of direct sunlight and away from any local sources of heat.

10.18 The material is considered to have reached a constant mass when the difference between successive weighings, after a further 1 hour drying at 105-110°C, is not more than 1 percent of the total of the previous moisture losses.

10.19 Sieve the material using a lateral and vertical motion accompanied by a slight jarring action to keep the material moving over the sieve. It may be necessary to unblock the sieves from time to time using the sieve brush. Continue this agitation until no more than 1 percent by mass of residue will pass the sieve during a further 1 minute of continuous sieving. When sieving, the underside of the sieves may be lightly brushed with a soft fine brush to prevent aggregation of particles (balling) and blinding of the apertures.
10.20 The relationship applies to hydrometers calibrated at 20°C.

**Table 1 - Dynamic viscosity of water**

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Dynamic viscosity (mPa.s)</th>
<th>Temperature (°C)</th>
<th>Dynamic viscosity (mPa.s)</th>
<th>Temperature (°C)</th>
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**Table 2 – Density of water**

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<th>Density (t/m³)</th>
<th>Temperature (°C)</th>
<th>Density (t/m³)</th>
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<td>Density (t/m³)</td>
<td>Temperature (°C)</td>
<td>Density (t/m³)</td>
<td>Temperature (°C)</td>
<td>Density (t/m³)</td>
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<td>0.9956</td>
<td>40.0</td>
<td>0.9922</td>
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</tbody>
</table>
Test Method Q103F: Particle size distribution of soil – laser diffraction

1  Source

This method was developed in-house using techniques developed through internal departmental investigations. The principles of this technique are detailed in AS 4863.1 - Particle size analysis - Laser diffraction methods.

2  Scope

This method sets out a procedure for the quantitative determination of the particle size distribution of a soil sample, using test sieves for particles 0.075 mm and larger and a laser diffraction instrument for particles finer than 0.075 mm.

A sample of material is pumped into the laser diffraction instrument where a laser beam is directed at the particles and scattered at angles relative to the size of the particles. The instrument software uses a mathematical model to convert the detected angles of scatter into a particle size volume distribution. This particle size volume distribution up to 0.075 mm is combined with the sieve analysis of larger particles to produce a percent passing distribution that is characteristic of the entire sample.

3  Definitions

Volume under percentage is the total volume of all particles with a diameter less than that of a particular size category, expressed as a percentage of the total volume of all particles in a sample. The equivalent of the "percent passing" result calculated when using the hydrometer method for particle size distribution analysis.

4  Apparatus

The following apparatus is required:

4.1  Laser diffraction instrument with a liquid dispersion unit, measuring range including 0.001 mm to 0.075 mm and the capability of measuring and reporting a volume distribution of predetermined particle sizes.

4.2  Sample splitting device capable of splitting a 500 mL sample into 10 representative subsamples.

4.3  Mechanical dispersion device.

4.4  Beaker, glass beaker of 1000 mL capacity.

4.5  Cylinder, glass measuring cylinder of 500 mL capacity.

4.6  Cylinder, glass measuring cylinder of 500 mL capacity with stopper.

4.7  Wash bottle, containing distilled water.

4.8  Beakers, 12 glass beakers of 250 mL capacity.

4.9  Funnel.

4.10  Soil sample divider.

4.11  Balance of suitable capacity, with a resolution of at least 1 g and with a limit of performance within the range of ± 5 g.

4.12  Plastic sample container of suitable volume.

4.13  Sieve, 0.075 mm wash sieve complying with AS 1152.
4.14 Spray bottle, containing distilled water.

5 Materials

5.1 Dispersing agent

- Prepare by dissolving 33 g of sodium hexametaphosphate (LR Grade) and 7 g of anhydrous sodium carbonate (LR Grade) or 18.9 g of sodium carbonate decahydrate (LR Grade) in one litre of water (Note 10.1 and 10.2).

5.2 Distilled water.

6 Procedure

The procedure shall be as follows:

6.1 Sample Preparation

6.1.1 Prepare a sample as detailed in Test Method Q101, air drying the material as necessary. Obtain a representative test portion and determine the particle size distribution of the coarse fraction as detailed in Test Method Q103A.

6.1.2 Further prepare the material by screening it on a 2.36 mm sieve and split it using the soil sample divider to produce a representative, fine fraction subsample of approximately 30 g for particle size distribution analysis by laser diffraction.

6.1.3 Add approximately 100 mL of the dispersing agent to the subsample and allow it to stand for at least 12 hours.

6.1.4 Transfer the subsample to the mechanical dispersion device using the wash bottle to ensure all particles are transferred, and disperse for approximately 15 minutes.

6.1.5 Transfer the mechanically dispersed suspension to the 0.075 mm wash sieve which is placed over a funnel that drains into a 500 mL measuring cylinder and use minimal distilled water from the spray bottle to wash all fines to passing 0.075 mm.

6.1.6 Pour the sample from the 500 mL measuring cylinder into the second 500 mL measuring cylinder with stopper and invert a number of times to ensure a homogenous distribution of the particles throughout the sample.

6.1.7 Pour the sample into the sample splitting device reducing it to 10 representative slurry aliquots. Use minimal distilled water from the wash bottle to flush all particles remaining in the cylinder and the funnel into the slurry aliquots.

6.2 Determination of Optimum Parameters

6.2.1 Switch on the dispersion unit and optical bench and allow them to warm up for at least 30 minutes.

6.2.2 Fill the 1000 mL beaker with distilled water and circulate at 2000 RPM for 1 minute.

6.2.3 Before measurements are performed it is necessary to conduct trials to determine the optimum settings for parameters such as pump speed, ultrasonic strength and ultrasonic duration for a particular sample.

6.2.4 Using the principles outlined in the relevant user manual, take a number of manual measurements of the sample to determine the optimum parameters for that sample (Note 10.3).
6.2.5 Using the principles outlined in the relevant user manual, create a standard operating procedure (SOP) that will take ten measurements of the sample and report the volume distribution at the following predetermined particle sizes: 0.05 mm, 0.035 mm, 0.025 mm, 0.015 mm, 0.0125 mm, 0.01 mm, 0.0075 mm, 0.005 mm, 0.0025 mm, 0.002 mm and 0.001 mm. This SOP will be used for a specific sample and include the parameters determined in Step 6.2.3.

6.2.6 Empty the 1000 mL beaker and refill to approximately 700 mL with distilled water.

6.2.7 Manually run the pump at 2000 RPM for 1 minute.

6.2.8 Repeat Steps 6.2.5 and 6.2.6 at least twice to flush the system.

6.3 Measurement Procedure

6.3.1 Using the SOP created in Step 6.2.4 allow the system to complete any automatic checks required prior to measurement such as electronic background and optical alignment.

6.3.2 Confirm that all data produced by the automatic checks in Step 6.3.1 are within limits required to continue with the measurement. If this is not the case it may be necessary to stop the procedure pending maintenance of the system before the process is resumed at Subsection 6.2.

6.3.3 Add one full aliquot into the liquid dispersion unit using the wash bottle and minimal distilled water to ensure the transfer of all particles.

6.3.4 Lower the pump arm and note the obscuration level (Note 10.4).

6.3.5 When an obscuration level within the limits described by the manufacturer is achieved, record the obscuration and complete the measurement.

6.3.6 Record the volume under percentage readings measured at each of the predetermined particle sizes.

6.3.7 Record the volume distribution percentile readings \(d(0.1), d(0.5)\) and \(d(0.9)\) for all ten measurements and the average.

6.3.8 After the completion of the measurement empty the 1000 mL beaker and refill to approximately 700 mL with distilled water.

6.3.9 Manually run the pump at 2000 RPM for 1 minute.

6.3.10 Repeat Steps 6.3.8 and 6.3.9 at least twice to flush the system.

6.3.11 Refill the 1000 mL beaker with distilled water and run the pump until the sample tubes are filled.

7 Calculations

7.1 Repeatability

7.1.1 Calculate the repeatability of \(d(0.1), d(0.5), \) and \(d(0.9)\) as follows:

\[
R_{(0.1,0.5,0.9)} = \left( \frac{d_{\text{max}}(0.1,0.5,0.9) - d_{\text{min}}(0.1,0.5,0.9)}{d_{\text{avg}}(0.1,0.5,0.9)} \right) \times 100
\]

Where \(R_{(0.1,0.5,0.9)}\) = repeatability of volume distribution percentile reading \(d(0.1), d(0.5)\) or \(d(0.9)\) (%)
\[ d_{\text{ma}}(0.1,0.5,0.9) = \text{maximum volume distribution percentile reading } d(0.1), d(0.5) \text{ or } d(0.9) \]

\[ d_{\text{m}}(0.1,0.5,0.9) = \text{minimum volume distribution percentile reading } d(0.1), d(0.5) \text{ or } d(0.9) \]

\[ d_{\text{avm}}(0.1,0.5,0.9) = \text{average volume distribution percentile reading } d(0.1), d(0.5) \text{ or } d(0.9) \]

\[ d(0.1) = \text{volume distribution percentile reading } d(0.1) \]

\[ d(0.5) = \text{volume distribution percentile reading } d(0.5) \]

\[ d(0.9) = \text{volume distribution percentile reading } d(0.9) \]

7.1.2 Compare the calculated repeatability of \(d(0.1), d(0.5)\) and \(d(0.9)\) and, if they comply with the relevant criteria in Table 1, calculate the percent passing. Otherwise repeat the measurement (Note 10.5).

7.2 For each measurement, calculate the percent passing as follows:

\[
P_i = \left(\frac{P_{0.075} V_i}{100}\right)
\]

Where:

- \(P_i\) = percent passing at the \(i\)th measurement
- \(P_{0.075}\) = percent passing the 0.075 mm sieve as determined in 8.1.1
- \(V_i\) = volume under percentage reading of the \(i\)th measurement

8 **Records**

Retain the following information:

8.1 Details of the optimum parameters determined in Subsection 6.2.

8.2 Obscuration at time of measurement.

8.3 Real and imaginary part of the refractive index.

8.4 Dispersant type and quantity.

8.5 Instrument type and identification.

9 **Reporting**

Report the following values and general information:

9.1 Particle size measured to the nearest 0.001 mm.

9.2 The percent passing to the nearest 0.01%.

9.3 If required, a chart displaying the plot of percent passing versus particle size on semi-logarithmic graph paper.
10 Notes on method

10.1 Before handling sodium hexametaphosphate, anhydrous sodium carbonate or sodium carbonate decahydrate, the operator must consult the relevant Safety Data Sheet (SDS).

10.2 This solution is unstable and must be freshly prepared approximately once a month with the preparation and expiry dates being recorded on the container.

10.3 The general process for determination of the optimum parameters may include incrementally increasing the pump speed until all particulates are flowing through the system then incrementally increasing the level of ultrasonication until de-aglomeration is achieved. The operator is required to draw on experience and training in order to optimise the test parameters and minimise the contribution of operator error to the uncertainty of the test results. When these optimum parameters have been determined, at least 5 measurements should be taken on the same aliquot with no ultrasonication to ensure the consistency of readings. There are a number of potential causes for not effectively identifying the optimum parameters for a sample, including: incorrect preparation of the sample, incomplete de-aglomeration and insufficient pump speed. These may be overcome but could require the retesting of multiple aliquots before a reliable SOP can be created.

The following parameters are standard for all SOP created under the scope of this method:

- Particle refractive index 1.555
- Absorption 0.01
- Dispersant Water
- Dispersant refractive index 1.330
- Analysis model General purpose

10.4 Before measurement can take place the obscuration level must be within limits described by the manufacturer. If the obscuration level is showing less than the lower limit one or more full aliquots may be added to the 1000 mL beaker to raise the obscuration level to within limits but care must be taken not to add more aliquots than the beaker can hold without spillage occurring while stirring. If the obscuration is showing greater than the upper limit the ratio of sample to dispersant in the 1000 mL beaker must be reduced. This can be achieved through the addition of distilled water to the 1000 mL beaker or the further reduction of the representative slurry aliquots. If further reduction is chosen care must be taken to ensure the new, twice reduced, slurry aliquots remain representative of the original sample.

10.5 Upon completion of the measurement it is necessary to perform a repeatability check to confirm the validity of the results. If the requirements are not met it is an indication that the sample is changing in some manner and the optimum parameters for the SOP may need to be reassessed.

Table 1 – Repeatability assessment values

<table>
<thead>
<tr>
<th>Volume distribution percentile</th>
<th>Repeatability</th>
<th>d(0.5) ≥ 0.01 mm</th>
<th>d(0.5) &lt; 0.01 mm</th>
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<tbody>
<tr>
<td>d(0.5)</td>
<td></td>
<td>R(0.5) ≤ 3%</td>
<td>R(0.5) ≤ 6%</td>
</tr>
<tr>
<td>d(0.1)</td>
<td></td>
<td>R(0.1) ≤ 5%</td>
<td>R(0.1) ≤ 10%</td>
</tr>
<tr>
<td>d(0.9)</td>
<td></td>
<td>R(0.9) ≤ 5%</td>
<td>R(0.9) ≤ 10%</td>
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Test Method Q104A: Liquid limit of soil

1 Source
This method is based on BS 1377-2: Methods of test for soils for civil engineering purposes – Part 2: Classification tests – Method 4.3: Cone penetrometer method. However, the liquid limit is defined in this method as the moisture content at a penetration of 15.5 mm. There are some other minor procedural differences.

2 Scope
This method describes the procedure for the determination of the liquid limit of the portion of a soil passing the 0.425 mm sieve using the cone penetrometer apparatus. The liquid limit is defined notionally as the moisture content at which the soil passes from the plastic to the liquid state, as determined by this procedure.

3 Apparatus
Where appropriate, the working tolerances of particular apparatus are contained in Table 1.

The following apparatus is required:

3.1 Penetrometer, any suitable penetrometer which permits the cone holder to move vertically in the guide without appreciable friction and which has the following features:

3.1.1 Depth indicator, with a resolution, maximum recorded indication error and a maximum recorded repeatability error not exceeding the working tolerances. A device such as a dial gauge, calliper rule, displacement transducer or similar would be suitable (Note 9.1).

3.1.2 Penetration cone, a polished stainless steel cone with a cone angle of 30°.

3.1.3 The total moving mass of the cone, cone holder, shaft and any adjusting masses is 80 g.

3.2 Cone wear template, consisting of a metal plate 1.75 mm thick, with a hole of 1.5 mm diameter.

3.3 Timing device, a stopwatch or audible seconds counter accurate to 0.5 seconds.

3.4 Balance of suitable capacity, having a resolution of at least 0.01 g and with a limit of performance within the range of ± 0.05 g.

3.5 Mixing bowl, about 150 mm diameter and 100 mm deep.

3.6 Drying ovens:

3.6.1 Oven of suitable capacity, having a temperature of 45-50°C and complying with AS 1289.0.

3.6.2 Oven of suitable capacity, having a temperature of 105-110°C and complying with AS 1289.0.

3.7 Spatula.

3.8 Containers with lids, for moisture content determination.

3.9 Test receptacles, containers having an internal diameter of 50 mm and an internal depth of 45 mm. Suitable containers are of heavy gauge aluminium, about 1.2 mm thick.

3.10 Potable water.

3.11 Curing containers, airtight containers to be used for curing of samples.
4 Adjustment of apparatus

4.1 Check that the penetrometer shaft falls freely before each use or on a daily basis.

4.2 Check the sharpness of the cone at least daily using the cone wear template. If the point cannot be felt when brushed lightly with the tip of the finger when the cone is pushed through the hole, the cone must be replaced.

5 Procedure

The procedure shall be as follows:

5.1 Prepare the sample as detailed in Section 5 of Test Method Q101, either air drying the material or drying in a 45-50°C oven as necessary. Obtain a representative subsample and further prepare the material as detailed in Subsection 6.4 of Test Method Q101 using a mortar and pestle and screening it on a 0.425 mm sieve to produce a fine fraction subsample of approximately 300 g.

5.2 Transfer the soil fines to the mixing bowl and add a small amount of potable water.

5.3 Mix the soil and water thoroughly for several minutes until it becomes a stiff homogeneous paste ready for curing. A penetration in the range of 9 mm to 12 mm, as determined in Steps 5.6 to 5.13, provides a suitable moisture content for effective curing.

5.4 Place the soil/water mixture in an airtight container to cure for at least 12 hours to allow the moisture to permeate the soil.

5.5 After curing, mix the soil/water thoroughly for 3 minutes.

5.6 Determine the mass of a moisture content container and lid ($m_1$).

5.7 Fill the test receptacle by placing the test material in the bottom of the container and exerting adequate pressure on the spatula to displace the soil/water mixture in an outward direction to remove any air from the mixture.

5.8 Completely fill the container in this manner and level the surface of the mixture with no more than three strokes of the spatula held almost flat. The soil/water mixture in the test container is now ready for penetration.

5.9 To prevent moisture loss during testing, cover the mixing bowl with a moist cloth.

5.10 Zero the depth indicator gauge with the penetrometer shaft and cone at the maximum height.

5.11 Position the filled test receptacle centrally under the point of the cone of the penetrometer and bring the cone into contact with the surface of the soil/water mixture.

5.12 Release the penetrometer shaft and allow the cone to penetrate the soil/water mixture for a period of $5 \pm 0.5$ seconds.

5.13 Depress the depth indicator plunger with a light downward pressure and record the depth of penetration of the cone into the soil to the nearest 0.1 mm.

5.14 Return the penetrometer head to its original position, remove the test receptacle and clean the penetration cone.

5.15 Remove the soil/water mixture from the test container and add it back into the mixing bowl.

5.16 Wipe the test receptacle clean with a moist cloth and store inverted ready for the next penetration test or use a clean test receptacle.
5.17 Thoroughly remix the soil sample in the mixing bowl for a period of 30 seconds and repeat Steps 5.6 to 5.16.

5.18 Compare the two penetrations and, if they are within 1.0 mm of each other, then the results may be averaged. Record this average as the penetration value of the sample \( (p_i) \). If the two penetrations are not within 1.0 mm of each other, then repeat Steps 5.6 to 5.16.

5.19 If the average penetration is less than 10 mm, add additional water to the soil/water mixture and thoroughly mix for 3 minutes. Repeat Steps 5.6 to 5.18 to achieve an average penetration value between 10-12 mm.

5.20 Immediately after the penetration of the second subsample of an acceptable pair of results, remove the mixture from the test receptacle and return it to the mixing bowl. Remix the soil/water mixture for 30 seconds.

5.21 After this remixing, place about 10-15 g of the soil sample in a moisture container and firmly replace the lid (Note 9.2).

5.22 Record the mass of the container, lid and wet soil to the nearest 0.01 g \( (m_w) \). Determine the moisture content of the sample as detailed in Test Method Q102A. Record the moisture content to the nearest 0.1 percent \( (w_i) \).

5.23 Repeat Steps 5.6 to 5.22 four times for successive moisture increments. It is desirable that the first two penetration values of the liquid limit test are less than 14.5 mm, one penetration is between 14.5 mm and 16.5 mm and two penetration values are greater than 16.5 mm. The same penetrometer must be used for the complete liquid limit test. The sample shall be thoroughly remixed for a period of 3 minutes after each moisture increment.

6 Calculations

Calculate the liquid limit of the soil as follows:

6.1 Determine the relationship between the moisture contents \( (w_i) \) and the penetrations \( (p_i) \) using linear regression analysis of the following relationship:

\[
w = b (\log_{10} p) + a
\]

where
- \( w \) = moisture content (%)
- \( b \) = slope of linear relationship
- \( p \) = penetration (mm)
- \( a \) = y intercept of linear relationship

6.2 Determine the slope of the linear relationship as follows:

\[
b = \frac{n \sum \log_{10} p w - \sum \log_{10} p \sum w}{n \sum \log_{10} p^2 - (\sum \log_{10} p)^2}
\]

where
- \( b \) = slope of linear relationship
- \( n \) = number of pairs of test results (5)
- \( \sum \log_{10} p w \) = sum of the products of the corresponding results for the \( \log_{10} \) penetrations \( (p_i) \) and moisture contents \( (w_i) \)
\[ \sum \log_{10} p = \text{sum of the log10 penetrations (} p_i \text{)} \]
\[ \sum w = \text{sum of the moisture contents (} w_i \text{)} \]
\[ (\sum \log_{10} p)^2 = \text{sum of the squares of the log10 penetrations (} p_i \text{)} \]

6.3 Determine the y intercept of the linear relationship as follows:

\[ a = \frac{1}{n} \left( \sum w - b \sum \log_{10} p \right) \]

where
\[ a = \text{y intercept of linear relationship} \]
\[ n = \text{number of pairs of test results (5)} \]
\[ \sum w = \text{sum of the moisture contents (} w_i \text{)} \]
\[ b = \text{slope of linear relationship} \]
\[ \sum \log_{10} p = \text{sum of the log10 penetrations (} p_i \text{)} \]

6.4 Calculate the liquid limit of the soil as follows:

\[ y = 1.19b + a \]

where
\[ y = \text{liquid limit of the soil (Note 9.3)} \]
\[ b = \text{slope of linear relationship} \]
\[ a = \text{y intercept of linear relationship} \]

7 Report
Report the liquid limit to the nearest 0.2%.

8 Precision
8.1 Repeatability
Duplicate tests on the same sample by the same operator are acceptable if the results do not differ by more than 0.23 \( \sqrt{L} \), where \( L \) is the average liquid limit for the duplicate tests.

8.2 Reproducibility
Duplicate tests on the same sample by different laboratories are acceptable if the results do not differ by more than 0.94 \( \sqrt{L} \), where \( L \) is the average liquid limit for the duplicate tests.

9 Notes on method
9.1 Some devices such as calliper rules (digital or vernier displays) do not require a repeatability assessment as detailed in AS 1984. For such devices, the requirement for repeatability error in Table 1 will not apply.

9.2 This quantity of soil is less than that required by Test Method Q102A. However, because of the uniformity of the soil that constitutes the sample, it is considered to be an acceptable quantity.
9.3 The calculation in Step 6.4 has been simplified from \( y = (\log_{10} 15.5)b + a \).

**Table 1 – Working tolerances for apparatus**

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Value</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penetrometer - depth indicator</td>
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<td></td>
</tr>
<tr>
<td>Resolution (mm)</td>
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<td>Maximum</td>
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<tr>
<td>Indication error (mm)</td>
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<td>± 0.2</td>
</tr>
<tr>
<td>Repeatability error (mm)</td>
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<td>± 0.05</td>
</tr>
<tr>
<td>Penetration cone</td>
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<td></td>
</tr>
<tr>
<td>Cone angle (degrees)</td>
<td>30</td>
<td>± 1</td>
</tr>
<tr>
<td>Cone, cone holder and shaft</td>
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<td></td>
</tr>
<tr>
<td>Mass (g)</td>
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<td>± 0.1</td>
</tr>
<tr>
<td>Cone wear template</td>
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<td></td>
</tr>
<tr>
<td>Thickness (mm)</td>
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<td>± 0.1</td>
</tr>
<tr>
<td>Hole diameter (mm)</td>
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<td>± 0.05</td>
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<tr>
<td>Test receptacles</td>
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<td></td>
</tr>
<tr>
<td>Internal diameter (mm)</td>
<td>50</td>
<td>± 5</td>
</tr>
<tr>
<td>Internal depth (mm)</td>
<td>45</td>
<td>± 10</td>
</tr>
</tbody>
</table>
Test Method Q104D: Liquid limit of soil - one point

1 Source

This method is based on BS 1377-2: Methods of test for soils for civil engineering purposes – Part 2: Classification tests – Method 4.4: One-point cone penetrometer method. However, the liquid limit is defined in this method as the moisture content at a penetration of 15.5 mm, thus the factor calculated in Step 6.1 will be different from the source method. There are some other minor procedural differences.

This method also includes variations developed through internal departmental investigations (Main Roads Barcaldine District, "Determination of the Liquid Limit of Decomposed Sandstone by the Cone Point Method" D07-03-1987 and Vanderstaay A.G.B., “Material Sources in Western Queensland”, Western Queensland Best Practice Guidelines – WQ33, May 2000) to allow the testing of Winton sandstone material.

2 Scope

This method describes a one-point procedure for the determination of the liquid limit of the portion of a soil passing the 0.425 mm sieve using the cone penetrometer apparatus.

This method is less accurate than the standard method described in Test Method Q104A. In the case of any doubts when using this method, the sample should be retested using Test Method Q104A (except for Winton Sandstones, which cannot be tested using Test Method Q104A).

3 Apparatus

Where appropriate, the working tolerances of particular apparatus are contained in Table 1.

The following apparatus is required:

3.1 Penetrometer, any suitable penetrometer which permits the cone holder to move vertically in the guide without appreciable friction and which has the following features:

3.1.1 Depth indicator, with a resolution, maximum recorded indication error and a maximum recorded repeatability error not exceeding the working tolerances. A device such as a dial gauge, calliper rule, displacement transducer or similar device would be suitable.

3.1.2 Penetration cone, a polished stainless steel cone with a cone angle of 30°.

3.1.3 The total moving mass of the cone, cone holder, shaft and any adjusting masses is 80 g.

3.1.4 Cone wear template, consisting of a metal plate 1.75 mm thick, with a hole of 1.5 mm diameter.

3.2 Timing device, a stopwatch or audible seconds counter accurate to 0.5 seconds.

3.3 Balance of suitable capacity, having a resolution of at least 0.01 g and with a limit of performance within the range of ± 0.05 g.

3.4 Mixing bowl, about 150 mm diameter and 100 mm deep.

3.5 Drying ovens:

3.5.1 Oven of suitable capacity, having a temperature of 45-50°C and complying with AS 1289.0.

3.5.2 Oven of suitable capacity, having a temperature of 105-110°C and complying with AS 1289.0.

3.6 Spatula.
3.7 Containers with lids, for moisture content determination.

3.8 Test receptacles, containers having an internal diameter of 50 mm and an internal depth of 45 mm. Suitable containers are of heavy gauge aluminium, about 1.2 mm thick.

3.9 Potable water.

3.10 Curing containers, airtight containers to be used for curing of samples.

4 Adjustment on apparatus

4.1 Check that the penetrometer shaft falls freely before each use or on a daily basis.

4.2 Check the sharpness of the cone at least daily using the cone wear template. If the point cannot be felt when brushed lightly with the tip of the finger when the cone is pushed through the hole, the cone must be replaced.

5 Procedure

The procedure shall be as follows:

5.1 For materials other than Winton Sandstone:

5.1.1 Prepare the sample as detailed in Section 5 of Test Method Q101, either air drying the material or drying in a 45-50°C oven as necessary. Obtain a representative subsample and further prepare the material as detailed in Subsection 6.4 of Test Method Q101 using a mortar and pestle and screening it on a 0.425 mm sieve to produce a fine fraction subsample of approximately 150 g.

5.1.2 Transfer the test portion to the mixing bowl and add a small amount of potable water.

5.1.3 Mix the soil and water thoroughly for several minutes until it becomes a stiff homogeneous paste ready for curing. A penetration in the range of 9 mm to 21 mm, as determined in Steps 5.1.7 to 5.1.13, provides suitable moisture content for effective curing.

5.1.4 Place the soil/water mixture in an airtight container to cure for at least 12 hours to allow the moisture to permeate the soil.

5.1.5 After curing, mix the soil/water thoroughly for 3 minutes.

5.1.6 Determine the mass of a moisture content container and lid ($m_1$).

5.1.7 Fill the test receptacle by placing the test material in the bottom of the container and exerting adequate pressure on the spatula to displace the soil/water mixture in an outward direction to remove any air from the mixture.

5.1.8 Completely fill the container in this manner and level the surface of the mixture with no more than three strokes of the spatula held almost flat. The soil/water mixture in the test container is now ready for penetration.

5.1.9 To prevent moisture loss during testing, cover the mixing bowl with a moist cloth.

5.1.10 Zero the depth indicator with the penetrometer shaft and cone at the maximum height.

5.1.11 Position the filled test receptacle centrally under the point of the cone of the penetrometer and bring the cone into contact with the surface of the soil/water mixture.

5.1.12 Release the penetrometer shaft and allow the cone to penetrate the soil/water mixture for a period of $5 \pm 0.5$ seconds.
5.1.13 Depress the indicator plunger with a light downward pressure and record the depth of penetration of the cone into the soil to the nearest 0.1 mm.

5.1.14 Return the penetrometer head to its original position, remove the test receptacle and clean the penetration cone.

5.1.15 Remove the soil/water mixture from the test container and add it back into the mixing bowl.

5.1.16 Wipe the test receptacle clean with a moist cloth and store inverted ready for the next penetration test or use a clean test receptacle.

5.1.17 Thoroughly remix the soil sample in the mixing bowl for a period of 30 seconds and repeat Steps 5.1.7 to 5.1.16.

5.1.18 Compare the two penetrations and, if they are within 1.0 mm of each other and the average penetration is within the 10-21 mm range, then the results may be averaged \(( \bar{p} )\). Record this average as the penetration value of the sample. If the two penetrations are not within 1.0 mm of each other, then repeat Steps 5.1.7 to 5.1.16.

5.1.19 If the average penetration is less than 10 mm, add additional water to the soil/water mixture and thoroughly mix for 3 minutes. Repeat Steps 5.1.7 to 5.1.18 to achieve an average penetration value between 10-21 mm.

5.1.20 Immediately after the penetration of the second subsample of an acceptable pair of results, remove the mixture from the test receptacle and return it to the mixing bowl. Remix the soil/water mixture for 30 seconds.

5.1.21 After this remixing, take a representative sample of and place in a pre-weighed moisture container and firmly replace the lid. A 10-15 g moisture sample is adequate for this test due to the uniformity of the test portion.

5.1.22 Determine the mass of the container and wet soil \( ( m_2 ) \). Determine the moisture content of the sample as detailed in Test Method Q102A.

5.2 For Winton Sandstone materials (Note 8.1):

5.2.1 Prepare the sample as detailed in Section 5 of Test Method Q101, either air drying the material or drying in a 45-50°C oven as necessary. Obtain a representative subsample and further prepare the material as detailed in Subsection 6.4 of Test Method Q101 using a mortar and pestle and screening it on a 0.425 mm sieve to produce a fine fraction subsample of approximately 200 g.

5.2.2 Transfer the test portion to the mixing bowl and add potable water (Note 8.2).

5.2.3 Mix the soil and water thoroughly for 5 minutes. The addition of small increments of water to facilitate mixing is permitted provided the total mixing time remains 5 minutes.

5.2.4 Place the soil/water mixture in an airtight container to cure for at least 12 hours to allow the moisture to permeate the soil.

5.2.5 After curing, mix the soil/water thoroughly for 10 minutes.

5.2.6 Determine the mass of a moisture content container and lid \( ( m_1 ) \).

5.2.7 Fill the test receptacle by placing the test material in the bottom of the container and exerting adequate pressure on the spatula to displace the soil/water mixture in an outward direction to remove any air from the mixture.
5.2.8 Completely fill the container in this manner and level the surface of the mixture with only one stroke of the spatula held almost flat. The soil/water mixture in the test container is now ready for penetration.

5.2.9 To prevent moisture loss during testing, cover the mixing bowl with a moist cloth.

5.2.10 Zero the depth indicator with the penetrometer shaft and cone at the maximum height.

5.2.11 Position the filled test receptacle centrally under the point of the cone of the penetrometer and bring the cone into contact with the surface of the soil/water mixture.

5.2.12 Release the penetrometer shaft and allow the cone to penetrate the soil/water mixture for a period of 5 ± 0.5 seconds.

5.2.13 Depress the indicator plunger with a light downward pressure and record the depth of penetration of the cone into the soil to the nearest 0.1 mm.

5.2.14 Return the penetrometer head to its original position, remove the test receptacle and clean the penetration cone.

5.2.15 Discard the soil/water mixture in the test receptacle.

5.2.16 Wipe the test receptacle clean with a moist cloth and store inverted ready for the next penetration test or use a clean test receptacle.

5.2.17 Repeat Steps 5.2.7 to 5.2.14.

5.2.18 Compare the two penetrations and, if they are within 1.0 mm of each other and the average penetration is within the 10-21 mm range, then the results may be averaged (p). Record this average as the penetration value of the sample. If the two penetrations are not within 1.0 mm of each other or outside the 10-21 mm range, then discard the sample and repeat the entire test.

5.2.19 Immediately after the penetration of the second subsample of an acceptable pair of results, remove the top surface layer of the soil water mixture in the test receptacle with a spatula and place in a pre-weighed moisture container and firmly replace the lid. A 10-15 g moisture sample is adequate for this test due to the uniformity of the test portion.

5.2.20 Determine the mass of the container and wet soil (m₂). Determine the moisture content of the sample as detailed in Test Method Q102A.

6 Calculation

6.1 Calculate the correction factor for penetration value as follows:

\[ f = 2.1261^p^{-0.2752} \]

where \( f \) = correction factor for penetration value of the sample
\( p \) = average penetration value (mm)

6.2 Calculate the liquid limit of the soil as follows:

\[ w_{cl} = wp^f \]

where \( w_{cl} \) = liquid limit of the soil
\( w \) = moisture content of soil
\( f \) = correction factor for penetration value of the sample
7 Reporting

Report the following values and general information:

7.1 Liquid limit to the nearest 0.2%.

7.2 If the material tested is Winton Sandstone, this should be reported.

8 Notes on method

8.1 The mixing times specified in Steps 5.2.3 and 5.2.5 need to be strictly adhered to for Winton Sandstone. Variations in mixing time can significantly affect the results.

8.2 The water added should be sufficient to produce the desired consistency slightly stiffer than liquid limit at the conclusion of mixing.

Table 1 – Working tolerances for apparatus

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Value</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penetrometer - depth indicator</td>
<td></td>
<td>Maximum</td>
</tr>
<tr>
<td>Resolution (mm)</td>
<td>0.1</td>
<td>Maximum</td>
</tr>
<tr>
<td>Indication error (mm)</td>
<td>0.0</td>
<td>± 0.2</td>
</tr>
<tr>
<td>Repeatability error (mm)</td>
<td>0.0*</td>
<td>± 0.05</td>
</tr>
<tr>
<td>Penetration cone</td>
<td></td>
<td>± 1</td>
</tr>
<tr>
<td>Cone angle (°)</td>
<td>30</td>
<td>± 1</td>
</tr>
<tr>
<td>Cone, Cone holder and shaft</td>
<td></td>
<td>± 0.1</td>
</tr>
<tr>
<td>Mass (g)</td>
<td>80</td>
<td>± 0.1</td>
</tr>
<tr>
<td>Cone wear template</td>
<td></td>
<td>± 0.1</td>
</tr>
<tr>
<td>Thickness (mm)</td>
<td>1.75</td>
<td>± 0.1</td>
</tr>
<tr>
<td>Hole diameter (mm)</td>
<td>1.5</td>
<td>± 0.05</td>
</tr>
<tr>
<td>Test receptacles</td>
<td></td>
<td>± 5</td>
</tr>
<tr>
<td>Internal diameter (mm)</td>
<td>50</td>
<td>± 5</td>
</tr>
<tr>
<td>Internal depth (mm)</td>
<td>45</td>
<td>± 10</td>
</tr>
</tbody>
</table>

* Some devices such as calliper rules (digital or vernier displays) do not require a repeatability assessment as detailed in AS 1984. For such devices, the requirement for repeatability error will not apply.
Test Method Q105: Plastic limit and plasticity index of soil

1 Source

This method is based on AS 1289.3.2.1: Soil classification tests – Determination of the plastic limit of a soil – Standard method and AS 1289.3.3.1: Soil classification tests – Calculation of the plasticity index of a soil except as follows:

a) when determining plastic limit, the sample is initially prepared to an oven or air dried condition
b) for compliance testing required by Transport and Main Roads technical specifications the sample is then brought to a moisture content higher than the liquid limit before commencing the test
c) for other testing the sample is then brought to a moisture content sufficient to allow the sample to be shaped into a ball
d) rolling of soil threads between the hands is not permitted
e) the definition of the endpoint where the soil thread reaches the plastic limit differs from the source method, and
f) for the plasticity index, the calculation is based on a liquid limit determined using a cone penetrometer.

2 Scope

This method describes the procedure for the determination of the plastic limit of the portion of a soil passing the 0.425 mm sieve. The plastic limit is notionally defined as the moisture content at which the soil passes from the semisolid to the plastic state as determined in accordance with this standard procedure.

The plasticity index is defined as the numerical difference between the liquid limit and plastic limit and is a measure of the range over which the soil is notionally considered to be in the plastic state.

The weighted plasticity index (WPI) is defined as the product of the plasticity index (PI) of a soil and the percentage of the soil finer than 0.425 mm.

3 Apparatus

Where appropriate, the working tolerances of particular apparatus are contained in Table 1.

The following apparatus is required:

3.1 Balance of suitable capacity, having a resolution of at least 0.01 g and with a limit of performance within the range of ± 0.05 g.

3.2 Glass plate, about 300 mm square and 10 mm thick, either ground glass or lightly sand blasted.

3.3 Drying oven of suitable capacity, having a temperature of 105-110°C and complying with AS 1289.0.

3.4 Containers with lids, for moisture content determination.

3.5 Reference rod, 3.0 mm diameter and approximately 90 mm long.
4 Determination of plastic limit

The procedure shall be as follows:

4.1 Where a low plasticity (Table 2) sample is being tested, obtain approximately 50 g of the soil/water mixture used in the liquid limit test (Q104A or Q104D) at the first average penetration greater than or equal to 15.5 mm.

4.2 Where a medium or high plasticity (Table 2) sample is being tested, obtain approximately 50 g of the soil/water mixture used in the liquid limit test (Q104A or Q104D) when it is sufficiently homogeneous and plastic to be shaped into a ball.

4.3 Form a subsample of about 10 g into a ball and cover the remaining material to avoid evaporation.

4.4 Roll the subsample between the fingers and the glass plate using sufficient pressure to continually reduce the diameter (Note 8.1).

4.5 When the length of the thread is approximately 90 mm long, divide the thread into three or four equal lengths as excessively long threads become unwieldy and break apart. Cover the threads to avoid evaporation.

4.6 Roll each length in turn between the fingers and the glass plate using sufficient pressure to continually reduce the diameter to 3 mm when compared to the reference rod. If the thread reaches 3 mm without crumbling, cover the thread to avoid further moisture loss (Notes 8.2, 8.3 and 8.4).

4.7 Roll all threads to a 3 mm diameter and then knead them together and reform into a ball.

4.8 Repeat the process of rolling and kneading as described in Steps 4.4 to 4.7 until crumbling of the soil thread occurs (Note 8.5).

4.9 As each soil thread reaches the plastic limit, place it in a container for moisture determination and replace the lid.

4.10 Repeat Steps 4.3 to 4.9 until at least 10 g of soil has been placed in the container. Determine the moisture content (\( w_1 \)) of the test portion as detailed in Test Method Q102A (Note 8.6).

4.11 Repeat Steps 4.3 to 4.10 for a second determination of the plastic limit of the soil (\( w_2 \)).

5 Calculations

5.1 Calculate the plastic limit as follows:

\[
PL = \frac{w_1 + w_2}{2}
\]

where

- \( PL \) = plastic limit of the soil
- \( w_1 \) = moisture content of first test portion (%)
- \( w_2 \) = moisture content of second test portion (%)

5.1.1 Compare the individual moisture contents and, if they vary by more than \( 0.43 \sqrt{PL} \) where \( PL \) is the plastic limit, then repeat the test.

5.1.2 Round the plastic limit (\( PL \)) to the nearest 0.2 percent.
5.2 Calculate the plasticity index as follows:

\[ \text{PI} = \text{LL} - \text{PL} \]

where

- \( \text{PI} \) = plasticity index of the soil (Note 8.7)
- \( \text{LL} \) = reported liquid limit of the soil, obtained from either Test Method Q104A or Q104D (%)
- \( \text{PL} \) = plastic limit of the soil (%)

5.3 If required, calculate the weighted plasticity index as follows:

\[ \text{WPI} = \text{PI} \times 0.425 \]

where

- \( \text{WPI} \) = weighted plasticity index of the soil (%)
- \( \text{PI} \) = plasticity index of the soil (%)
- \( 0.425 \times \text{P}_{0.425} \) = percentage passing the 0.425 mm sieve, obtained from Test Method Q103A (Note 8.8)

6 Reporting

Report the following values and information:

6.1 Plastic limit to the nearest 0.2% (if required).
6.2 Plasticity index to the nearest 0.2%.
6.3 Weighted plasticity index to the nearest 1% (if required).

7 Precision

7.1 Repeatability

7.1.1 Plastic Limit

Duplicate tests by the same operator are acceptable if they do not differ by more than

\[ 0.31 \times \text{PL} \]

where \( \text{PL} \) is the average plastic limit for the duplicate tests.

7.1.2 Plasticity Index

Duplicate tests by the same operator are acceptable if the results do not differ by more than

\[ 0.33 \times \text{PI} \]

where \( \text{PI} \) is the average plasticity index for the duplicate tests.

7.2 Reproducibility

7.2.1 Plastic Limit

Duplicate tests from different laboratories are acceptable if they do not differ by more than

\[ 1.73 \times \text{PL} \]

where \( \text{PL} \) is the average plastic limit for the duplicate tests.

7.2.2 Plasticity Index

Duplicate tests from different laboratories are acceptable if the results do not differ by more than

\[ 1.82 \times \text{PI} \]

where \( \text{PI} \) is the average plasticity index for the duplicate tests.

8 Notes on method

8.1 For highly plastic soils, it may not be possible to roll the soil/water mixture because of its high moisture content. Should this be the case, spread the soil on the glass plate to facilitate drying.
at room temperature and remix thoroughly at regular intervals to ensure even distribution of moisture. Mixing techniques such as heavy kneading and hand mixing may be used to facilitate drying. Continue the drying and mixing until the soil is able to be rolled.

8.2 If at any time during the rolling process the soil thread crumbles or ceases to roll before the diameter reaches 3 mm, the soil thread shall be considered to be at the plastic limit and the test continued from Step 4.9.

8.3 Crumbling will manifest itself differently for various types of soil. Some soils fall apart in numerous small aggregations of particles; others may form an outside tubular layer that starts splitting at both ends. The splitting progresses towards the middle and finally the thread falls apart in numerous small platey particles.

8.4 Some soils show a tendency to crumble or cease to roll prematurely due to excessive pressure. Premature crumbling can also be due to planes formed in the soil mass while kneading it. It is important that the soil thread crumbles or ceases to roll due to decreasing moisture content only. The operator should therefore ensure that the soil thread is truly homogeneous with no planes or fissures in it and that the pressure exerted is just sufficient to diminish the diameter of the thread without distorting it. Oblique rolling can also cause premature crumbling of the soil thread, and care should be taken to ensure that the rolling force is normal to the axis of the thread.

8.5 The plastic limit test is liable to a significant amount of personal variation and operators require a great deal of practice before they get the “feel” for all soils and are able to determine the endpoint accurately. It is important that the procedure detailed in this method is followed carefully so as to eliminate all possible personal sources of variation.

8.6 The quantity of soil is less than that required by Test Method Q102A. However, because of the uniformity of the soil that constitutes the sample, it is considered to be an acceptable quantity.

8.7 If the plastic limit is greater than the liquid limit, record the plasticity index as zero.

8.8 The value of the percent passing the 0.425 mm sieve from Test Method Q103A used in the calculation should be unrounded or recorded to 0.01%.

Table 1 – Working tolerances for apparatus

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Dimension</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference rod</td>
<td>Diameter (mm)</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Table 2 – Plasticity definitions

<table>
<thead>
<tr>
<th>Material</th>
<th>Liquid Limit Range (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low plasticity</td>
<td>≤ 35</td>
</tr>
<tr>
<td>Medium plasticity</td>
<td>&gt; 35 ≤ 50</td>
</tr>
<tr>
<td>High plasticity</td>
<td>&gt; 50</td>
</tr>
</tbody>
</table>
Test Method Q106: Linear shrinkage of soil

1 Source

This method applies the principles of AS 1289.3.4.1 – Determination of the linear shrinkage of a soil – Standard method. It differs from this Australian Standard in the cross-sectional shape of the mould, trimming technique, drying requirements and the reporting interval (Notes 8.1 and 8.2).

2 Scope

This method describes the procedure for the determination of the linear shrinkage of that portion of a soil passing a 0.425 mm sieve. The linear shrinkage is defined as the percentage decrease in the longitudinal dimension of a soil bar when it is dried out from the liquid limit to the oven dry state.

The oven drying technique should be used for any compliance testing required by Department of Transport and Main Roads technical specifications.

The method also includes calculation of the weighted linear shrinkage which is defined as the product of the linear shrinkage of a soil and the percentage of the soil finer than 0.425 mm (Note 8.3).

3 Apparatus

Where appropriate, the working tolerances of particular apparatus are contained in Table 1.

The following apparatus is required:

3.1 Drying ovens:

3.1.1 Oven of suitable capacity, having a temperature of 45-50°C and complying with AS 1289.0.

3.1.2 Oven of suitable capacity, having a temperature of 105-110°C and complying with AS 1289.0.

3.2 Linear shrinkage mould, stainless steel or brass mould, length 150 mm, width at top 25 mm, width at bottom 20 mm, depth 15 mm (Figure 1).

3.3 Suitable measuring device, with a resolution of at least 0.1 mm, e.g. digital callipers.

3.4 Spatula.

3.5 Scalpel or similar alternative.

3.6 Marker and paper.

3.7 Steel ruler approximately 300 mm in length.

4 Materials

The following material is required:

4.1 Mould oil, a light oil such as Caltex Mould Oil 20 (Notes 8.4 and 8.5).

5 Procedure

The procedure shall be as follows:

5.1 Filling and finishing the mould

5.1.1 Lightly oil the dry shrinkage mould.

5.1.2 Fill the mould with a subsample of the soil/water mixture which has been prepared as detailed in Test Method Q104A or Q104D. Take the linear shrinkage subsample while the penetration is at 15.5 ± 1.0 mm.
5.1.3 Press the soil firmly into the mould, taking care to fill the corners and to eliminate air bubbles. Undertake this filling with the spatula held at right angles to the length of the mould, firstly, by firming the soil along one side of the mould, then the other. Finally, fill any indentations in the top such that the soil is left just proud of the edges of the mould.

5.1.4 Cut off the surplus soil with the steel ruler by drawing the steel ruler from the longitudinal centre of the mould towards each side in turn. Then a maximum of two full sideways sweeps can be used to smooth the surface if required. Wipe the ruler clean before each pass.

5.1.5 Where the linear shrinkage subsample is a low plasticity material (Table 2), dry the filled mould as detailed in Step 5.2.

5.1.6 Where the linear shrinkage subsample is a medium or high plasticity material (Table 2), dry the filled mould as detailed in Step 5.3.

5.2 Oven drying

5.2.1 Place the filled mould in a 45-50°C oven for a minimum of two hours prior to being dried to a constant mass in a 105-110°C oven (Notes 8.6 and 8.7).

5.3 Air drying

5.3.1 Place the filled mould away from direct sunlight and allow to air-dry for 24 hours or until a distinct colour change is noted.

5.3.2 Place the filled mould in a 105-110°C oven and dry to constant mass (Note 8.7).

5.4 Measurement

5.4.1 Unbroken Soil Bar

a) Remove the soil bar from the mould and carefully remove any lip at each end of the soil bar.

b) Determine the internal length of the mould from the approximate geometric centre of one end of the mould to a similar point on the other end (L₁).

c) Place the bar on a strip of paper and shape the paper to conform to the longitudinal profile of the bottom of the bar. Mark the length on the paper using the scalpel with the mid points at each end clearly indicated.

d) Determine the distance between the two mid points as the bottom length of the soil bar (L₂).

e) Repeat Step c) for the top of the bar.

f) Determine the distance between the two mid points as the top length of the soil bar (L₃).

5.4.2 Broken Soil Bar

a) Remove the soil bar from the mould and carefully remove any lip at each end of the soil bar.

b) Determine the internal length of the mould from the approximate geometric centre of one end of the mould to a similar point on the other end (L₁).

c) Place the bar on a strip of paper and shape the paper to conform to the longitudinal profile of the bottom of the bar. Mark the length on the paper using the scalpel with the mid points at each end clearly indicated.
d) Place the second segment such that the end where the first break occurred is coincident with the marked end of the break in the first segment. Mark the end of the second segment on the paper using the scalpel with the mid-point clearly indicated.

e) Place and mark all subsequent segments in sequence as described in Step d) until all segments have been marked on the paper.

f) Determine the distance between the first and last mid points as the bottom length of the soil bar \( L_2 \).

g) Repeat Steps c) to e) for the top of the soil bar.

h) Determine the distance between the first and last mid points as the top length of the soil bar \( L_3 \).

i) Record the number of breaks in the soil bar at the completion of measurement.

6 Calculation

6.1 Calculate the linear shrinkage of the soil as follows:

\[
LS = \frac{L_1 - 0.5(L_2 + L_3)}{L_1} \times 100
\]

where

- \( LS \) = linear shrinkage of the soil (%)
- \( L_1 \) = internal length of the mould (mm)
- \( L_2 \) = bottom length of the soil bar (mm)
- \( L_3 \) = top length of the soil bar (mm)

6.2 If required, calculate the weighted linear shrinkage as follows:

\[
WLS = L_1 \times P_{0.425}
\]

where

- \( WLS \) = weighted linear shrinkage of the soil (%)
- \( L_1 \) = linear shrinkage of the soil (%)
- \( P_{0.425} \) = percentage passing the 0.425 mm sieve, obtained from Test Method Q103A (Note 8.8)

7 Reporting

Report the following values and information:

7.1 Linear shrinkage to the nearest 0.2%.

7.2 Air drying (if used).

7.3 Weighted linear shrinkage (WLS) to the nearest 1% (if required).

8 Notes on method

8.1 The use of a trapezoidal cross section mould and the drying process were developed through internal departmental investigations as reported in Vanderstaay A.G.B., “An analysis of the linear shrinkage test MRD Test Method Q106 – 1986”, Main Roads Department, Central Division, CR383, 1986.
8.2 The use of a ruler for the trimming of the mould was developed through internal departmental investigations as reported in Moule B., “Analysis of the proposed linear shrinkage trimming method”, Department of Transport and Main Roads, Materials Services Branch, 2008.

8.3 The weighted linear shrinkage may also be defined as the shrinkage product. For example the “Unsealed Roads Manual”, Australian Roads Research Board, 3rd Edition, March 2009, uses this terminology.

8.4 Before handling oil, the operator must consult the relevant Safety Data Sheet (SDS).

8.5 Other mould oils such at Shellmould P5, Reochem Mould Oil 20 and Caltex Mould Oil 222 have also been found to be suitable.

8.6 Where a moulded material breaks apart during drying to such a degree it cannot be measured, it may be retested as detailed in Subsection 5.3.

8.7 The filled mould is considered to have reached a constant mass when the difference between successive weighings, after a further 1 hour drying at 105-110°C, is not more than 1 percent of the total of the previous moisture losses.

8.8 The value of the percentage passing the 0.425 mm sieve from Test Method Q103A used in the calculation should be unrounded or recorded to 0.01%.

**Table 1 – Working tolerances for apparatus**

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Value (mm)</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (mm)</td>
<td>150</td>
<td>± 5</td>
</tr>
<tr>
<td>Inside width – top (mm)</td>
<td>25</td>
<td>± 0.5</td>
</tr>
<tr>
<td>Inside width – bottom (mm)</td>
<td>20</td>
<td>± 0.5</td>
</tr>
<tr>
<td>Inside depth (mm)</td>
<td>15</td>
<td>± 0.5</td>
</tr>
</tbody>
</table>

**Table 2 – Plasticity definitions**

<table>
<thead>
<tr>
<th>Material</th>
<th>Liquid Limit Range (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low plasticity</td>
<td>≤ 35</td>
</tr>
<tr>
<td>Medium plasticity</td>
<td>&gt; 35 ≤ 50</td>
</tr>
<tr>
<td>High plasticity</td>
<td>&gt; 50</td>
</tr>
</tbody>
</table>
Figure 1 – Linear shrinkage mould
Test Method Q109: Apparent particle density of soil

1 Source

This method applies the principles of AS 1289.3.5.1: Determination of the soil particle density of a soil – Standard method. It differs from this Australian Standard in variations to the apparatus and techniques used and in the reporting interval.

2 Scope

This method describes the procedure for the determination of the apparent particle density of a soil. The apparent particle densities of the coarse fraction and the fine fraction are determined using separate procedures and a weighted average of these values is then used to determine the apparent particle density of the soil. The method allows the proportions of the coarse and fine fractions to be determined by either weighing or particle size distribution.

3 Apparatus

The following apparatus is required:

3.1 Sieve, 2.36 mm complying with AS 1152.

3.2 Balance of suitable capacity, having a resolution of at least 1 g and with a limit of performance within the range of ± 5 g.

3.3 Containers of suitable size for drying the coarse and fine fraction subsamples prepared in Step 4.1.2 or 4.2.2.

3.4 Drying oven of suitable capacity, having a temperature of 105-110°C and complying with AS 1289.0.

4 Procedure

The procedure shall be as follows in accordance with either Subsections 4.1 or 4.2:

4.1 Proportions determined by weighing fractions

4.1.1 Prepare the bulk sample as detailed in Section 5 of Test Method Q101 to produce a representative subsample of appropriate size.

4.1.2 Further prepare the subsample as detailed in Test Method Q101 Section 6.3 and 6.4 using a 2.36 mm sieve to produce an unwashed coarse fraction subsample and an unwashed fine fraction subsample. Ensure sufficient material is prepared to yield at least 10 kg retained 2.36 mm and 200 g passing 2.36 mm.

4.1.3 Place the coarse and fine fractions in containers and dry in the oven to a constant mass. Determine the mass of the coarse fraction \( m_c \) and the mass of the fine fraction \( m_f \) (Note 7.1).

4.1.4 Thoroughly wash the coarse fraction only, to remove any dust and other coatings.

4.1.5 Place the washed coarse fraction in a container and again dry in the oven to a constant mass (Note 7.1).

4.1.6 Determine the apparent particle density of the coarse fraction and the fine fraction as detailed in Test Methods Q109A and Q109B respectively.

Superseded
4.2 **Proportions determined by particle size distribution**

4.2.1 Prepare the bulk sample as detailed in Section 5 of Test Method Q101 to produce two representative samples of appropriate size.

4.2.2 Prepare the first sample as detailed in Test Method Q101 Section 6.3 and 6.4 using a 2.36 mm sieve to produce an unwashed coarse fraction subsample and an unwashed fine fraction subsample. Ensure sufficient material is prepared to yield at least 10 kg retained 2.36 mm and 200 g passing 2.36 mm.

4.2.3 Prepare the second sample to produce a particle size distribution subsample with a mass that complies with the minimum mass requirements of Test Method Q103A.

4.2.4 Thoroughly wash the coarse fraction, to remove any dust and other coatings.

4.2.5 Place the washed coarse fraction in a container and dry in the oven to a constant mass (Note 7.1).

4.2.6 Place the fine fraction in a container and dry in the oven to a constant mass (Note 7.1).

4.2.7 Using the subsample prepared in Step 4.2.3, determine the percent passing the 2.36 mm sieve \( P_{2.36} \) as detailed in Test Method Q103A.

4.2.8 Determine the apparent particle density of the coarse fraction and the fine fraction as detailed in Test Methods Q109A and Q109B respectively.

5 **Calculations**

The calculations shall be as follows as appropriate:

5.1 **Proportions determined by weighing fractions**

5.1.1 Determine the percent coarse fraction to the nearest 1% as follows:

\[
P_c = \frac{100m_c}{m_c + m_f}
\]

where

- \( P_c \) = percent coarse fraction
- \( m_c \) = mass of coarse fraction (g)
- \( m_f \) = mass of fine fraction (g)

5.1.2 Determine the percent fine fraction to the nearest 1% as follows:

\[
P_f = \frac{100m_f}{m_c + m_f}
\]

where

- \( P_f \) = percent fine fraction
- \( m_c \) = mass of coarse fraction (g)
- \( m_f \) = mass of fine fraction (g)
5.2 Proportions determined by particle size distribution

5.2.1 Determine the percent coarse fraction to the nearest 1% as follows:

\[ P_c = 100 - P_{2.36} \]

where \( P_c \) = percent coarse fraction
\( P_{2.36} \) = percentage passing the 2.36 mm sieve

5.2.2 Determine the percent fine fraction to the nearest 1% as follows:

\[ P_f = P_{2.36} \]

where \( P_f \) = percent fine fraction
\( P_{2.36} \) = percent passing the 2.36 mm sieve

5.3 Determine the apparent particle density of the soil as follows:

\[ \rho_{st} = \frac{100}{\frac{P_c}{\rho_c} + \frac{P_f}{\rho_f}} \]

where \( \rho_{st} \) = apparent particle density of the soil sample (t/m³)
\( \rho_c \) = apparent particle density (coarse fraction) (t/m³)
\( \rho_f \) = apparent particle density (fine fraction) (t/m³)
\( P_c \) = percent coarse fraction
\( P_f \) = percent fine fraction

6 Reporting

Report the apparent particle density to the nearest 0.001 t/m³.

7 Notes on method

7.1 A fraction is considered to have reached a constant mass when the difference between successive weighings, after a further 1 hour drying at 105-110°C, is not more than 1 percent of the total of the previous moisture losses.
Test Method Q109A: Apparent particle density of soil - fine fraction

1 Source
This method applies the principles of AS 1289.3.5.1: Determination of the soil particle density of a soil - Standard method. It differs from this Australian Standard in the size of apparatus and techniques employed and in the reporting interval.

2 Scope
This method describes the procedure for the determination of the apparent particle density of the fine fraction of a soil. The passing 2.36 mm material is tested in this procedure.

3 Apparatus
The following apparatus is required:

3.1 Balance of suitable capacity, with a resolution of 0.001 g and with a limit of performance within the range of ± 0.005 g.
3.2 Density bottles of about 100 mL capacity.
3.3 Hotplate.
3.4 Vacuum desiccator.
3.5 Vacuum source such as a vacuum pump or a filter pump.
3.6 Constant temperature environment such as a water bath or environmental chamber maintained at a constant temperature within the range of 20 - 30°C to within ± 1.0°C.
3.7 Wash bottle.
3.8 Thermometer, a partial or total immersion thermometer or other suitable temperature measuring device with a temperature range of at least 0-50°C and graduated to 1°C or less with an uncertainty of no more than 0.5°C.

4 Materials
The following materials are required:

4.1 Distilled water.

5 Procedure
The procedure shall be as follows:

5.1 Obtain two representative test portions of approximately 100 g from the fine fraction prepared in Test Method Q109 (Note 9.1).
5.2 Wash the density bottle and stopper with distilled water and dry.
5.3 Determine the mass of the bottle and stopper (m₁).
5.4 Using one of the test portions, fill the density bottle to about one-third of its capacity.
5.5 Determine the mass of the bottle, stopper and soil (m₂).
5.6 Add distilled water to fill the bottle to about two-thirds of its capacity and allow the soil to soak for at least 24 hours.
5.7 Boil the contents of the bottle on the hotplate and allow to simmer for at least 10 minutes.

5.8 Transfer the bottle to the vacuum desiccator and gradually apply a partial vacuum of 13 kPa or less absolute pressure until the bottle and contents have cooled (Notes 9.2 and 9.3).

5.9 Fill the bottle with distilled water and place it in the constant temperature environment for a minimum of one hour and allow it to reach an equilibrium temperature. During this time, add distilled water from the wash bottle as necessary to maintain the water level (Note 9.4).

5.10 When the bottle and contents have reached an equilibrium temperature, determine the temperature of the constant temperature environment to the nearest 1ºC.

5.11 Add additional distilled water to the bottle if necessary and insert the stopper.

5.12 Dry the outside of the bottle and determine the mass of the bottle, stopper and soil (m<sub>3</sub>).

5.13 Empty the bottle and clean with distilled water.

5.14 Fill the bottle with distilled water and place it in the constant temperature environment for a minimum of one hour and allow it to reach the equilibrium temperature. During this time, add distilled water from the wash bottle as necessary to maintain the water level (Notes 9.4 and 9.5).

5.15 When the bottle and contents have reached an equilibrium, add additional water if necessary and insert the stopper.

5.16 Dry the outside of the bottle and determine the mass of the bottle and stopper (m<sub>4</sub>).

5.17 Repeat Steps 5.2 to 5.16 for the second test portion.

6 Calculations

6.1 Calculate the apparent particle density of each test portion as follows:

$$\rho_i = \frac{m_2-m_1}{(m_3-m_4)-(m_3-m_2)} \rho_w$$

where

- $\rho_i$ = apparent particle density of the fine fraction (t/m³)
- $\rho_w$ = density of water at the temperature of the constant temperature environment (t/m³) (see Table 1)
- $m_1$ = mass of bottle and stopper (g)
- $m_2$ = mass of bottle, stopper and dry test portion (g)
- $m_3$ = mass of bottle, stopper, test portion and water (g)
- $m_4$ = mass of bottle, stopper and water (g)

6.2 Compare the results from the two test portions and, if they do not differ by more than 0.020 t/m³, average the results. Otherwise repeat the test.

7 Reporting

Report the average as the apparent particle density (fine fraction) to the nearest 0.001 t/m³.
8 Precision

8.1 Repeatability

The average results for duplicate tests by the same operator are acceptable if their means do not differ by more than 0.016 t/m³.

8.2 Reproducibility

The average results for duplicate tests from different laboratories are acceptable if their means do not differ by more than 0.040 t/m³.

9 Notes on method

9.1 Where the apparent particle density of only the fine fraction is required, prepare an unwashed fine fraction subsample as detailed in Test Method Q109. It is not necessary to determine the percentages of the coarse or fine fractions.

9.2 Care needs to be taken to ensure that any entrapped air doesn’t bubble too violently otherwise small drops of suspension can be ejected through the mouth of the bottle.

9.3 A partial vacuum of 13 kPa absolute pressure is approximately equivalent to a -88 kPa reading on a vacuum gauge at sea level.

9.4 Store the wash bottle in the constant temperature environment in order to minimise equilibration time.

9.5 The mass of the bottle filled with water may be determined at regular intervals in the constant temperature environment or it may be determined immediately after the volume of aggregate has been determined. For either determination the temperature of the constant temperature environment must be the same as the temperature in Step 5.10.

Table 1 – Density of water

<table>
<thead>
<tr>
<th>Temperature (ºC)</th>
<th>Density (t/m³)</th>
<th>Temperature (ºC)</th>
<th>Density (t/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>0.9982</td>
<td>26</td>
<td>0.9968</td>
</tr>
<tr>
<td>21</td>
<td>0.9980</td>
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<td>0.9965</td>
</tr>
<tr>
<td>22</td>
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<tr>
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</tr>
<tr>
<td>25</td>
<td>0.9970</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Test Method Q109B: Apparent particle density of soil - coarse fraction

1 Source

This method applies the principles of AS 1289.3.5.1: Determination of the soil particle density of a soil – Standard method. It differs from this Australian Standard in allowing an additional weighing technique and in the reporting interval. Precision estimates are based on values reported in ASTM C127: Specific Gravity and Absorption of Coarse Aggregate.

2 Scope

This method describes the procedure for the determination of the apparent particle density of the coarse fraction of a soil. The retained 2.36 mm material is tested in this procedure with volume measurement being made using either below balance or above balance techniques.

3 Apparatus

The following apparatus is required:

3.1 Balance of suitable capacity, with a resolution of at least 0.1 g and with a limit of performance within the range of ± 0.5 g. For the below balance technique, a balance capable of below balance weighing is required (Subsection 4.3 only). For the above balance technique, a second balance is desirable.

3.2 Container of suitable capacity to contain the wire basket. An overflow is required (Subsection 4.3 only).

3.3 Balance bench, equipped with a hole for below balance weighing (Subsection 4.3 only).

3.4 Wire basket of suitable capacity to contain the test portion and a thin wire to suspend the basket.

3.5 Thermometer, a partial or total immersion thermometer or other suitable temperature measuring device with a temperature range of at least 0-50ºC and graduated to 1ºC or less with an uncertainty of no more than 0.5ºC.

3.6 Laboratory stand (Subsection 4.4 only).

3.7 Absorbent cloth and a fan (optional) (Subsection 4.4 only).

4 Procedure

The procedure shall be as follows:

4.1 Obtain two representative test portions of approximately 5 kg from the coarse fraction prepared in Test Method Q109.

4.2 Determine the mass of a test portion (m1), immerse it in water and allow it to soak for at least 24 hours.

4.3 Density measurement using below balance weighing

This method applies where the appropriate equipment is available to allow the test portion volume to be determined by suspending the portion below a balance in a container of water.

4.3.1 Place the container directly below the hole in the balance bench and fill it until water escapes from the overflow.
4.3.2 Attach the basket to the balance so that it is completely immersed in water, then tare the balance.

4.3.3 Transfer the test portion to the basket and agitate the stone to remove any entrapped air.

4.3.4 Determine the mass of the fully immersed test portion (m₂).

4.3.5 Determine the temperature of the water in the container to the nearest 1ºC.

4.4 Density measurement using above balance weighing

This method applies where the appropriate equipment is available to allow the test portion volume to be determined by suspending the portion in a container of water placed on the balance pan.

4.4.1 Fill the container to a level which will allow all of the basket to be completely immersed and place the container on the balance.

4.4.2 Position the laboratory stand directly above the container. Suspend the basket from the stand such that it is completely immersed in water without touching any part of the container, then tare the balance.

4.4.3 At the end of the soaking period remove the aggregate from soaking.

4.4.4 Place the aggregate one stone deep on a dry cloth and roll and wipe the particles until all visible films of water have been removed but the surfaces of the aggregate still appear damp (Note 8.1).

4.4.5 Determine the mass of the saturated surface-dry test portion (m₃) (Note 8.2).

4.4.6 Transfer the test portion to the basket and agitate the stone to remove any entrapped air.

4.4.7 Determine the mass of the test portion (m₄).

4.4.8 Determine the temperature of the water in the container to the nearest 1ºC.

4.5 Repeat Steps 4.2 to 4.3.5 or Steps 4.2 and 4.4.1 to 4.4.8 as appropriate for the second test portion.

5 Calculations

5.1 Calculate the apparent particle density of each test portion using the appropriate formula as follows:

5.1.1 Below Balance Weighing

\[ \rho_c = \frac{\rho_w (m_1 - m_2)}{m_1 m_2} \]

where

- \( \rho_c \) = apparent particle density of the coarse fraction (t/m³)
- \( \rho_w \) = density of water at the test temperature (t/m³) (see Table 1)
- \( m_1 \) = mass of dry test portion (g)
- \( m_2 \) = mass of fully immersed test portion (g)
5.1.2 Above Balance Weighing

\[ \rho_c = \frac{m_1}{m_3 - (m_2 - m_1)} \rho_w \]

where

- \( \rho_c \) = apparent particle density of the coarse fraction (t/m³)
- \( \rho_w \) = density of water at the test temperature (t/m³) (see Table 1)
- \( m_1 \) = mass of dry test portion (g)
- \( m_2 \) = mass of saturated surface-dry test portion (g)
- \( m_3 \) = mass of fully immersed test portion (g)

5.2 Compare the results from the two test portions and, if they do not differ by more than 0.020 t/m³, average the results. Otherwise repeat the test.

6 Reporting

Report the average as the apparent particle density (coarse fraction) to the nearest 0.001 t/m³.

7 Precision

7.1 Repeatability

The average results for duplicate tests by the same operator are acceptable if their means do not differ by more than 0.014 t/m³.

7.2 Reproducibility

The average results for duplicate tests from different laboratories are acceptable if their means do not differ by more than 0.023 t/m³.

8 Notes on method

8.1 A gentle current of air may be used to accelerate drying but care must be taken to minimise evaporation and not dry the particles past the damp stage.

8.2 It is convenient to use the second balance to determine this mass.

Table 1 - Density of water

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Density (t/m³)</th>
<th>Temperature (°C)</th>
<th>Density (t/m³)</th>
<th>Temperature (°C)</th>
<th>Density (t/m³)</th>
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</thead>
<tbody>
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<td>28</td>
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<td>Density (t/m³)</td>
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<td>Density (t/m³)</td>
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</table>
Test Method Q113A: California Bearing Ratio of soil - standard

1 Source
This method applies the principles of AS 1289.6.1.1: Determination of the California Bearing Ratio of a soil for a remoulded specimen. It differs from this standard in that it uses multiple specimens and limits the amount of correction which can be applied to the force – penetration curve to 0.5 mm. There are also a number of minor changes to apparatus requirements.

2 Scope
This method describes the procedure for the determination of the California Bearing Ratio (CBR) of soil, gravel and crushed rock materials. California Bearing Ratio is defined as the ratio of the force required to cause a circular plunger of 1932 mm² area to penetrate the material for a specified distance expressed as a percentage of a standard force. The standard forces used in this method are 13,200 and 19,800 newtons for penetrations of 2.5 and 5.0 mm respectively.

Test specimens are prepared from passing 19.0 mm material, cured at a range of moisture contents and compacted using a compactive effort of 596 kJ/m³. They are then tested either in a soaked or unsoaked condition. The method allows for the determination of CBR Maximum Dry Density (CBR MDD) and CBR Optimum Moisture Content (CBR OMC) as well as the optional determination of swell and post penetration moisture content. Neither CBR MDD nor CBR OMC may be used for compaction control. The CBR of the material is determined at CBR Optimum Moisture Content (CBR OMC).

3 Apparatus
Where appropriate, the working tolerances of particular apparatus are contained in Tables 1 and 2.

The following apparatus is required:

3.1 CBR machine, fitted with a moveable lower platen which travels at a uniform vertical upward rate of 1 mm/min when measured loaded.

3.2 Force measuring device, equipped with an indicator having a resolution not exceeding 25 newtons (Notes 8.1 and 8.2).

3.3 Penetration piston, having a diameter of 49.6 mm and about 190 mm long. The piston must have provision for affixing a suitable penetration gauge (Note 8.3).

3.4 Penetration gauge, such as a dial gauge with a resolution of 0.01 mm and a travel of 25 mm, or a displacement transducer of at least equal performance.

3.5 Mould assembly, comprising a cylindrical metal mould having an internal diameter of 152 mm and a height of 178 mm, two detachable baseplates and a removable collar having a height of about 60 mm which can be firmly attached to the mould. One baseplate (perforated baseplate) should have 28 x 3 mm diameter holes uniformly distributed over the area of the plate.

3.6 Spacer disc, having a diameter of 150 mm and a height of 61 mm.

3.7 Stem and perforated plate, having a diameter of 150 mm, mass of 1000 g and with 42 x 3 mm diameter holes uniformly distributed over the plate.

3.8 Soaking weight, having a mass of 4500 g and a diameter of approximately 150 mm, with a centre hole of approximately 55 mm diameter. The surface of the weight in contact with the
perforated plate is to be centrally recessed to a minimum depth of 2 mm for a diameter of approximately 120 mm.

3.9 Surcharge weights, two metal weights each having a mass of 2250 g and a diameter of 150 mm, with a centre hole of approximately 55 mm diameter.

3.10 Swell gauge, consisting of a tripod and a suitable gauge, for example, a dial gauge with a resolution of 0.01 mm and a travel of 25 mm.

3.11 Balance of suitable capacity, having a resolution of at least 1 g and with a limit of performance within the range of ± 5 g.

3.12 Rammer, a metal rammer having a 50 mm diameter face, a drop mass of 2700 g and a drop height of 300 mm.

3.13 Sieves, 19.0 mm and 9.50 mm complying with AS 1152.

3.14 Water bath, of sufficient depth to immerse the moulded specimen in water.

3.15 Level and rigid foundation upon which to compact the specimen, for example, a 100 mm thick sound concrete floor or a concrete block of at least 100 kg mass.

3.16 Straightedge, made of steel and having the approximate dimensions of length 250 mm, width 25 mm and thickness 3 mm, preferably with a bevelled edge.

3.17 Sealable containers, suitable for curing soil samples.

3.18 Sample extruder, such as a jack, lever frame or other device suitable for extracting compacted soil specimens from the mould.

3.19 Material height gauge. A flat steel bar, about 250 mm long, 25 mm wide and 1-3 mm thick is satisfactory (Note 8.4).

3.20 Mixing apparatus, such as a tray, trowel or scoop and water sprayer.

4 Materials

The following materials are required:

4.1 Filter paper, a coarse filter paper such as Whatman No. 1.

4.2 Mould oil, a light mould oil such as Caltex Mould Oil 20 (Note 8.5).

5 Procedure

The procedure shall be as follows:

5.1 Sample preparation

5.1.1 Prepare the bulk sample as detailed in Section 5 of Test Method Q101 to produce a representative subsample of appropriate size.

5.1.2 Further prepare the material by screening the subsample on a 19.0 mm sieve as detailed in Q101, Steps 6.2.1 to 6.2.3. Ensure that any aggregations are broken up to pass a 9.50 mm sieve.

5.1.3 Prepare four or more representative test portions of appropriate mass (Note 8.6).

5.1.4 Thoroughly mix each test portion in turn with sufficient water so that the range of their moisture contents is judged to straddle optimum moisture content (Note 8.7). The moisture increments between portions shall be essentially equal (Note 8.8).
5.1.5 After mixing, place each test portion in a sealed container and allowed to cure for an appropriate time for the material (Table 3).

5.2 Mould preparation

5.2.1 Lightly oil the inside of the mould and then assemble the mould and perforated baseplate.

5.2.2 Determine the mass of the mould and perforated baseplate \( (m_1) \). When a soaked CBR test is to be performed, add two filter papers to the mould and perforated baseplate.

5.2.3 Attach the second baseplate to the mould, invert the mould and remove the perforated baseplate and both filter papers, if added. Insert the spacer disc in the mould and attach the collar to the mould.

5.3 Compaction

5.3.1 Spread the cured test portion on the mixing tray and thoroughly remix. Take a representative subsample and determine the compacted moisture content \( (w) \) as detailed in Test Method Q102A.

5.3.2 Place sufficient of the mixed test portion in the mould to achieve a mean compacted height within the range of 39 mm to 44 mm.

5.3.3 Compact the material in the mould using 53 blows of the rammer falling freely through its full height. Deliver the first 44 blows in four cycles of 11 blows with 8 distributed around the mould circumference and 3 in the central area. Deliver the remaining 9 blows with 7 around the circumference and 2 in the central area.

5.3.4 Measure the height of the compacted specimen using the layer depth gauge at a minimum of four locations such that the mean of the measurements is representative of the average height of the specimen. Discard the specimen if its mean height falls outside the range of 39 mm to 44 mm.

5.3.5 Repeat Steps 5.3.2 to 5.3.4, except that the mean compacted height of the specimen shall be within the range of 78 mm to 83 mm.

5.3.6 Repeat Steps 5.3.2 to 5.3.4, except that the mean compacted height of the specimen shall be within the range of 117 mm to 122 mm.

5.3.7 Remove the collar and level the compacted material to the top of the mould by means of the straightsedge. Fill any holes developed in the surface due to removal of coarse material using some of the excess material. When a soaked CBR test is to be performed, place a filter paper on the surface of the compacted material.

5.3.8 Reattach the perforated baseplate to the mould and invert the mould. Remove the second baseplate and spacer disc. When a soaked CBR test is to be performed, place a filter paper on the surface of the compacted material.

5.3.9 Determine the mass of the mould, perforated baseplate and compacted material \( (m_2) \).

5.3.10 Where the compacted material is to be tested in the soaked condition, soak the compacted material as detailed in Subsection 5.4.

5.3.11 Where the compacted material is to be tested in the unsoaked condition, penetrate the compacted material as detailed in Subsection 5.5.

5.3.12 Prepare additional moulds as detailed in Subsection 5.2 and Subsection 5.3 for the other test portions so that at least four specimens are penetrated. These specimens shall include at least two specimens dry of OMC and shall provide a range of moisture content which
straddles OMC and adequately defines the dry density/moisture content relationship under these particular compaction conditions. If necessary, cure, compact and penetrate additional test portions as detailed in Subsections 5.1, 5.3 and 5.5.

5.4 Soaking

5.4.1 Centrally locate the stem and perforated plate together with a soaking weight on the filter paper.

5.4.2 Obtain an initial reading for swell at a marked reference point by placing the tripod of the swell gauge on the top of the mould so that the contact point of the dial gauge is in contact with the highest point of the stem. Record the dial gauge reading \( r_1 \) and then remove the swell gauge.

5.4.3 Place the mould in the water bath, allowing free access of water to the top and bottom of the specimen. Soak the specimen for 96 ± 4 hours with the water level being maintained above the mould during this period.

5.4.4 Take a final reading for swell by locating the swell gauge in the same position (Step 5.4.2) on top of the mould. Record the dial gauge reading \( r_2 \) and then remove the swell gauge.

5.4.5 Remove the mould from the water bath and tilt the mould to pour off any excess water, then return it to the upright position and allow to drain for 15 minutes. Do not disturb the surface of the specimen during the removal of water.

5.4.6 Remove the soaking weight and stem and perforated plate from the mould.

5.4.7 Penetrate the specimen as detailed in Subsection 5.5.

5.5 Penetration

5.5.1 Centrally locate the two surcharge weights on the compacted sample in the mould.

5.5.2 Position the mould on the platen of the CBR machine so that the mould is located centrally under the penetration piston and the piston almost touches the surface of the material.

5.5.3 Zero the force measuring device indicator and seat the penetration piston by applying a force of about 45 N (Note 8.9).

5.5.4 Zero the force measuring device indicator and penetration gauge (Note 8.10).

5.5.5 Commence penetration of the specimen and record the force measuring device indicator readings for every 0.5 mm penetration to a minimum penetration of 7.5 mm.

5.5.6 Remove the mould from the CBR machine, then remove the surcharge weights. Extrude the compacted soil from the mould and obtain any requested final moisture content \( w_f \) as follows:

a) For compacted material penetrated in the soaked condition:
   i. Remove the filter papers and obtain a moisture sample to a depth of 30 mm from the end of the specimen which contains the penetration depression.
   ii. Obtain a second moisture sample from a uniform section through the entire depth of the remainder of the specimen.
   iii. Determine the moisture content \( w_f \) of each sample in accordance with Test Method Q102A.
b) For compacted material penetrated in the unsoaked condition:
   i. Obtain a moisture sample from a uniform section through the entire depth of the specimen.
   ii. Determine the moisture content \( w_f \) of the sample in accordance with Test Method Q102A.

6 Calculations

6.1 Compacted dry density

6.1.1 Calculate the compacted dry density to the nearest 0.001 t/m\(^3\) as follows:

\[
\rho_d = \frac{100(m_2 - m_1)}{V(100 + w_a)}
\]

where
- \( \rho_d \) = compacted dry density (t/m\(^3\))
- \( m_2 \) = mass of mould, baseplate and compacted material (g)
- \( m_1 \) = mass of mould and baseplate (g)
- \( V \) = effective volume of mould (cm\(^3\))
- \( w_a \) = compacted moisture content (%)

6.2 Zero air voids line

6.2.1 Determine at least two moisture content points for the chosen air voids line, from the apparent particle density (Note 8.11) by using dry density values corresponding to the lowest and highest values determined in Step 6.1 as follows (Note 8.12):

\[
\frac{100 - V_a}{\rho_d} - \frac{100}{\rho_s} = w
\]

where
- \( w \) = moisture content, expressed as a percentage of the mass of dry material
- \( V_a \) = volume of chosen air voids, expressed as a percentage of the volume of undried material
- \( \rho_d \) = dry density of material (t/m\(^3\))
- \( \rho_s \) = apparent particle density (t/m\(^3\))

6.3 Swell

6.3.1 If the measurement of swell is required, calculate it for each specimen as follows:

\[
S = \left( \frac{r_2 - r_1}{117} \right) \times 100
\]

where
- \( S \) = swell (%)
- \( r_2 \) = final dial gauge reading (mm)
- \( r_1 \) = initial dial gauge reading (mm)
6.4 Bearing ratio

Determine the bearing ratio at 2.5 mm and 5.0 mm penetration for each specimen as follows:

6.4.1 Convert the force indicator readings to applied forces in newtons using the appropriate calibration for the force measuring device (Note 8.13).

6.4.2 Plot the applied forces against the corresponding penetration values and draw a smooth curve through the points.

6.4.3 When the force-penetration curve commences with a concave upward portion (refer to Figure 1 and Note 8.14), adjust the penetration scale as follows:

a) Draw a tangent through the steepest part of the curve so as to intersect the penetration axis.

b) The intercept with the penetration (x) axis shall be the new origin provided that its value does not exceed 0.5 mm.

c) Where the intercept exceeds 0.5 mm, the new origin shall be 0.5 mm.

d) Adjust the 2.5 mm and 5.0 mm values in relation to the re-designated origin.

6.4.4 Determine the values of applied force \( f_{2.5} \) and \( f_{5.0} \) corresponding to the adjusted 2.5 mm and 5.0 mm penetrations.

6.4.5 Calculate the bearing ratio at 2.5 mm and 5.0 mm penetrations and record these ratios as \( CBR_{2.5} \) and \( CBR_{5.0} \) as follows:

\[
CBR_{2.5} = \frac{f_{2.5} \times 100}{13200}
\]

\[
CBR_{5.0} = \frac{f_{5.0} \times 100}{19800}
\]

where

- \( CBR_{2.5} \) = California Bearing Ratio corresponding to 2.5 mm penetration
- \( CBR_{5.0} \) = California Bearing Ratio corresponding to 5.0 mm penetration
- \( f_{2.5} \) = applied force corresponding to 2.5 mm penetration (N)
- \( f_{5.0} \) = applied force corresponding to 5.0 mm penetration (N)

6.5 California Bearing Ratio

6.5.1 Plot the compacted dry densities for the compacted specimens against their corresponding compacted moisture contents.

6.5.2 Plot the zero air voids data (corresponding to compacted dry densities and compacted moisture contents) on the same graph used in Step 6.5.1 and draw a straight line through the points.

6.5.3 Draw a smooth curve of best fit through the data points plotted in Step 6.5.1 with the wet leg of the curve tending parallel to the zero air voids line.

6.5.4 Plot the bearing ratios of the compacted specimens on a logarithmic scale against their corresponding compacted moisture contents on a linear scale.
6.5.5 Draw one smooth curve through bearing ratios corresponding to 2.5 mm penetration and draw another smooth curve through bearing ratios corresponding to 5.0 mm penetration.

6.5.6 Determine the bearing ratios corresponding to the peak of the compacted dry density versus compacted moisture content curve and record as CBR 2.5 mm and CBR 5.0 mm respectively.

6.5.7 Determine the peak compacted dry density and record as the CBR MDD. Determine the compacted moisture content corresponding to the peak dry density and record as the CBR OMC.

7 Reporting

7.1 The following shall be reported:

7.1.1 A tabulation of compacted moisture content to the nearest 0.1% and compacted dry density to the nearest 0.001 t/m³, together with the bearing ratio at 2.5 mm penetration and the bearing ratio at 5.0 mm penetration for each specimen.

7.1.2 A graph of compacted dry density versus compacted moisture content together with a plot of the zero air voids line or assumed zero air voids line.

7.1.3 A graph of bearing ratio versus compacted moisture content.

7.1.4 The CBR MDD to the nearest 0.01 t/m³.

7.1.5 CBR OMC to the nearest 0.2% for moisture contents up to 20% and to the nearest 0.5% for moisture contents greater than 20%.

7.1.6 CBR 2.5 mm and CBR 5.0 mm (refer to Table 4).

7.1.7 The material CBR value which is the largest numerical value of either CBR 2.5 mm or CBR 5.0 mm (Refer to Table 4).

7.1.8 Test condition, that is, soaked or unsoaked.

7.2 The following may be reported:

7.2.1 Swell of each soaked specimen to the nearest 0.1% for values less than 10, otherwise to the nearest 1% (optional).

7.2.2 Final moisture content of each specimen after penetration (optional).

7.2.3 The force-penetration graph of the specimen having the compacted moisture content closest to CBR OMC (optional).

8 Notes on method

8.1 The force measuring device shall be calibrated over its complete operating range. This will require further points near to zero in addition to those required by AS 2193.

8.2 For each test, a force measuring device shall be selected which is Class C for that part of its operating range which corresponds to the forces required to produce plunger penetrations of 2.5 mm and greater.

8.3 Where a device such as a load transducer is used to measure the applied force, the penetration gauge may be affixed to the frame of the machine.

8.4 A material height gauge, which allows monitoring of the height of compacted material relative to the top of a CBR mould, can be made from a steel bar as follows:
8.4.1 Commencing at one end of the bar, measure and mark distances of:

a) 39 mm and 34 mm for the acceptable range of the second layer, and

b) 78 mm and 73 mm for the acceptable range of the first layer.

8.5 Before handling oil, the operator must consult the relevant Safety Data Sheet (SDS).

8.6 As a guide, test portions can vary from 5500 g for a clay to 7000 g for a gravel.

8.7 In order to straddle optimum moisture content, it may be necessary to remove water from one or more test portions by air drying or oven drying at 45 to 50°C.

8.8 Suitable intervals for moisture increments range from 1% for a gravel to 2 to 3% for a clay.

8.9 In some very weak materials where the seating load causes significant penetration, this step can be omitted. However, this variation of the method must be reported.

8.10 Where zeroing the force measuring device indicator will invalidate the calibration of the device, the indicator shall not be zeroed and the reading shall be recorded as the seating deflection.

8.11 The value of the material's apparent particle density for calculating the air voids lines may be obtained using the method described in Q109 or assumed on the basis of previous tests. A rough check on the material particle density is to select the dry density and moisture content of the wettest data point, nominate a percent air voids (2% often gives a satisfactory result) and calculate an apparent particle density as follows:

\[
\rho_s = \frac{100\rho_d}{(100 - V_a)\rho_w}
\]

where

- \(\rho_s\) = apparent particle density (t/m³)
- \(\rho_d\) = dry density of material (t/m³)
- \(V_a\) = nominated air voids (%)
- \(\rho_w\) = moisture content expressed as a percentage of the mass of dry material

The material's apparent particle density so derived is taken as the assumed value.

8.12 Appropriate values of calculated dry density are the smallest and largest scale values used on the graph of calculated dry density versus initial moisture content.

8.13 Where the force measuring device indicator was not zeroed after the application of the seating load, the seating deflection shall be converted to applied force in newtons and subtracted from each of the calculated values of applied force.

8.14 This characteristic may be due to surface irregularities, material behaviour or other causes.

**Table 1 – Dimensions and tolerances for CBR equipment**

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Dimension</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBR machine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Platen travel rate – loaded (mm/min)</td>
<td>1</td>
<td>± 0.2</td>
</tr>
<tr>
<td>Penetration piston</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter (mm)</td>
<td>49.6</td>
<td>± 0.1</td>
</tr>
<tr>
<td>Apparatus</td>
<td>Dimension</td>
<td>Tolerance</td>
</tr>
<tr>
<td>---------------------------------------</td>
<td>-----------</td>
<td>-----------</td>
</tr>
<tr>
<td><strong>Mould</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal diameter (mm)</td>
<td>152</td>
<td>± 1</td>
</tr>
<tr>
<td>Height (mm)</td>
<td>178</td>
<td>± 1</td>
</tr>
<tr>
<td><strong>Perforated baseplate</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hole number</td>
<td>28</td>
<td>+5, -0</td>
</tr>
<tr>
<td>Hole diameter (mm)</td>
<td>3</td>
<td>± 0.2</td>
</tr>
<tr>
<td><strong>Spacer disc</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter (mm)</td>
<td>150</td>
<td>± 0.5</td>
</tr>
<tr>
<td>Height (mm)</td>
<td>61</td>
<td>± 0.25</td>
</tr>
<tr>
<td><strong>Stem and perforated plate</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter (mm)</td>
<td>150</td>
<td>± 0.5</td>
</tr>
<tr>
<td>Mass (g)</td>
<td>1000</td>
<td>± 25</td>
</tr>
<tr>
<td>Hole number</td>
<td>42</td>
<td>± 0</td>
</tr>
<tr>
<td>Hole diameter (mm)</td>
<td>3</td>
<td>± 0.2</td>
</tr>
<tr>
<td><strong>Soaking weight</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass (g)</td>
<td>4500</td>
<td>± 50</td>
</tr>
<tr>
<td><strong>Surcharge weight</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass (g)</td>
<td>2250</td>
<td>± 25</td>
</tr>
<tr>
<td>Diameter (mm)</td>
<td>150</td>
<td>± 0.5</td>
</tr>
<tr>
<td><strong>Levelling plate</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter (mm)</td>
<td>151</td>
<td>0, -1</td>
</tr>
<tr>
<td>Height (mm)</td>
<td>20</td>
<td>minimum</td>
</tr>
</tbody>
</table>

**Table 2 – Dimensions and tolerances for rammers**

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Dimension</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rammer – standard</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Face diameter (mm)</td>
<td>50</td>
<td>± 0.4</td>
</tr>
<tr>
<td>Drop (mm)</td>
<td>300</td>
<td>± 2.0</td>
</tr>
<tr>
<td>Mass (g)</td>
<td>2700</td>
<td>± 10</td>
</tr>
</tbody>
</table>

**Table 3 – Minimum curing time**

<table>
<thead>
<tr>
<th>Plasticity</th>
<th>Minimum curing time (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sands and unbound material*</td>
<td>2</td>
</tr>
<tr>
<td>Low (LL ≤ 35%)</td>
<td>48</td>
</tr>
<tr>
<td>Medium (35 &lt; LL ≤ 50%)</td>
<td>96 (4 days)</td>
</tr>
</tbody>
</table>
Plasticity | Minimum curing time (hours)
---|---
High (LL > 50%) | 168 (7 days)

* These can include naturally occurring sands and gravels, crushed rocks and manufactured materials with a fines (< 0.075 mm) content less than 12%.

LL = Liquid limit.

**Table 4 – Reporting intervals for CBR values**

<table>
<thead>
<tr>
<th>CBR value</th>
<th>Reporting interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1</td>
<td>nearest 0.2 units</td>
</tr>
<tr>
<td>1 to 10</td>
<td>nearest 0.5 units</td>
</tr>
<tr>
<td>11 to 30</td>
<td>nearest 1 unit</td>
</tr>
<tr>
<td>31 to 120</td>
<td>nearest 2 units</td>
</tr>
<tr>
<td>&gt; 120</td>
<td>nearest 5 units</td>
</tr>
</tbody>
</table>
Figure 1 – Typical force – penetration curves showing the determination of new penetration origins

No concave upward portion hence no new penetration origin

New penetration origin at 0.2mm

New penetration origin at 0.5mm (since intercept with X axis exceeds 0.5mm) and consequent adjustments to penetration scale.
Test Method Q113B: California Bearing Ratio of soil - modified

1  Source

This method applies the principles of AS 1289.6.1.1: Determination of the California Bearing Ratio of a soil for a remoulded specimen. It differs from this standard in that it uses multiple specimens and limits the amount of correction which can be applied to the force – penetration curve to 0.5 mm. There are also a number of minor changes to apparatus requirements.

2  Scope

This method describes the procedure for the determination of the California Bearing Ratio (CBR) of soil, gravel and crushed rock materials. California Bearing Ratio is defined as the ratio of the force required to cause a circular plunger of 1932 mm² area to penetrate the material for a specified distance expressed as a percentage of a standard force. The standard forces used in this method are 13,200 and 19,800 newtons for penetrations of 2.5 and 5.0 mm respectively.

Test specimens are prepared from passing 19.0 mm material, cured at a range of moisture contents and compacted using a compactive effort of 2703 kJ/m³. They are then tested either in a soaked or unsoaked condition. The method allows for the determination of CBR Maximum Dry Density (CBR MDD) and CBR Optimum Moisture Content (CBR OMC), as well as the optional determination of swell and post penetration moisture content. Neither CBR MDD nor CBR OMC may be used for compaction control. The CBR of the material is determined at CBR Optimum Moisture Content (CBR OMC).

3  Apparatus

Where appropriate, the working tolerances of particular apparatus are contained in Tables 1 and 2.

The following apparatus is required:

3.1  CBR machine, fitted with a moveable lower platen which travels at a uniform vertical upward rate of 1 mm/min when measured loaded.

3.2  Force measuring device, equipped with an indicator having a resolution not exceeding 25 newtons (Notes 8.1 and 8.2).

3.3  Penetration piston, having a diameter of 49.6 mm and about 190 mm long. The piston must have provision for affixing a suitable penetration gauge (Note 8.3).

3.4  Penetration gauge, such as a dial gauge with a resolution of 0.01 mm and a travel of 25 mm, or a displacement transducer of at least equal performance.

3.5  Mould assembly, comprising a cylindrical metal mould having an internal diameter of 152 mm and a height of 178 mm, two detachable baseplates and a removable collar having a height of about 60 mm which can be firmly attached to the mould. One baseplate (perforated baseplate) should have 28 x 3 mm diameter holes uniformly distributed over the area of the plate.

3.6  Spacer disc, having a diameter of 150 mm and a height of 61 mm.

3.7  Stem and perforated plate, having a diameter of 150 mm, mass of 1000 g and with 42 x 3 mm diameter holes uniformly distributed over the plate.

3.8  Soaking weight, having a mass of 4500 g and a diameter of approximately 150 mm, with a centre hole of approximately 55 mm diameter. The surface of the weight in contact with the perforated plate is to be centrally recessed to a minimum depth of 2 mm for a diameter of approximately 120 mm.
3.9 Surcharge weights, two metal weights each having a mass of 2250 g and a diameter of 150 mm, with a centre hole of approximately 55 mm diameter.

3.10 Swell gauge, consisting of a tripod and a suitable gauge, for example, a dial gauge with a resolution of 0.01 mm and a travel of 25 mm.

3.11 Balance of suitable capacity, having a resolution of at least 1 g and with a limit of performance within the range of ± 5 g.

3.12 Rammer, a metal rammer having a 50 mm diameter face, a drop mass of 4900 g and a drop height of 450 mm.

3.13 Sieves, 19.0 mm and 9.50 mm complying with AS 1152.

3.14 Water bath, of sufficient depth to immerse the moulded specimen in water.

3.15 Level and rigid foundation upon which to compact the specimen, for example, a 100 mm thick sound concrete floor or a concrete block of at least 100 kg mass.

3.16 Straightedge, made of steel and having the approximate dimensions of length 250 mm, width 25 mm and thickness 3 mm, preferably with a bevelled edge.

3.17 Sealable containers, suitable for curing soil samples.

3.18 Sample extruder, such as a jack, lever frame or other device suitable for extracting compacted soil specimens from the mould.

3.19 Material height gauge. A flat steel bar, about 250 mm long, 25 mm wide and 1-3 mm thick is satisfactory (Note 8.4).

3.20 Mixing apparatus, such as a tray, trowel or scoop and water sprayer.

4 Materials

The following materials are required:

4.1 Filter paper, a coarse filter paper such as Whatman No.1.

4.2 Mould oil, a light mould oil such as Caltex Mould Oil 20 (Note 8.5).

5 Procedure

The procedure shall be as follows:

5.1 Sample preparation

5.1.1 Prepare the bulk sample as detailed in Section 5 of Test Method Q101 to produce a representative subsample of appropriate size.

5.1.2 Further prepare the material by screening the subsample on a 19.0 mm sieve as detailed in Q101, Steps 6.2.1 to 6.2.3. Ensure that any aggregations are broken up to pass a 9.50 mm sieve.

5.1.3 Prepare four or more representative test portions of appropriate mass (Note 8.6).

5.1.4 Thoroughly mix each test portion in turn with sufficient water so that the range of their moisture contents is judged to straddle optimum moisture content (Note 8.7). The moisture increments between portions shall be essentially equal (Note 8.8).

5.1.5 After mixing, place each test portion in a sealed container and allow to cure for an appropriate time for the material (Table 3).
5.2 Mould preparation

5.2.1 Lightly oil the inside of the mould and then assemble the mould and perforated baseplate.

5.2.2 Determine the mass of the mould and perforated baseplate \( (m_1) \). When a soaked CBR test is to be performed, add two filter papers to the mould and perforated baseplate.

5.2.3 Attach the second baseplate to the mould, invert the mould and remove the perforated baseplate and both filter papers, if added. Insert the spacer disc in the mould and attach the collar to the mould.

5.3 Compaction

5.3.1 Spread the cured test portion on the mixing tray and thoroughly remix. Take a representative subsample and determine the compacted moisture content \( (w) \) as detailed in Test Method Q102A.

5.3.2 Place sufficient of the mixed test portion in the mould to achieve a mean compacted height within the range of 39 mm to 44 mm.

5.3.3 Compact the material in the mould using 88 blows of the rammer falling freely through its full height. Deliver the blows in eight cycles of 11 blows with 8 distributed around the mould circumference and 3 in the central area.

5.3.4 Measure the height of the compacted specimen using the layer depth gauge at a minimum of four locations such that the mean of the measurements is representative of the average height of the specimen. Discard the specimen if its mean height falls outside the range of 39 mm to 44 mm.

5.3.5 Repeat Steps 5.3.2 to 5.3.4, except that the mean compacted height of the specimen shall be within the range of 78 mm to 83 mm.

5.3.6 Repeat Steps 5.3.2 to 5.3.4, except that the mean compacted height of the specimen shall be within the range of 117 mm to 122 mm.

5.3.7 Remove the collar and level the compacted material to the top of the mould by means of the straightedge. Fill any holes developed in the surface due to the removal of coarse material using some of the excess material. When a soaked CBR test is to be performed, place a filter paper on the surface of the compacted material.

5.3.8 Reattach the perforated baseplate to the mould and invert the mould. Remove the second baseplate and spacer disc. When a soaked CBR test is to be performed, place a filter paper on the surface of the compacted material.

5.3.9 Determine the mass of the mould, perforated baseplate and compacted material \( (m_2) \).

5.3.10 Where the compacted material is to be tested in the soaked condition, soak the compacted material as detailed in Subsection 5.4.

5.3.11 Where the compacted material is to be tested in the unsoaked condition, penetrate the compacted material as detailed in Subsection 5.5.

5.3.12 Prepare additional moulds as detailed in Subsection 5.2 and Subsection 5.3 for the other test portions so that at least four specimens are penetrated. These specimens shall include at least two specimens dry of OMC and shall provide a range of moisture content which straddles OMC and adequately defines the dry density/moisture content relationship under these particular compaction conditions. If necessary, cure, compact and penetrate additional test portions as detailed in Subsections 5.1, 5.3 and 5.5.
5.4 Soaking

5.4.1 Centrally locate the stem and perforated plate together with a soaking weight on the filter paper.

5.4.2 Obtain an initial reading for swell at a marked reference point by placing the tripod of the swell gauge on the top of the mould so that the contact point of the dial gauge is in contact with the highest point of the stem. Record the dial gauge reading ($r_1$) and then remove the swell gauge.

5.4.3 Place the mould in the water bath, allowing free access of water to the top and bottom of the specimen. Soak the specimen for $96 \pm 4$ hours with the water level being maintained above the mould during this period.

5.4.4 Take a final reading for swell by locating the swell gauge in the same position (Step 5.4.2) on top of the mould. Record the dial gauge reading ($r_2$) and then remove the swell gauge.

5.4.5 Remove the mould from the water bath and tilt the mould to pour off any excess water, then return it to the upright position and allow to drain for 15 minutes. Do not disturb the surface of the specimen during the removal of water.

5.4.6 Remove the soaking weight and stem and perforated plate from the mould.

5.4.7 Penetrate the specimen as detailed in Subsection 5.5.

5.5 Penetration

5.5.1 Centrally locate the two surcharge weights on the compacted sample in the mould.

5.5.2 Position the mould on the platen of the CBR machine so that the mould is located centrally under the penetration piston and the piston almost touches the surface of the material.

5.5.3 Zero the force measuring device indicator and seat the penetration piston by applying a force of about 45 N (Note 8.9).

5.5.4 Zero the force measuring device indicator and penetration gauge (Note 8.10).

5.5.5 Commence penetration of the specimen and record the force measuring device indicator readings for every 0.5 mm penetration to a minimum penetration of 7.5 mm.

5.5.6 Remove the mould from the CBR machine, then remove the surcharge weights. Extrude the compacted soil from the mould and obtain any requested final moisture content ($w_f$) as follows:

a) For compacted material penetrated in the soaked condition:
   i. Remove the filter papers and obtain a moisture sample to a depth of 30 mm from the end of the specimen which contains the penetration depression.
   ii. Obtain a second moisture sample from a uniform section through the entire depth of the remainder of the specimen.
   iii. Determine the moisture content ($w_f$) of each sample in accordance with Test Method Q102A.

b) For compacted material penetrated in the unsoaked condition:
   i. Obtain a moisture sample from a uniform section through the entire depth of the specimen.
ii. Determine the moisture content \( w_f \) of the sample in accordance with Test Method Q102A.

6 Calculations

6.1 Compacted dry density

6.1.1 Calculate the compacted dry density to the nearest 0.001 t/m³ as follows:

\[
\rho_d = \frac{100(m_2 - m_1)}{V(100 + w)}
\]

where
- \( \rho_d \) = compacted dry density (t/m³)
- \( m_2 \) = mass of mould, baseplate and compacted material (g)
- \( m_1 \) = mass of mould and baseplate (g)
- \( V \) = effective volume of mould (cm³)
- \( w \) = compacted moisture content (%)

6.2 Zero air voids line

6.2.1 Determine at least two moisture content points for the chosen air voids line, from the apparent particle density (Note 8.11) by using dry density values corresponding to the lowest and highest values determined in Step 6.1 as follows (Note 8.12):

\[
w = \frac{100 - V_a}{\rho_d - \rho_a} 100
\]

where
- \( w \) = moisture content, expressed as a percentage of the mass of dry material
- \( V_a \) = volume of chosen air voids, expressed as a percentage of the volume of undried material
- \( \rho_d \) = dry density of material (t/m³)
- \( \rho_a \) = apparent particle density (t/m³)

6.3 Swell

If the measurement of swell is required, calculate it for each specimen as follows:

\[
S = \left( \frac{r_2 - r_1}{117} \right) 100
\]

where
- \( S \) = swell (%)  
- \( r_2 \) = final dial gauge reading (mm)  
- \( r_1 \) = initial dial gauge reading (mm)
6.4 **Bearing ratio**

Determine the bearing ratio at 2.5 mm and 5.0 mm penetration for each specimen as follows:

6.4.1 Convert the force indicator readings to applied forces in newtons using the appropriate calibration for the force measuring device (Note 8.13).

6.4.2 Plot the applied forces against the corresponding penetration values and draw a smooth curve through the points.

6.4.3 When the force-penetration curve commences with a concave upward portion (refer to Figure 1 and Note 8.14), adjust the penetration scale as follows:

   a) Draw a tangent through the steepest part of the curve so as to intersect the penetration axis.

   b) The intercept with the penetration (x) axis shall be the new origin provided that its value does not exceed 0.5 mm.

   c) Where the intercept exceeds 0.5 mm, the new origin shall be 0.5 mm.

   d) Adjust the 2.5 mm and 5.0 mm values in relation to the re-designated origin.

6.4.4 Determine the values of applied force \( f_{2.5} \) and \( f_{5.0} \) corresponding to the adjusted 2.5 mm and 5.0 mm penetrations.

6.4.5 Calculate the bearing ratio at 2.5 mm and 5.0 mm penetrations and record these ratios as \( \text{CBR}_{2.5} \) and \( \text{CBR}_{5.0} \) as follows:

\[
\text{CBR}_{2.5} = \frac{f_{2.5} \times 100}{13200}
\]

\[
\text{CBR}_{5.0} = \frac{f_{5.0} \times 100}{19800}
\]

where \( \text{CBR}_{2.5} \) = California Bearing Ratio corresponding to 2.5 mm penetration

\( \text{CBR}_{5.0} \) = California Bearing Ratio corresponding to 5.0 mm penetration

\( f_{2.5} \) = applied force corresponding to 2.5 mm penetration (N)

\( f_{5.0} \) = applied force corresponding to 5.0 mm penetration (N)

6.5 **California Bearing Ratio**

6.5.1 Plot the compacted dry densities for the compacted specimens against their corresponding compacted moisture contents.

6.5.2 Plot the zero air voids data (corresponding to compacted dry densities and compacted moisture contents) on the same graph used in Step 6.5.1 and draw a straight line through the points.

6.5.3 Draw a smooth curve of best fit through the data points plotted in Step 6.5.1 with the wet leg of the curve tending parallel to the zero air voids line.
6.5.4 Plot the bearing ratios of the compacted specimens on a logarithmic scale against their corresponding compacted moisture contents on a linear scale.

6.5.5 Draw one smooth curve through bearing ratios corresponding to 2.5 mm penetration and draw another smooth curve through bearing ratios corresponding to 5.0 mm penetration.

6.5.6 Determine the bearing ratios corresponding to the peak of the compacted dry density versus compacted moisture content curve and record as CBR 2.5 mm and CBR 5.0 mm respectively.

6.5.7 Determine the peak compacted dry density and record as the CBR MDD. Determine the compacted moisture content corresponding to the peak dry density and record as the CBR OMC.

7 Reporting

7.1 The following shall be reported:

7.1.1 A tabulation of compacted moisture content to the nearest 0.1% and compacted dry density to the nearest 0.001 t/m³, together with the bearing ratio at 2.5 mm penetration and the bearing ratio at 5.0 mm penetration for each specimen.

7.1.2 A graph of compacted dry density versus compacted moisture content together with a plot of the zero air voids line or assumed zero air voids line.

7.1.3 A graph of bearing ratio versus compacted moisture content.

7.1.4 The CBR MDD to the nearest 0.01 t/m³.

7.1.5 CBR OMC to the nearest 0.2% for moisture contents up to 20% and to the nearest 0.5% for moisture contents greater than 20%.

7.1.6 CBR 2.5 mm and CBR 5.0 mm (refer to Table 4).

7.1.7 The material CBR value which is the largest numerical value of either CBR 2.5 mm or CBR 5.0 mm (Refer to Table 4).

7.1.8 Test condition, that is, soaked or unsoaked.

7.2 The following may be reported:

7.2.1 Swell of each soaked specimen to the nearest 0.1% for values less than 10, otherwise to the nearest 1% (optional).

7.2.2 Final moisture content of each specimen after penetration (optional).

7.2.3 The force-penetration graph of the specimen having the compacted moisture content closest to CBR OMC (optional).

8 Notes on method

8.1 The force measuring device shall be calibrated over its complete operating range. This will require further points near to zero in addition to those required by AS 2193.

8.2 For each test, a force measuring device shall be selected which is Class C for that part of its operating range which corresponds to the forces required to produce plunger penetrations of 2.5 mm and greater.

8.3 Where a device such as a load transducer is used to measure the applied force, the penetration gauge may be affixed to the frame of the machine.
8.4 A material height gauge, which allows monitoring of the height of compacted material relative to the top of a CBR mould, can be made from a steel bar as follows:

8.4.1 Commencing at one end of the bar, measure and mark distances of:
   a) 39 mm and 34 mm for the acceptable range of the second layer, and
   b) 78 mm and 73 mm for the acceptable range of the first layer.

8.5 Before handling oil, the operator must consult the relevant Safety Data Sheet (SDS).

8.6 As a guide, test portions can vary from 5500 g for a clay to 7000 g for a gravel.

8.7 In order to straddle optimum moisture content, it may be necessary to remove water from one or more test portions by air drying or oven drying at 45 to 50°C.

8.8 Suitable intervals for moisture increments range from 1% for a gravel to 2 to 3% for a clay.

8.9 In some very weak materials where the seating load causes significant penetration, this step can be omitted. However, this variation of the method must be reported.

8.10 Where zeroing the force measuring device indicator will invalidate the calibration of the device, the indicator shall not be zeroed and the reading shall be recorded as the seating deflection.

8.11 The value of the material's apparent particle density for calculating the air voids lines may be obtained using the method described in Q109 or assumed on the basis of previous tests. A rough check on the material particle density is to select the dry density and moisture content of the wettest data point, nominate a percent air voids (2% often gives a satisfactory result) and calculate an apparent particle density as follows:

\[
\rho_s = \frac{100 \rho_d}{(100-V_a) \omega}
\]

where

\( \rho_s \) = apparent particle density (t/m³)

\( \rho_d \) = dry density of material (t/m³)

\( V_a \) = nominated air voids (%)

\( \omega \) = moisture content expressed as a percentage of the mass of dry material

The material's apparent particle density so derived is taken as the assumed value.

8.12 Appropriate values of calculated dry density are the smallest and largest scale values used on the graph of calculated dry density versus initial moisture content.

8.13 Where the force measuring device indicator was not zeroed after the application of the seating load, the seating deflection shall be converted to applied force in newtons and subtracted from each of the calculated values of applied force.

8.14 This characteristic may be due to surface irregularities, material behaviour or other causes.
### Table 1 – Dimensions and tolerances for CBR equipment

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Dimension</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBR machine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Platen travel rate – loaded (mm/min)</td>
<td>1</td>
<td>± 0.2</td>
</tr>
<tr>
<td>Penetration piston</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter (mm)</td>
<td>49.6</td>
<td>± 0.1</td>
</tr>
<tr>
<td>Mould</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal diameter (mm)</td>
<td>152</td>
<td>± 1</td>
</tr>
<tr>
<td>Height (mm)</td>
<td>178</td>
<td>± 1</td>
</tr>
<tr>
<td>Perforated baseplate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hole number</td>
<td>28</td>
<td>+5, -0</td>
</tr>
<tr>
<td>Hole diameter (mm)</td>
<td>3</td>
<td>± 0.2</td>
</tr>
<tr>
<td>Spacer disc</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter (mm)</td>
<td>150</td>
<td>± 0.5</td>
</tr>
<tr>
<td>Height (mm)</td>
<td>61</td>
<td>± 0.25</td>
</tr>
<tr>
<td>Stem and perforated plate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter (mm)</td>
<td>150</td>
<td>± 0.5</td>
</tr>
<tr>
<td>Mass (g)</td>
<td>1000</td>
<td>± 25</td>
</tr>
<tr>
<td>Hole number</td>
<td>42</td>
<td>± 0</td>
</tr>
<tr>
<td>Hole diameter (mm)</td>
<td>3</td>
<td>± 0.2</td>
</tr>
<tr>
<td>Soaking weight</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass (g)</td>
<td>4500</td>
<td>± 50</td>
</tr>
<tr>
<td>Surcharge weight</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass (g)</td>
<td>2250</td>
<td>± 25</td>
</tr>
<tr>
<td>Diameter (mm)</td>
<td>150</td>
<td>± 0.5</td>
</tr>
<tr>
<td>Levelling plate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter (mm)</td>
<td>151</td>
<td>0, -1</td>
</tr>
<tr>
<td>Height (mm)</td>
<td>20</td>
<td>minimum</td>
</tr>
</tbody>
</table>

### Table 2 – Dimensions and tolerances for rammers

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Dimension</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rammer – standard</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Face diameter (mm)</td>
<td>50</td>
<td>± 0.4</td>
</tr>
<tr>
<td>Drop (mm)</td>
<td>300</td>
<td>± 2.0</td>
</tr>
<tr>
<td>Mass (g)</td>
<td>2700</td>
<td>± 10</td>
</tr>
</tbody>
</table>
Table 3 – Minimum curing time

<table>
<thead>
<tr>
<th>Plasticity</th>
<th>Minimum curing time (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sands and unbound material*</td>
<td>2</td>
</tr>
<tr>
<td>Low (LL ≤ 35%)</td>
<td>48</td>
</tr>
<tr>
<td>Medium (35 &lt; LL ≤ 50%)</td>
<td>96 (4 days)</td>
</tr>
<tr>
<td>High (LL &gt; 50%)</td>
<td>168 (7 days)</td>
</tr>
</tbody>
</table>

*These can include naturally occurring sands and gravels, crushed rocks and manufactured materials with a fines (< 0.075 mm) content less than 12%.

**LL = Liquid limit.**

Table 4 – Reporting intervals for CBR values

<table>
<thead>
<tr>
<th>CBR value</th>
<th>Reporting interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1</td>
<td>nearest 0.2 units</td>
</tr>
<tr>
<td>1 to 10</td>
<td>nearest 0.5 units</td>
</tr>
<tr>
<td>11 to 30</td>
<td>nearest 1 unit</td>
</tr>
<tr>
<td>31 to 120</td>
<td>nearest 2 units</td>
</tr>
<tr>
<td>&gt; 120</td>
<td>nearest 5 units</td>
</tr>
</tbody>
</table>
Figure 1 – Typical force – penetration curves showing the determination of new penetration origins

No concave upward portion hence no new penetration origin

New penetration origin at 0.2mm

New penetration origin at 0.5mm (since intercept with X axis exceeds 0.5mm) and consequent adjustments to penetration scale.
Test Method Q113C: California Bearing Ratio of soil at nominated levels of dry density and moisture content

1 Source

This method applies the principles of AS 1289.6.1.1: Determination of the California Bearing Ratio of a soil for a remoulded specimen. It differs from this standard in that it requires compaction moisture samples to be taken only before the commencement of compaction and limits the amount of correction which can be applied to the force – penetration curve to 0.5 mm. There is also provision to allow for a longer soaking period. There are also a number of minor changes to apparatus requirements.

2 Scope

This method sets out the procedure for the single point determination of the California Bearing Ratio (CBR) of soils, and is used for estimating design subgrade strength. California Bearing Ratio is defined as the ratio of the force required to cause a circular plunger of 1932 mm² area to penetrate the material for a specified distance, expressed as a percentage of a standard force. The standard forces used in this method are 13,200 and 19,800 newtons for penetrations of 2.5 and 5.0 mm respectively.

Test specimens are prepared by compacting passing 19.0 mm material to a nominated dry density and moisture content using standard or modified compactive effort in accordance with Test Method Q145A. They are then tested either in a soaked or unsoaked condition. The duration of soaking can be either 4 or 10 days.

3 Apparatus

Where appropriate, the working tolerances of particular apparatus are contained in Tables 1 and 2.

The following apparatus is required:

3.1 CBR machine, fitted with a moveable lower platen which travels at a uniform vertical upward rate 1 mm/min when measured loaded.

3.2 Force measuring device, equipped with an indicator resolution not exceeding 25 newtons (Notes 8.1 and 8.2).

3.3 Penetration piston, having a diameter of 49.6 mm and about 190 mm long. The piston must have provision for affixing a suitable penetration gauge (Note 8.3).

3.4 Penetration gauge, such as a dial gauge with a resolution of 0.01 mm and a travel of 25 mm, or a displacement transducer of at least equal performance.

3.5 Mould assembly, comprising a cylindrical metal mould having an internal diameter of 152 mm and a height of 178 mm, two detachable baseplates and a removable collar having a height of about 60 mm which can be firmly attached to the mould. One baseplate (perforated baseplate) should have 28 x 3 mm diameter holes uniformly distributed over the area of the plate.

3.6 Spacer disc, having a diameter of 150 mm and a height of 61 mm.

3.7 Stem and perforated plate, having a diameter of 150 mm, mass of 1000 g and with 42 x 3 mm diameter holes uniformly distributed over the plate.

3.8 Soaking weight, having a mass of 4500 g and a diameter of approximately 150 mm, with a centre hole of approximately 55 mm diameter. The surface of the weight in contact with the perforated plate is to be centrally recessed to a minimum depth of 2 mm for a diameter of approximately 120 mm.
3.9 Surcharge weights, two metal weights each having a mass of 2250 g and a diameter of 150 mm, with a centre hole of approximately 55 mm diameter.

3.10 Swell gauge, consisting of a tripod and a suitable gauge, for example, a dial gauge with a resolution of 0.01 mm and a travel of 25 mm.

3.11 Balance of suitable capacity, having a resolution of at least 1 g and with a limit of performance within the range of ± 5 g.

3.12 Steel rammer, having a 50 mm diameter face. For standard compactive effort, the rammer shall have a drop mass of 2700 g and a drop height of 300 mm. For modified compactive effort, the rammer shall have a drop mass of 4900 g and a drop height of 450 mm.

3.13 Levelling plate, having a height of at least 20 mm and a diameter of 151 mm.

3.14 Sieves, 19.0 mm and 9.50 mm complying with AS 1152.

3.15 Water bath, of sufficient depth to immerse the moulded specimen in water.

3.16 Level and rigid foundation upon which to compact the specimen, for example, a 100 mm thick sound concrete floor or a concrete block of at least 100 kg mass.

3.17 Straightedge, made of steel and having the approximate dimensions of length 250 mm, width 25 mm and thickness 3 mm, preferably with a bevelled edge.

3.18 Sealable containers, suitable for curing soil samples.

3.19 Sample extruder, such as a jack, lever frame or other device suitable for extracting compacted soil specimens from the mould.

3.20 Material height gauge. A flat steel bar, about 250 mm long, 25 mm wide and 1-3 mm thick is satisfactory (Note 8.4).

3.21 Mixing apparatus, such as a tray, trowel or scoop and water sprayer.

4 Materials
The following materials are required:

4.1 Filter paper, a coarse filter paper such as Whatman No. 1.

4.2 Mould oil, a light mould oil such as Caltex Mould Oil 20 (Note 8.5).

5 Procedure
The procedure shall be as follows:

5.1 Sample Preparation

5.1.1 Prepare the bulk sample as detailed in Section 5 of Test Method Q101 to produce a representative subsample of appropriate size.

5.1.2 Further prepare the material by screening the subsample on a 19.0 mm sieve as detailed in Q101, Steps 6.2.1 to 6.2.3. Ensure that any aggregations are broken up to pass a 9.50 mm sieve.

5.1.3 Prepare representative test portions as follows:

a) One test portion for hygroscopic moisture content, and

b) The required number of test portions for compaction and determine the mass of each test portion \( m_i \) (Note 8.6).
5.1.4 Determine the hygroscopic moisture content \((w_i)\) of the test portion prepared in Step 5.1.3 a) as detailed in Test Method Q102A.

5.1.5 If the optimum moisture content (OMC) and maximum dry density (MDD) are not known, prepare and test additional test portions as detailed in the relevant test method from Test Methods Q142A or Q142B as appropriate (Note 8.7) using the specified curing time for the material (Table 3).

5.2 Curing

5.2.1 For each test portion calculate the dry mass of material as follows:

\[
m_2 = \frac{100m_1}{100+w_i}
\]

where 
- \(m_2\) = mass of dry material in test portion (g)
- \(m_1\) = mass of wet material in test portion (g)
- \(w_i\) = hygroscopic moisture content (%)

5.2.2 For each test portion calculate the mass of mixing water to be added as follows:

\[
m_3 = \frac{(m_2w_2)}{100} \cdot (m_1-m_2)
\]

where 
- \(m_3\) = mass of mixing water to be added (g)
- \(m_2\) = mass of dry material in test portion (g)
- \(w_2\) = target compaction moisture content (%)
- \(m_1\) = mass of wet material in test portion (g)

5.2.3 Measure out the required mass of mixing water to be added \((m_3)\).

5.2.4 Spread out the test portion on the mixing tray and add the mixing water to the material in small increments and combine thoroughly to form a uniform mixture (Note 8.8).

5.2.5 After mixing place the mixture into a curing container to cure for the specified period of time for the material (Table 3).

5.3 Compaction

5.3.1 Undertake all necessary calculations, mould preparation and compaction of the test portion as detailed in Test Method Q145A. For portions requiring standard compaction the test portion will be compacted in three layers. For portions requiring modified compaction the test portion will be compacted in five layers.

5.3.2 Where the compacted material is to be tested in the soaked condition, soak the compacted material as detailed in Subsection 5.4.

5.3.3 Where the compacted material is to be tested in the unsoaked condition, penetrate the compacted material as detailed in Subsection 5.5.
5.4 Soaking

5.4.1 Place a filter paper on the compacted material. Centrally locate the stem and perforated plate together with a soaking weight on the filter paper.

5.4.2 Obtain an initial reading at a marked reference point by placing the tripod of the swell gauge on the top of the mould so that the contact point of the dial gauge is in contact with the highest point of the stem. Record the dial gauge reading \( r_1 \) before removing the swell gauge.

5.4.3 Place the mould in the water bath, allowing free access of water to the top and bottom of the specimen. Soak the specimen for:

a) 96 ± 4 hours (Note 8.9), or
b) 240 ± 4 hours (Note 8.10)

with the water level being maintained above the mould during this period.

5.4.4 Take a final reading by locating the swell gauge in the same position as previously (Step 5.4.2) on top of the mould. Record the dial gauge reading \( r_2 \) before removing the swell gauge.

5.4.5 Remove the mould from the water bath and tilt the mould to pour off any excess water, then return it to the upright position and allow to drain for 15 minutes. Do not disturb the surface of the specimen during the removal of water.

5.4.6 Remove the soaking weight and stem and perforated plate from the mould.

5.4.7 Penetrate the specimen as detailed in Subsection 5.5.

5.5 Penetration

5.5.1 Centrally locate the two surcharge weights on the compacted sample in the mould.

5.5.2 Position the mould on the platen of the CBR machine so that the mould is located centrally under the penetration piston and the piston almost touches the surface of the material.

5.5.3 Zero the force measuring device indicator and seat the penetration piston by applying a force of about 45 N (Note 8.11).

5.5.4 Zero the force measuring device indicator and penetration gauge (Note 8.12).

5.5.5 Commence the penetration of the specimen and record the force measuring device indicator readings for every 0.5 mm penetration to a minimum penetration of 7.5 mm.

5.5.6 Remove the mould from the CBR machine, then remove the surcharge weights. Extrude the compacted soil from the mould and obtain any requested final moisture content (FMC) as follows:

a) For compacted material penetrated in the soaked condition:

i. Remove the filter papers and obtain a moisture sample to a depth of 30 mm from the end of the specimen which contains the penetration depression.

ii. Obtain a second moisture sample from a uniform section through the entire depth of the remainder of the specimen.

iii. Determine the moisture content (FMC) of each sample in accordance with Test Method Q102A.
b) For compacted material penetrated in the unsoaked condition:
   i. Obtain a moisture sample from a uniform section through the entire depth of the specimen.
   ii. Determine the moisture content (FMC) of the sample in accordance with Test Method Q102A.

6 Calculations

6.1 Calculate the achieved compacted dry density and achieved relative compaction as detailed in Test Method Q145A.

6.2 Compare the achieved compacted dry density and target compacted dry density and if they differ by more than 0.020 t/m³, repeat the test.

6.3 Calculate the achieved compaction moisture content and the achieved percentage of OMC as detailed in Test Method Q145A.

6.4 Compare the achieved compaction moisture content and the target compaction moisture content and if they differ by more than 1.0%, repeat the test.

6.5 If the measurement of swell is required (Note 8.10), calculate as follows:

\[ S = \frac{r_2 - r_1}{117} \times 100 \]

where
- \( S \) = swell (%)
- \( r_2 \) = final dial gauge reading (mm)
- \( r_1 \) = initial dial gauge reading (mm)

6.6 Calculate the bearing ratio at 2.5 mm and 5.0 mm penetration as follows:

6.6.1 Convert the force indicator readings to applied forces in newtons using the appropriate calibration for the force measuring device (Note 8.13).

6.6.2 Plot the applied forces against the corresponding penetration values and draw a smooth curve through the points.

6.6.3 When the force-penetration curve commences with a concave upward portion (refer to Figure 1 and Note 8.14), adjust the penetration scale as follows:

a) Draw a tangent through the steepest part of the curve so as to intersect the penetration axis.

b) The intercept with the penetration (x) axis shall be the new origin provided that its value does not exceed 0.5 mm.

c) Where the intercept exceeds 0.5 mm, the new origin shall be 0.5 mm.

d) Adjust the 2.5 mm and 5.0 mm values in relation to the re-designated origin.

6.6.4 Determine the values of applied force (\( f_{2.5} \) and \( f_{5.0} \)) corresponding to the adjusted 2.5 mm and 5.0 mm penetrations.
6.6.5 Calculate the bearing ratio at 2.5 mm and 5.0 mm penetrations and record these ratios as \( \text{CBR}_{2.5} \) and \( \text{CBR}_{5.0} \) as follows:

\[
\text{CBR}_{2.5} = \frac{f_{2.5} \times 100}{13200} \\
\text{CBR}_{5.0} = \frac{f_{5.0} \times 100}{19800}
\]

where \( \text{CBR}_{2.5} \) = California Bearing Ratio corresponding to 2.5 mm penetration

\( \text{CBR}_{5.0} \) = California Bearing Ratio corresponding to 5.0 mm penetration

\( f_{2.5} \) = applied force corresponding to 2.5 mm penetration (N)

\( f_{5.0} \) = applied force corresponding to 5.0 mm penetration (N)

7 Reporting

Report the following values:

7.1 The target compacted dry density to the nearest 0.001 t/m³ and if required the nominated relative compaction to the nearest 0.1%.

7.2 The target compaction moisture content to the nearest 0.1% and if required the nominated relative moisture content as a percentage of OMC to the nearest 1%.

7.3 The achieved compacted dry density and compaction moisture content as detailed in Test Method Q145A.

7.4 If required, the achieved relative compaction and achieved percentage of OMC content as detailed in Test Method Q145A.

7.5 \( \text{CBR}_{2.5} \) and \( \text{CBR}_{5.0} \) (refer to Table 4).

7.6 The material CBR value which is the largest numerical value of either \( \text{CBR}_{2.5} \) or \( \text{CBR}_{5.0} \) (refer to Table 4).

7.7 Test condition, that is, soaked or unsoaked.

7.8 Duration of soaking, that is, 4 or 10 days.

7.9 Swell to the nearest 0.1% for values less than 10%, otherwise to the nearest 1%.

7.10 Moisture content after penetration of the penetrated end of the specimen and the moisture content of the remainder of any soaked specimen.

7.11 Moisture content after penetration for any unsoaked specimen.

7.12 The force-penetration graph of the specimen (optional).

8 Notes on method

8.1 This force measuring device must be calibrated over its complete operating range. This will require further points near to zero in addition to those required by AS 2193.
8.2 A force measuring device is to be used which is at least Class C as defined in AS 2193 for that part of its operating range which corresponds to the forces required to produce plunger penetrations of 2.5 mm and greater.

8.3 Where a device such as a load transducer is used to measure the applied force, the penetration gauge may be affixed to the frame of the machine.

8.4 A material height gauge, which allows monitoring of the height of compacted material relative to the top of a CBR mould, can be made from a steel bar as follows:

8.4.1 CBR Mould – Standard (Std) compaction.

Commencing at one end of the bar, measure and mark distances of:
- a) 39 mm and 34 mm for the acceptable range of the second layer, and
- b) 78 mm and 73 mm for the acceptable range of the first layer.

8.4.2 CBR Mould – Modified (Mod) compaction.

Commencing at one end of the bar, measure and mark distances of:
- a) 20 mm and 25 mm for the acceptable range of the fourth layer,
- b) 50 mm and 45 mm for the acceptable range of the third layer,
- c) 72 mm and 67 mm for the acceptable range of the second layer, and
- d) 96 mm and 91 mm for the acceptable range of the first layer.

8.4.3 Mark each face with the appropriate compactive effort (Std or Mod).

8.5 Before handling oils, the operator must consult the relevant Safety Data Sheet (SDS).

8.6 As a guide, the size of the compaction test portions can vary from 5500 g for a clay to 7000 g for a gravel.

8.7 If required for this test determine the optimum moisture content and maximum dry density as detailed in Test Methods Q142A or Q142B using passing 19.0 mm material and a Type A mould.

8.8 It is important that water is thoroughly mixed into the material and the test portion cured for sufficient time to allow the water to become evenly distributed throughout the material.

8.9 If the soaking period is not specified, then 96 hours should be used.

8.10 The 10 day (240 hours) soaked conditions and swell measurement are specified by the Department of Transport and Main Roads, *Pavement Design Manual*, Section 5, January 2009.

8.11 In some very weak materials where the seating load causes significant penetration, this step can be omitted. However, this variation to the method must be reported.

8.12 Where zeroing the force measuring device indicator will invalidate the calibration of the device, do not zero the indicator but record the reading as the seating deflection.

8.13 Where the force measuring device indicator was not zeroed after the application of the seating load, convert the seating deflection to applied force in newtons and subtract this value from each of the calculated values of applied force.

8.14 This characteristic may be due to surface irregularities, material behaviour or other causes.
### Table 1 – Dimensions and tolerances for CBR equipment

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Dimension</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CBR machine</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Platen travel rate – loaded (mm/min)</td>
<td>1</td>
<td>± 0.2</td>
</tr>
<tr>
<td><strong>Penetration piston</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter (mm)</td>
<td>49.6</td>
<td>± 0.1</td>
</tr>
<tr>
<td><strong>Mould</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal diameter (mm)</td>
<td>152</td>
<td>± 1</td>
</tr>
<tr>
<td>Height (mm)</td>
<td>178</td>
<td>± 1</td>
</tr>
<tr>
<td><strong>Perforated baseplate</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hole number</td>
<td>28</td>
<td>+5, -0</td>
</tr>
<tr>
<td>Hole diameter (mm)</td>
<td>3</td>
<td>± 0.2</td>
</tr>
<tr>
<td><strong>Spacer disc</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter (mm)</td>
<td>150</td>
<td>± 0.5</td>
</tr>
<tr>
<td>Height (mm)</td>
<td>61</td>
<td>± 0.25</td>
</tr>
<tr>
<td><strong>Stem and perforated plate</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter (mm)</td>
<td>150</td>
<td>± 0.5</td>
</tr>
<tr>
<td>Mass (g)</td>
<td>1000</td>
<td>± 25</td>
</tr>
<tr>
<td>Hole number</td>
<td>42</td>
<td>± 0</td>
</tr>
<tr>
<td>Hole diameter (mm)</td>
<td>3</td>
<td>± 0.2</td>
</tr>
<tr>
<td><strong>Soaking weight</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass (g)</td>
<td>4500</td>
<td>± 50</td>
</tr>
<tr>
<td><strong>Surcharge weight</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass (g)</td>
<td>2250</td>
<td>± 25</td>
</tr>
<tr>
<td>Diameter (mm)</td>
<td>150</td>
<td>± 0.5</td>
</tr>
<tr>
<td><strong>Levelling plate</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter (mm)</td>
<td>151</td>
<td>0, -1</td>
</tr>
<tr>
<td>Height (mm)</td>
<td>20</td>
<td>minimum</td>
</tr>
</tbody>
</table>

### Table 2 – Dimensions and tolerances for rammers

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Dimension</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rammer – standard</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Face diameter (mm)</td>
<td>50</td>
<td>± 0.4</td>
</tr>
<tr>
<td>Drop (mm)</td>
<td>300</td>
<td>± 2.0</td>
</tr>
<tr>
<td>Mass (g)</td>
<td>2700</td>
<td>± 10</td>
</tr>
</tbody>
</table>
Table 3 – Minimum curing time

<table>
<thead>
<tr>
<th>Plasticity</th>
<th>Minimum curing time (hours)</th>
<th>Sample moisture content within $\omega_2 \pm 2%$</th>
<th>Sample moisture content outside $\omega_2 \pm 2%$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sands and unbound material*</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Low (LL ≤ 35%)</td>
<td>24</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>Medium (35 &lt; LL ≤ 50%)</td>
<td>48</td>
<td>96 (4 days)</td>
<td></td>
</tr>
<tr>
<td>High (LL &gt; 50%)</td>
<td>96 (4 days)</td>
<td>168 (7 days)</td>
<td></td>
</tr>
</tbody>
</table>

* These can include naturally occurring sands and gravels, crushed rocks and manufactured materials with a fines (< 0.075 mm) content less than 12%.

LL = Liquid limit, $\omega_2$ = target compaction moisture content.

Table 4 – Reporting intervals for CBR values

<table>
<thead>
<tr>
<th>CBR value</th>
<th>Reporting interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1</td>
<td>nearest 0.2 units</td>
</tr>
<tr>
<td>1 to 10</td>
<td>nearest 0.5 units</td>
</tr>
<tr>
<td>11 to 30</td>
<td>nearest 1 unit</td>
</tr>
<tr>
<td>31 to 120</td>
<td>nearest 2 units</td>
</tr>
<tr>
<td>&gt; 120</td>
<td>nearest 5 units</td>
</tr>
</tbody>
</table>

Superseded
Figure 1 – Typical force – penetration curves showing the determination of new penetration origins

No concave upward portion hence no new penetration origin

New penetration origin at 0.2mm

New penetration origin at 0.5mm (since intercept with X axis exceeds 0.0mm) and consequent adjustments to penetration scale.
Test Method Q114B: Insitu California Bearing Ratio - dynamic cone penetrometer

1 Source

This method is based on AS 1289.6.3.2: Soil strength and consolidation tests - Determination of the penetration resistance of a soil – 9 kg dynamic cone penetrometer test. There are some minor procedural differences and the results are converted to California Bearing Ratio (CBR) values rather than number of blows per 25 mm.


2 Scope

This method sets out the procedure to determine the insitu California Bearing Ratio of soils and fine crushed rock. The method has particular application for fine grained materials since the presence of rock particles, 6 mm and larger, may interfere with the test.

The test gives a continuous record of bearing value with depth below an existing surface, usually without the need to excavate to the depth at which the readings are required.

3 Apparatus

Where appropriate, the working tolerances of particular apparatus are contained in Table 1. The following apparatus is required:

3.1 Standard dynamic cone penetrometer consisting of three (3) parts as follows (refer to Figure 1):

3.1.1 Sliding drop hammer, with a mass of 9000 g and a free vertical fall of 510 mm on a 16 mm diameter shaft fitted with a stop and anvil. The travel of the drop hammer must be checked before each test to ensure the correct drop height is maintained.

3.1.2 Steel rod(s), 16 mm diameter and not exceeding 1500 mm in length that attach securely to the anvil.

3.1.3 Hardened steel cone, with a 30° included angle which must attach securely to the steel rod and have a diameter of 20 mm.

3.2 Extractor, such as a modified vehicle jack.

3.3 Displacement measuring device, with a resolution not exceeding 1 mm.

4 Test site preparation

4.1 Remove any loose material and vegetation from around the test site to create a flat and level surface to undertake the test and measure the penetration of the steel cone.

4.2 Where there is an overlying layer of clay, silt, sand or fine gravel up to 6 mm in particle size, it is possible to test through the layer.

4.3 Where there is an overlying layer of medium gravel or other coarser material, excavate a hole in the overlying layer of sufficient size to perform the test.
5 Test procedure

The procedure shall be as follows:

5.1 Holding the penetrometer vertically, seat the cone such that the widest part of the cone is embedded to a depth of 50 mm using part hammer drops if needed (refer to Figure 1). Zero the displacement measuring device or take a zero reading.

5.2 Drive the cone into the ground by raising the hammer to the stop and allowing it to fall freely striking the anvil. Record the penetration to the nearest millimetre, ensuring the displacement measuring device remains vertical.

5.3 Repeat Step 5.2 until either:

5.3.1 required depth is achieved, or
5.3.2 full length of rod(s) is used, or
5.3.3 eight consecutive full hammer drops give a cumulative penetration less than 20 mm.

5.4 At the completion of the test, remove the steel rod and cone using the extractor jack. Back hammering must not be used to remove the steel rod and cone as this may alter the drop height.

5.5 If required, obtain a sample of the soil and determine the moisture content as detailed in Test Method Q102A or record the moisture condition of the soil.

6 Calculations

Calculate the equivalent California Bearing Ratio value as follows:

6.1 Plot the penetration (mm) against number of hammer blows.

6.2 Analyse the penetration against number of hammer blows plot to identify the layers present and determine for each layer the following (Note 8.1):

6.2.1 the number of the first blow \( a \) \( N_a \) and penetration recorded \( a \) \( P_a \) for the layer, and
6.2.2 the number of the final blow \( b \) \( N_b \) and penetration recorded \( b \) \( P_b \) for the layer.

6.3 Determine the average penetration rate \( r \) for each layer as follows:

\[
r = \frac{(P_b - P_a)}{(N_b - N_a)}
\]

where

- \( r \) = average penetration rate (mm/blow)
- \( P_b \) = penetration recorded at blow \( b \) (mm)
- \( P_a \) = penetration recorded at blow \( a \) (mm)
- \( N_b \) = number of the final blow \( b \) for the layer
- \( N_a \) = number of the first blow \( a \) for the layer
6.4 Calculate the equivalent California Bearing Ratio value for each layer as follows:

\[
CBR = 10^{0.881 + 1.16 \log_{10} \left( \frac{25}{r} \right)}
\]

where \( CBR \) = equivalent California Bearing Ratio value
\( r \) = average penetration rate (mm/blow)

7 Reporting

The following shall be reported:

7.1 Reference point for all layer measurements, such as the surface.
7.2 Depth from the reference point for the start and end of each layer.
7.3 Thickness of each layer (mm), if required.
7.4 Equivalent California Bearing Ratio (CBR) value for each layer rounded to the reporting interval detailed in Table 2.
7.5 Moisture content of the soil or the moisture condition of the soil, that is, wet, moist or dry, if required.

8 Notes on method

8.1 Where multiple layers are identified, the final blow and penetration recorded for the upper layer will be the same as the initial blow and penetration for the lower layer.

Table 1 – Working tolerances for apparatus

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Dimension</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sliding drop hammer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass (g)</td>
<td>9000</td>
<td>± 100</td>
</tr>
<tr>
<td>Free vertical fall (mm)</td>
<td>510</td>
<td>± 5</td>
</tr>
<tr>
<td>Steel rods</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length (mm)</td>
<td>1500</td>
<td>Maximum</td>
</tr>
<tr>
<td>Cone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cone angle (°)</td>
<td>30</td>
<td>-</td>
</tr>
<tr>
<td>Maximum diameter (mm)</td>
<td>20</td>
<td>± 0.2</td>
</tr>
</tbody>
</table>

Table 2 – Reporting intervals for CBR values

<table>
<thead>
<tr>
<th>CBR value</th>
<th>Reporting interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1</td>
<td>nearest 0.2 units</td>
</tr>
<tr>
<td>1 to 10</td>
<td>nearest 0.5 units</td>
</tr>
<tr>
<td>11 to 30</td>
<td>nearest 1 unit</td>
</tr>
<tr>
<td>31 to 60</td>
<td>nearest 2 units</td>
</tr>
<tr>
<td>&gt; 60</td>
<td>report as &gt; 60</td>
</tr>
</tbody>
</table>
Figure 1 – Assembled dynamic cone penetrometer
Test Method Q115: Unconfined compressive strength of stabilised materials

1 Source

This method was developed in-house using techniques evolved through internal departmental research investigations.

2 Scope

This method describes the procedure to determine the unconfined compressive strength (UCS) of compacted specimens of soils and crushed rock which have been either modified or stabilised with a stabilising agent or are in their natural state. The method has particular application as a laboratory design procedure but can also be used to test field-moulded specimens in order to check field processes.

In the laboratory, test specimens may be prepared by compacting passing 19.0 mm material by standard or modified compactive effort or to a nominated dry density and moisture content, as detailed in Test Method Q145A. Where density/moisture parameters are not directly specified, standard compactive effort is to be used.

In the field, test specimens are prepared by compacting passing 19.0 mm material using standard or modified compactive effort as required by the governing specifications.

This method may also be used to test core specimens removed from a stabilised material by dry coring.

3 Apparatus

Where appropriate, the working tolerances of particular apparatus are contained in Tables 1 and 2.

The following apparatus is required:

3.1 Mould assembly (Mould A), comprising a cylindrical metal mould having an internal diameter of 105 mm and an effective height of 115.5 mm, fitted with a detachable baseplate and a removable collar assembly about 60 mm high, both of which can be firmly attached to the mould.

3.2 Steel rammer or alternatively, a mechanical compactor may be used provided that it meets the essential requirements of drop height, mass and energy input (Note 12.1).

3.3 Level rigid foundation on which to compact the specimen, for example a sound concrete floor about 100 mm or more in thickness or a concrete block of at least 100 kg mass.

3.4 Balances:

3.4.1 Balance of suitable capacity, with a resolution of at least 1 g and with a limit of performance within the range of ± 5 g.

3.4.2 Balance of suitable capacity to weigh stabilising agents, with a resolution of at least 0.1 g and with a limit of performance within the range of ± 0.5 g (Note 12.2).

3.5 Sieve, 19.0 mm and 9.50 mm complying with AS 1152.

3.6 Material height gauge. A flat steel bar, about 250 mm long, 25 mm wide and 1-3 mm thick is satisfactory (Note 12.3).

3.7 Levelling plate, a steel plate having a diameter of about 104 mm and a height of about 20 mm.
3.8 Steel straightedge, about 250 mm long, 25 mm wide and 3 mm thick, preferably with one bevelled edge.

3.9 Mallet, a rubber mallet with a face of 75 mm diameter and a mass of 1000 g.

3.10 Sample extractor, such as a jack, lever frame or other suitable device for extruding compacted specimens from the mould.

3.11 Calliper, with a resolution not exceeding 0.1 mm and complying with AS 1984 or JIS B 7507.

3.12 Capping jig, suited to 105 mm diameter specimens and complying with the requirements of AS 1012.9.

3.13 CBR machine, fitted with a moveable lower platen which travels at a uniform vertical upward rate of 1 mm/min when measured loaded and with an upper platen which has a spherical seat.

3.14 Force measuring device, at least Class C as defined in AS 2193 for that part of its operating range which corresponds to the maximum force applied to any test specimen. It shall be equipped with an indicator of a resolution not exceeding 25 N.

3.15 Engineer’s square, with a minimum blade length of 100 mm.

3.16 Steel rule.

4 Materials

The following materials are required:

4.1 Capping compound, special high-strength cementitious material such as dental plaster or a low heat mortar (Note 12.4).

4.2 Mould oil, a light oil such as Caltex Mould Oil 20 (Note 12.4).

5 Sample preparation

5.1 Laboratory mixing

5.1.1 Prepare the bulk sample as detailed in Section 5 of Test Method Q101 to produce a representative subsample of appropriate size. It may be necessary to partially dry the bulk sample before preparation so that the material is sufficiently dry to allow uniform mixing of the stabilising agent with the host material.

5.1.2 Screen the subsample on the 19.0 mm sieve as detailed in Test Method Q101, Steps 6.2.1 to 6.2.3, ensuring that any aggregations are broken up to pass a 9.50 mm sieve.

5.1.3 Split out a UCS compaction test portion for each stabilising agent content as well as a single test portion for determining hygroscopic moisture content as detailed in Test Method Q101, Steps 6.2.4 to 6.2.6. Each UCS compaction test portion must be of sufficient quantity to mould three specimens and provide a subsample for determining the compaction moisture content (Note 12.5).

5.1.4 Where the UCS moulding moisture content and dry density are not specified, prepare sufficient additional test portions to undertake dry density/moisture relationship (MDR) testing as detailed in Test Method Q142A or Q142B as appropriate, as indicated in Table 3 (Note 12.6).

5.2 Field mixing

5.2.1 Sample the field mixed material as soon as possible after the completion of mixing and seal the bulk sample in an airtight container for transport to the moulding location.
5.2.2  Screen the sample on a 19.0 mm sieve as detailed in Test Method Q101, Steps 6.2.1 to 6.2.3, ensuring moisture loss is minimised.

5.2.3  Split out a UCS compaction test portion, as detailed in Test Method Q101, Steps 6.2.4 to 6.2.6, of sufficient quantity to compact three specimens and provide a subsample for determining the compaction moisture content (Note 12.5).

5.2.4  Place the test portion in an airtight container and put aside to precondition for 45 minutes, timed from when field mixing was commenced.

5.3  Core specimens

5.3.1  Obtain at least three core samples about 100 mm diameter as detailed in Test Method Q070.

5.3.2  Prepare the core samples as detailed in Q303A Subsection 4.2 without air-drying to obtain three specimens with a height/diameter ratio of at least 1.1 for testing (Note 12.7).

5.3.3  Cap and test the specimens as detailed in Sections 8 and 9.

6  Moulding

6.1  Laboratory mixed material

6.1.1  Determine the maximum dry density (MDD) and optimum moisture content (OMC) as detailed in Test Method Q142A or Q142B (Mould A) for each stabilising agent content identified at Step 5.1.4.

6.1.2  Where multiple MDR tests are performed using stabilising agent contents greater than zero percent, analyse these results as follows:
   a)  Plot separately MDD and OMC against stabilising agent content. Draw a line or curve of best fit through each plot.
   b)  Repeat any MDR test where its result is erratic within the set.
   c)  Interpolate values of dry density and moisture content from the respective plots to obtain the compaction dry density and compaction moisture content for each stabilising agent content to be used in the testing program.

6.1.3  Determine the quantity of stabilising agent, then mix and condition each UCS compaction test portion as detailed in Test Method Q135A (Notes 12.8 and 12.9).

6.1.4  Using the procedure detailed in Test Method Q145A, calculate the mass of wet mixture per layer, determine the achieved compaction moisture content, then mould three specimens, compacting each in three equal layers. Compaction must be completed within 65 minutes, timed from when the mixing water was first added to the mixture of host material and stabilising agent.

6.2  Field mixed material

6.2.1  Clean and assemble each mould and baseplate, lightly oiling the internal surfaces. Inspect and clean the rammer or mechanical compactor and ensure that it is free in the guide.

6.2.2  Determine the mass \( m_1 \) of each mould and baseplate, attach the collars and place the assemblies on the rigid foundation.

6.2.3  At the end of the required conditioning period, spread the test portion on the mixing tray and thoroughly remix.
6.2.4 Obtain a subsample of the mixture and determine the achieved compaction moisture content as detailed in Test Method Q102A.

6.2.5 Mould the three specimens simultaneously in three equal layers using 25 rammer blows per layer for standard compaction or 42 rammer blows per layer for modified compaction, distributing the blows evenly over the surface of each layer. Simultaneous compaction is achieved by compacting the same layer in each mould one after the other. Compaction must be completed within 65 minutes, timed from when the mixing water was added to the mixture of the host material and stabilising agent.

6.2.6 For each mould, free the material from around the collar of the mould assembly, then carefully remove the collar.

6.2.7 Level the compacted specimens to the top of their respective mould using a straightedge. Employ the straightedge to patch any hollows developed in the surface using smaller sized material.

6.2.8 Determine the mass \( (m_2) \) of each mould, baseplate and compacted material.

7 Demoulding and curing

7.1 At the completion of moulding, demould any specimens which were compacted using the host material only. These specimens are ready for capping and testing. Where there is any delay in testing, seal the specimens in plastic wrapping to prevent moisture loss.

7.2 For specimens containing stabilising agent, demould and cure these as detailed in Test Method Q135B.

8 Capping

8.1 At the end of the specified curing period, examine the condition of each specimen and cap any specimen end which meets one or more of the following criteria:

8.1.1 The surface was not levelled using the straightedge at Step 6.2.7.

8.1.2 The end is more than 2 degrees out of square with the longitudinal axis.

8.1.3 Edge breaks, small depressions or other irregularities exist which, when considered together, would cause the force to be applied over 90 percent or less of the surface area.

8.2 Remove surface water from any end to be capped and apply a thin cap of capping compound using the capping jig.

8.3 Allow each cap to harden for 1 hour after capping. To minimise moisture loss from the specimen, either cover the exposed surfaces with plastic wrapping or place the specimen in a sealed container.

9 Testing

9.1 Determine the average diameter (D) of each test specimen to the nearest 0.1 mm from two diameters measured at right angles to each other.

9.2 For core specimens, determine the height (h) of each test specimen to the nearest 1 mm.

9.3 Place the test specimen centrally on the lower platen of the CBR machine such that the top of the specimen is uppermost.

9.4 Apply a compressive force to the specimen and record the maximum applied force (F) in kN.
10 Calculations

10.1 For all specimens:

10.1.1 Calculate the unconfined compressive strength for each specimen to the nearest 0.05 MPa as follows:

\[ UCS = \frac{1273F}{D^2} \]

where

- \( UCS \) = unconfined compressive strength (MPa)
- \( F \) = applied force at failure (kN)
- \( D \) = average specimen diameter (mm)

10.1.2 Calculate the average unconfined compressive strength to the nearest 0.05 MPa.

10.2 For laboratory mixed material:

10.2.1 Using the achieved compaction moisture content, calculate the achieved compacted dry density and the achieved relative compaction for each specimen as detailed in Test Method Q145A.

10.3 For core specimens:

10.3.1 Calculate the correction factor for each specimen as follows:

\[ f_c = -0.42 + 2.83x + 2.233x^2 + 0.8x^3 - 0.1067x^4 \]

where

- \( f_c \) = correction factor for the specimen height/diameter ratio
- \( x \) = specimen height/diameter ratio

10.3.2 Calculate the corrected unconfined compressive strength for each specimen as follows (Note 12.10):

\[ UCS_c = \frac{UCS}{0.899296} \]

where

- \( UCS_c \) = corrected unconfined compressive strength (MPa)
- \( UCS \) = unconfined compressive strength (MPa)
- \( f_c \) = correction factor for the specimen height/diameter ratio

10.3.3 Calculate the average corrected unconfined compressive strength to the nearest 0.05 MPa.

11 Reporting

Report the following values and general information:

11.1 General information:

a) Source and description of the host material.

b) Source, type and quantity of the stabilising agent(s).

c) Sample type (that is, laboratory mixed, field mixed or cores).
11.2 For laboratory mixed material:
   a) Target compacted dry density, achieved compacted dry density, achieved relative compaction, target compaction moisture content, achieved compaction moisture content and achieved percentage of OMC as detailed in Test Method Q145A.
   b) Compaction standard used, that is standard or modified
   c) UCS of each specimen and the average UCS to the nearest 0.1 MPa (Note 12.11).
   d) A plot of average UCS versus stabilising agent content.

11.3 For field mixed material:
   a) UCS of each specimen and the average UCS to the nearest 0.1 MPa (Note 12.11).

11.4 For core specimens:
   a) Specimen diameter to the nearest 0.1 mm.
   b) Specimen height to the nearest 1 mm.
   c) UCS of each specimen to the nearest 0.1 MPa (Note 12.11).
   d) Corrected UCS of each specimen and the average corrected UCS to the nearest 0.1 MPa (Note 12.11).

12 Notes on method

12.1 A mechanical form of apparatus may be used provided the essential dimensions are adhered to and the rammer has a free vertical fall of the correct height with blows being uniformly distributed and in keeping with any prescribed cycle of blows. It is also essential that the design of the machine is such that the mould can be attached to a level and rigid support base.

12.2 The balance referred to is suitable for most applications where stabilising agent is being added to the material. The balance used must have a resolution which displays to one significant figure more than the mass being weighed and a limit of performance commensurate with the resolution.

12.3 A material height gauge which allows monitoring of the height of compacted material relative to the top of a Mould A can be made from a steel bar and marked as follows:

12.3.1 Commencing at one end of the bar, measure and mark distances of:
   a) 5.5 mm for the upper range of the third layer
   b) 33.5 to 38.5 mm for the acceptable range of the second layer, and
   c) 72.5 to 77.5 mm for the acceptable range of the first layer.

12.3.2 Mark the face with the appropriate mould size (A).

12.4 Before handling capping compounds or oil, the operator must consult the relevant Safety Data Sheet (SDS).
12.5 A test portion mass of 10 kg will be adequate for determining UCS for most materials. A gravel may, however, require up to 12 kg while it may be possible to use as low as 8 kg for a heavy clay.

12.6 Usually four test portions are sufficient for each Q142A or Q142B test. For most materials, 2.5 kg should be adequate for each test portion mass. A gravel may, however, require up to 3 kg while it may be possible to use as low as 2 kg for a heavy clay.

12.7 Usually UCS specimens are compacted in a Mould A to produce specimens with a height/diameter ratio of 1.1 (115/105). Cores with the same height/diameter ratio will produce comparable results to traditional UCS specimens when tested.

12.8 When mixing and conditioning more than one test portion, the work must be sequenced such that both the time for conditioning and the time to completion of compaction are recognised. These times are measured from when the first increment of water is added to the mixture of material and stabilising agent.

12.9 Test portions which do not contain stabilising agents are to be compacted at the completion of mixing the material and water.

12.10 The value of 0.899296 is calculated using the height/diameter relationship for a height/diameter ratio of 1.1.

12.11 When the UCS value of one specimen is at variance with the other two specimens, report the average of two specimens, annotating the report accordingly.

### Table 1 – Dimensions and tolerances of compaction apparatus

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Dimension</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mould A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal diameter (mm)</td>
<td>105.0</td>
<td>± 0.5*</td>
</tr>
<tr>
<td>Height (mm)</td>
<td>115.5</td>
<td>± 0.5*</td>
</tr>
<tr>
<td>Nominal volume (cm³)</td>
<td>1000</td>
<td>± 15</td>
</tr>
<tr>
<td>Rammer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter; round foot (mm)</td>
<td>50</td>
<td>± 0.4</td>
</tr>
<tr>
<td>Area of rammer (mm²)</td>
<td>1964</td>
<td>± 31</td>
</tr>
<tr>
<td>Standard Compaction (Mould A)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drop (mm)</td>
<td>300</td>
<td>± 2.0 ‡</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>2.7</td>
<td>± 0.01 ‡</td>
</tr>
<tr>
<td>Energy delivered per blow (J)</td>
<td>7.94</td>
<td>± 0.08</td>
</tr>
<tr>
<td>Number of layers</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Number of blows/layer</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Energy input (kJ/m³)</td>
<td>596</td>
<td>± 14</td>
</tr>
<tr>
<td>Modified Compaction (Mould A)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drop (mm)</td>
<td>450</td>
<td>± 2.0 ‡</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>4.9</td>
<td>± 0.01 ‡</td>
</tr>
<tr>
<td>Energy delivered per blow (J)</td>
<td>21.62</td>
<td>± 0.08</td>
</tr>
<tr>
<td>Number of layers</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>
### Test Method Q115: Unconfined compressive strength of stabilised materials

<table>
<thead>
<tr>
<th>Apparatus Dimension Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of blows/layer</td>
</tr>
<tr>
<td>Energy input (kJ/m³)</td>
</tr>
</tbody>
</table>

* Either but not both of the tolerances may be exceeded provided that the specified tolerance on volume is not exceeded.
‡ Either but not both of the tolerances may be exceeded provided that the appropriate tolerance on energy delivered per blow is not exceeded.

**Table 2 – Dimensions and tolerances of testing apparatus**

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Dimension</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBR Machine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Platen travel rate – loaded (mm/min)</td>
<td>1</td>
<td>± 0.2</td>
</tr>
</tbody>
</table>

**Table 3 – Requirements for dry density/moisture relationship (MDR) tests**

<table>
<thead>
<tr>
<th>Design range in stabilising agent</th>
<th>MDR test requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material Only</td>
<td>1 test at 0% stabilising agent</td>
</tr>
<tr>
<td>Design Range ≤ 4%</td>
<td>1 test at 0% stabilising agent, if applicable</td>
</tr>
<tr>
<td></td>
<td>1 test at the central stabilising agent content</td>
</tr>
<tr>
<td>Design Range &gt; 4%</td>
<td>1 test at 0% stabilising agent, if applicable</td>
</tr>
<tr>
<td></td>
<td>1 test at the lowest stabilising agent content</td>
</tr>
<tr>
<td></td>
<td>1 test at the central stabilising agent content</td>
</tr>
<tr>
<td></td>
<td>1 test at the highest stabilising agent content</td>
</tr>
</tbody>
</table>
Test Method Q116A: Cement content of stabilised material - EDTA titration

This test shall be performed in accordance with AS 5101.3.2: Lime or cement content of stabilized pavement materials (EDTA method).
Test Method Q118: Bitumen content of stabilised material

1 Source
This method applies the principles of AS 2891.3.1: Bitumen content and aggregate grading - Reflux method.

2 Scope
This method describes the procedure for the determination of the bitumen content of a bitumen stabilised material by solvent extraction.

3 Apparatus
Where appropriate, the working tolerances of particular apparatus are contained in Table 1. The following apparatus is required:

3.1 Balances:
3.1.1 Balance of suitable capacity, with a resolution of at least 0.1 g and with a limit of performance within the range of ± 0.5 g.
3.1.2 Balance of suitable capacity, with a resolution of at least 0.001 g and with a limit of performance within the range of ± 0.005 g.
3.2 Centrifuge, an electric centrifuge capable of holding at least two 15 mL aliquots.
3.3 Hotplate, capable of maintaining a temperature of 305ºC (Note 8.1).
3.4 Fume cupboard.
3.5 Flask, conical flask of 2 L capacity with a ground glass neck of at least 55 mm diameter and fitted with a stopper.
3.6 Condenser, double surface condenser to fit the neck of the flask.
3.7 Beaker, of at least 100 mL capacity.
3.8 Containers, two flat-bottomed aluminium containers of approximate dimensions 100 mm diameter and 75 mm depth and equipped with tightly fitting slip-on lids.
3.9 Sieve, 2.36 mm complying with AS 1152.
3.10 Sieve brush.
3.11 Steel mortar and rubber pestle.

4 Materials
The following materials are required:

4.1 Solvent, toluene commercial grade (Notes 8.1 and 8.2).

5 Procedure
The test procedure shall be as follows:

5.1 Prepare a bulk sample as detailed in Section 5 of Test Method Q101 to produce a representative subsample of about 1200 g.
5.2 Sieve the test portion over a 2.36 mm sieve.
5.3 Transfer the material retained on the 2.36 mm sieve to a mortar and grind with a rubber pestle to break up any soil aggregations.

5.4 Sieve the ground sample over the 2.36 mm sieve.

5.5 Continue the sieving and grinding cycle in Steps 5.3 and 5.4 until only clean aggregate is retained on the 2.36 mm sieve.

5.6 Remix the material retained on the 2.36 mm sieve and the material passing the 2.36 mm sieve.

5.7 Weigh the flask with stopper and record the mass to the nearest 0.1 g (m_1).

5.8 With the flask held at an angle of about 45 degrees, transfer the test portion to the flask. Weigh the flask with stopper and record the mass to the nearest 0.1 g (m_2).

5.9 Add a quantity of solvent to the flask at least equivalent in mass to the mass of the test portion.

5.10 Fit the reflux condenser to the flask and gently warm the flask and contents on the hotplate in the fume cupboard to dissolve the bitumen (Note 8.3). Shake the flask frequently during this refluxing operation to prevent bitumen from caking on the bottom of the flask.

5.11 Allow the flask to cool to room temperature with the condenser still in position. Remove the condenser and fit the stopper.

5.12 Weigh the flask and stopper and record the mass to the nearest 0.1 g (m_3).

5.13 Perform the following procedure on two aliquots:

5.13.1 Using the beaker, transfer an aliquot of at least 15 mL of the solution from the flask to the centrifuge tube(s). Stopper the tube(s) immediately and centrifuge to separate any suspended mineral matter.

5.13.2 Weigh a container with lid and record the mass to the nearest 0.001 g (m_4).

5.13.3 Pour the supernatant liquid from the centrifuge tube(s) into the container, taking care not to disturb the settled mineral matter, and fit the lid. Weigh the container immediately and record the mass to the nearest 0.001 g (m_5).

5.13.4 Remove the lid and place the container on the hotplate maintained at a temperature of 305 ± 10°C in the fume cupboard to evaporate the solvent. Continue the heating for two minutes after fumes are first seen to rise from the bitumen (Note 8.4).

5.13.5 Remove the container from the hotplate, replace the lid and allow the container to cool to room temperature.

5.13.6 Weigh the container and lid and record the mass to the nearest 0.001 g (m_6).

6 Calculations

6.1 Calculate the bitumen content based on each aliquot to the nearest 0.01% as follows:

\[ B_a = \frac{(m_1 - m_2)(m_6 - m_4)100}{(m_5 - m_6)(m_2 - m_1)} \]

where \( B_a \) = bitumen content based on one aliquot (%)
\[ \begin{align*}
    m_3 &= \text{mass of flask and stopper, test portion and solvent (g)} \\
    m_2 &= \text{mass of flask and stopper and test portion (g)} \\
    m_6 &= \text{mass of container and lid and bitumen (g)} \\
    m_4 &= \text{mass of container and lid (g)} \\
    m_5 &= \text{mass of container and lid and supernatant liquid (g)} \\
    m_1 &= \text{mass of flask and stopper (g)}
\end{align*} \]

6.2 Provided the difference between the bitumen contents based on the two aliquots is less than 0.06%, calculate the bitumen content of the sample (B) as the average of the two results to the nearest 0.01% (Note 8.5).

7 Reporting

Report the bitumen content of the sample to the nearest 0.1%.

8 Notes on method

8.1 Before handling toluene, the operator must consult the relevant Safety Data Sheet (SDS).

8.2 An alternative solvent may be used provided that:
   a) it meets occupational health and safety requirements; and
   b) it can be demonstrated that use of the solvent achieves equivalent test results.

8.3 If the aggregate in the bottom of the flask is clean, then all the bitumen has been dissolved. If the aggregate retains a coating of bitumen then the refluxing should be continued until the aggregate is clean. For materials containing slag or other absorptive type aggregates, it may be necessary to heat the mixture for periods up to eight hours in order to extract all traces of absorbed or occluded bitumen.

8.4 Depending on the type of bitumen within the sample and/or container size, it may be necessary to vary the temperature of the hotplate and time of fuming of the bitumen film. The appropriate hotplate temperature and fuming time can be determined by calibrating against solutions of known bitumen content.

8.5 Where the difference between the bitumen contents based on the two aliquots is 0.06% or greater, Subsection 5.13 shall be repeated.

Table 1 – Working tolerances for apparatus

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Dimension</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hotplate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature distribution (°C)</td>
<td>305</td>
<td>± 10</td>
</tr>
</tbody>
</table>
Test Method Q120B: Organic content of soil - loss on ignition

1 Source
This test method was developed in-house with reference to the procedures described in "A Text-Book of Quantitative Inorganic Analysis including Elementary Instrumental Analysis" (3rd Edition) – Arthur I. Vogel: Section I, 60 – Thermogravimetric method of analysis.

2 Scope
This method describes the procedure for the determination of the organic content of soil by loss on ignition. It determines the total organic content of a sample (including any undecomposed organic matter such as particles of grass, sticks, and so on) by igniting the sample at 500°C in a furnace and calculating the resultant percentage mass loss.

3 Apparatus
The following apparatus is required:

3.1 Sieve, 2.36 mm complying with AS 1152.
3.2 Balance of suitable capacity, with a resolution of at least 0.0001 g and with a limit of performance within the range of ± 0.0005 g.
3.3 Drying oven of suitable capacity, having a temperature of 45-50°C and complying with AS 1289.0.
3.4 Drying oven, of suitable capacity having a temperature of 105-110°C and complying with AS 1289.0.
3.5 Furnace, maintained at 500 ± 25°C (Note 9.1).
3.6 Silica or platinum crucibles.
3.7 Desiccator, with silica gel self-indicating desiccant.
3.8 Crucible tongs.
3.9 Furnace gloves.

4 Sample preparation
4.1 Prepare a representative subsample of approximately 50 g passing the 2.36 mm sieve as detailed in Test Method Q101, Subsection 6.4 for fine fraction subsamples.
4.2 Oven dry the subsample at 45-50°C and transfer it to an airtight container in preparation for test.
4.3 Prior to test, heat the representative subsample in a 105-110°C oven for one hour, transfer to a desiccator and allow to cool to room temperature.

5 Procedure
Perform the following procedure in duplicate.

5.1 Heat the crucible in the furnace for one hour, cool in the desiccator and determine the mass to the nearest 0.0001 g.
5.2 Repeat Step 5.1 until constant mass is attained (Note 9.2).
5.3 Transfer a representative portion of approximately 5 g of the subsample into the crucible and determine the mass of the crucible and subsample portion to the nearest 0.0001 g ($m_i$).

5.4 Place the crucible into the furnace for two hours.

5.5 Remove the crucible from the furnace, cool in the desiccator, and determine the mass to the nearest 0.0001 g.

5.6 Return the crucible to the furnace for one hour and repeat Step 5.5.

5.7 Repeat Step 5.6, if necessary until constant mass is attained ($m_{i_f}$) (Note 9.2).

6 Calculations

6.1 Calculate the organic content of each subsample portion as follows:

$$OC = \frac{m_r - m_c}{m_r - m_i} \times 100$$

where

- $OC$ = organic content (%)
- $m_c$ = mass of crucible (g)
- $m_r$ = mass of crucible and residue (g)
- $m_i$ = mass of crucible and subsample portion (g)

6.2 Provided that the results for the two subsample portions do not differ by more than 0.45%, calculate the average of the results to the nearest 0.05%. Where the results differ by more than 0.45%, repeat the test procedure.

7 Reporting

Report the average result as the organic content of the sample to the nearest 0.05%.

8 Precision

8.1 Repeatability

The average results for duplicate tests by the same operator are acceptable if the means do not differ by more than 0.32%.

9 Notes on method

9.1 Prior to commencing this test, it is advisable to allow the furnace time to attain 500 ± 25°C.

9.2 For the purpose of this test, the definition of constant mass is that successive weighings do not differ by more than 0.0005 g. The mass recorded in the last weighing is the constant mass value.
Test Method Q122A: Resistivity of soil and water

1 Source

This method is based on the principles of a resistivity test method originally used by the California Division of Highways in estimating the service life of corrugated metal culverts.

2 Scope

This method describes the procedure for determining the resistivity of soil or water using a conductivity meter. It is applicable to the assessment of the corrosion properties of fine grained materials and water associated with metal culvert installations. A minimum resistivity value is determined for soil materials.

3 Apparatus

The following apparatus is required:

3.1 Conductivity meter, capable of measuring conductivity over the required range.

3.2 Conductivity cell, a cylindrical cell of rigid, durable plastic having approximate dimensions of external diameter 50 mm, internal diameter 26 mm and height 37 mm. The cell contains two nickel electrodes having a length equal to the height of the cell and a width of approximately 9 mm. The electrodes form part of the inner surface of the cell and are aligned with the curve of the cell wall so that the inner surface remains smooth and cylindrical. The electrodes are positioned to be diametrically opposed with their longer axis aligned parallel to the cell axis.

3.3 Panel, a glass or similar non-porous and non-conducting panel, approximately 200 mm square.

3.4 Balance of suitable capacity, with a resolution of at least 1 g and with a limit of performance within the range of ± 5 g.

3.5 Balance of suitable capacity, with a resolution of at least 0.001 g and with a limit of performance within the range of ± 0.005 g.

3.6 Drying oven of suitable capacity, having a temperature of 45-50°C and complying with AS 1289.0.

3.7 Burette, of 50 mL capacity.

3.8 Volumetric flask, of 250 mL capacity.

3.9 Sieve, 2.36 mm complying with AS 1152.

3.10 Mixing bowl, a stainless steel bowl having approximate dimensions of 150 mm diameter and 100 mm depth.

3.11 Spatula, suitable for mixing soil and water and having a width slightly smaller than the internal diameter of the conductivity cell.

4 Materials

The following materials are required:

4.1 Grease, stopcock grease or similar.

4.2 Distilled water or equivalent (for example, reverse osmosis water).
5 Reagents
The following reagent is required (Notes 11.1 and 11.2):

5.1 Potassium chloride solution
- Dissolve 0.373 ± 0.001 g of potassium chloride in distilled water (or equivalent) and make up to the mark in a 250 mL volumetric flask.

6 Sample preparation
Prepare the subsample as follows:

6.1 Prepare a representative subsample of approximately 100 g passing the 2.36 mm sieve as detailed in Test Method Q101, Subsection 6.4 for fine fraction subsamples.

6.2 Dry the subsample in the oven at a temperature of 45-50°C.

7 Calibration of conductivity meter
Calibrate the conductivity meter as follows:

7.1 Clean the conductivity cell to ensure it is free of contaminants.

7.2 Apply a thin layer of grease to the bottom end of the cell and place it (bottom end down) on the panel.

7.3 Rinse the cell with distilled water (or equivalent) then fill it with the potassium chloride solution (Notes 11.3 and 11.4).

7.4 Connect the cell to the conductivity meter and record the conductivity to the nearest 0.01 mS/cm in accordance with the procedure recommended by the meter's manufacturer.

7.5 Discard the solution in the cell and repeat Steps 7.3 and 7.4 until successive readings agree to within 0.01 mS/cm.

7.6 Adjust the conductivity reading to 2.76 mS/cm (Note 11.5).

7.7 Empty the cell and then rinse thoroughly (three to four times) with distilled water (or equivalent) to remove all traces of potassium chloride solution (Note 11.6).

8 Procedure
The procedure for soil samples or water samples as appropriate, is as follows:

8.1 Soil samples

8.1.1 Place the whole soil sample in the mixing bowl and add 5 mL of distilled water (or equivalent) from the burette (Note 11.7).

8.1.2 Thoroughly mix the contents of the mixing bowl with the spatula to produce a uniform soil/water mixture.

8.1.3 Apply a thin layer of grease to the bottom end of the conductivity cell. Seat the conductivity cell on the panel and, using the spatula, compact into the cell sufficient of the soil/water mixture to fill the cell.

8.1.4 Using the spatula, strike off the compacted soil level with the top of the cell (Note 11.4).

8.1.5 Connect the cell to the conductivity meter and record the conductivity in mS/cm to three significant figures in accordance with the procedure recommended by the meter’s manufacturer.
8.1.6 Disconnect the cell from the conductivity meter and return the compacted soil in the cell to the mixing bowl. Reincorporate the contents of the cell with the remainder of the soil/water mixture in the bowl using the spatula.

8.1.7 Add 1 mL of distilled water (or equivalent) from the burette to the contents of the bowl and thoroughly mix with the spatula to produce a uniform soil/water mixture (Note 11.8).

8.1.8 Repeat Steps 8.1.3 to 8.1.5.

8.1.9 Repeat Steps 8.1.6 to 8.1.8 until successive conductivity readings have reached a maximum or have begun to decrease. Record the maximum conductivity ($\gamma_{\text{max}}$) in mS/cm to three significant figures.

8.2 Water samples

8.2.1 Rinse the cell with distilled water (or equivalent) and apply a thin layer of grease to the bottom end of the conductivity cell and place it on the panel.

8.2.2 Seat the conductivity cell on the panel and fill with sufficient of the water sample to fill the cell (Notes 11.3 and 11.4).

8.2.3 Connect the cell to the conductivity meter and record the conductivity ($\gamma$) in mS/cm to three significant figures in accordance with the procedure recommended by the meter’s manufacturer.

9 Calculations

9.1 Calculate the minimum resistivity of the soil sample as follows:

$$\rho_{\text{min}} = \frac{10}{\gamma_{\text{max}}}$$

where $\rho_{\text{min}}$ = minimum resistivity of soil (ohm m)

$\gamma_{\text{max}}$ = maximum conductivity of soil (mS/cm)

9.2 Calculate the resistivity of the water sample as follows:

$$\rho = \frac{10}{\gamma}$$

where $\rho$ = resistivity of water (ohm m)

$\gamma$ = conductivity of water (mS/cm)

10 Reporting

Report the minimum resistivity of the soil or the resistivity of the water as appropriate in ohm m to three significant figures.

11 Notes on method

11.1 Unless otherwise indicated, all reagents are to conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.

11.2 Before handling potassium chloride, the operator must consult the relevant Safety Data Sheet (SDS).
11.3 If the potassium chloride solution or water sample leaks from between the panel and the conductivity cell, apply a thicker layer of grease to the bottom of the cell.

11.4 It is important that the cell is filled to exactly the same level during the calibration and testing operations. The cell must be just filled so that the potassium chloride solution, soil sample or water sample is in contact with the entire inner surfaces of the electrodes.

11.5 If calibration adjustment of the conductivity meter to read 2.76 mS/cm cannot be achieved, clean the cell electrodes using a fine abrasive such as emery flour. If calibration adjustment still cannot be achieved, record the conductivity reading at full adjustment (A). The calculation for the resistivity value for the sample should then be multiplied by the factor (A/2.76).

11.6 If during calibration or test, it is necessary to remove the cell from the panel, ensure both are cleaned thoroughly, rinse it with distilled water (or equivalent) and apply a fresh layer of grease to both the panel and the base of the cell prior to continuing with the test.

11.7 For different soil types, it may be necessary to vary the volume of distilled water initially added to the soil in the bowl. Sandy type materials of low plasticity may require only about 3 mL, while plastic materials containing a high proportion of clay could require up to 10 mL.

11.8 The addition of distilled water in increments greater than 1 mL may be necessary where a large volume of distilled water is required to be added to the sample to achieve a maximum conductivity condition.
Test Method Q122B: Resistivity of soil - reinforced earth

1 Source

This method was based on a test procedure developed by Henri Vidal for the measurement of the resistivity of soil materials to be used in reinforced earth structures.

2 Scope

This method describes the procedure for determining the resistivity of soil using a conductivity meter. It is applicable to materials having a maximum particle size smaller than 19.0 mm and intended for use in reinforced earth structures.

3 Apparatus

The following apparatus is required:

3.1 Sieve, 19.0 mm complying with AS 1152.

3.2 A balance of suitable capacity, with a resolution of at least 1 g and with a limit of performance within the range of ± 5 g.

3.3 A balance of suitable capacity, with a resolution of at least 0.001 g and with a limit of performance within the range of ± 0.005 g.

3.4 Rubber pestle.

3.5 Conductivity meter, capable of measuring conductivity over the required range.

3.6 Resistivity cell, a box shaped cell constructed from a non-conductive material such as plastic and fitted with two stainless steel electrodes containing small holes drilled near the bottom of the electrodes. The dimensions of the cell and electrodes and the location of the drilled holes are illustrated in Figure 1.

3.7 Volumetric flasks, of 2000 mL capacity.

4 Materials

The following material is required:

4.1 Distilled water or equivalent (for example, reverse osmosis water).

5 Reagents

The following reagent is required (Notes 11.1 and 11.2):

5.1 Potassium Chloride Solution

- Prepare two 2000 mL volumetric flasks, by adding 2.984 ± 0.001 g of potassium chloride to each flask, dissolving in distilled water (or equivalent) and making up to the mark.

6 Sample preparation

Prepare a representative subsample of approximately 5000 g passing the 19.0 mm sieve as detailed in Test Method Q101, Subsection 6.4 for fine fraction subsamples.
7 Standardisation of resistivity cell

Standardise the resistivity cell as follows:

7.1 Rinse and then fill the resistivity cell with the potassium chloride solution, so that the level of solution in all three cell compartments is flush with the top of the cell.

7.2 Connect the cell to the conductivity meter and record the conductivity ($\gamma_R$) to the nearest 0.01 mS/cm in accordance with the procedure recommended by the meter’s manufacturer.

7.3 Empty the cell and rinse thoroughly (three to four times) with distilled water (or equivalent) to remove all traces of potassium chloride solution.

8 Procedure

Perform the following procedure:

8.1 Add sufficient mass of the representative soil sample to the resistivity cell to fill it to approximately one quarter capacity.

8.2 Compact the sample in the resistivity cell using the rubber pestle.

8.3 Repeat Steps 8.1 and 8.2 three times to completely fill the cell with compacted sample.

8.4 Carefully add distilled water (or equivalent) to the sample and to the two end compartments of the cell until the cell has been completely filled.

8.5 Add additional distilled water (or equivalent) to the three cell compartments as required until the sample has been completely saturated (that is, the water level in all three compartments of the cell remains flush with the top of the cell for fifteen minutes).

8.6 Allow the cell to stand undisturbed for one hour.

8.7 Connect the cell to the conductivity meter and record the conductivity ($\gamma_s$) to the nearest 0.01 mS/cm in accordance with the procedure recommended by the meter’s manufacturer.

9 Calculations

Calculate the resistivity of the sample using as follows:

$$\rho = \frac{10 \gamma_R}{2.76 \gamma_s}$$

where

$\rho$ = resistivity (ohm m)

$\gamma_R$ = conductivity recorded during standardisation of the cell (mS/cm)

$\gamma_s$ = conductivity of sample (mS/cm)

10 Reporting

Report the resistivity of the sample in ohm m to three significant figures.

11 Notes

11.1 Before handling potassium chloride, the operator must consult the relevant Safety Data Sheet (SDS).
11.2 Unless otherwise indicated, all reagents are to conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.

Figure 1 – Resistivity cell
Test Method Q124: Sand equivalent of soil

This test shall be performed in accordance with AS/NZS 1289.3.7.1: Soil classification tests - Determination of the sand equivalent of a soil using a power-operated shaker.
Test Method Q125D: Capillary rise of stabilised material

1 Source

This method was developed in-house using techniques evolved through internal departmental research investigations.

2 Scope

This method sets out the procedure for the determination of the capillary rise of compacted specimens of soil or a soil-stabilising agent mixture.

Test specimens are prepared by compacting material passing 19.0 mm to a nominated dry density and moisture content using standard or modified compactive effort. Unless otherwise specified, standard compactive effort is to be used.

3 Apparatus

Where appropriate, the working tolerances of particular apparatus are contained in Table 1.

The following apparatus is required:

3.1 Mould assembly (Mould A), comprising a cylindrical metal mould having an internal diameter of 105 mm and an effective height of 115.5 mm, fitted with a detachable baseplate and a removable collar assembly about 60 mm high, both of which can be firmly attached to the mould.

3.2 Steel rammer, having a 50 mm diameter face. For standard compactive effort, the rammer shall have a drop mass of 2700 g and a drop height of 300 mm. For modified compactive effort, the rammer shall have a drop mass of 4900 g and a drop height of 450 mm.

3.3 Level rigid foundation on which to compact the specimen, for example, a sound concrete floor about 100 mm or more in thickness or a concrete block of at least 100 kg mass.

3.4 Balances:

3.4.1 Balance of suitable capacity, with a resolution of at least 1 g and with a limit of performance within the range of ± 5 g.

3.4.2 Balance of suitable capacity to weigh stabilising agents and moisture contents, with a resolution of at least 0.1 g and with a limit of performance within the range of ± 0.5 g.

3.5 Sieves, 19.0 mm and 9.50 mm complying with AS 1152.

3.6 Material height gauge. A flat steel bar, about 250 mm long, 25 mm wide and 1-3 mm thick is satisfactory (Note 11.1).

3.7 Levelling plate, a steel plate having a diameter of about 104 mm and a height of about 20 mm.

3.8 Steel straightedge, about 250 mm long, 25 mm wide and 3 mm thick, preferably with one bevelled edge.

3.9 Mallet, a rubber mallet with a face of 75 mm diameter and a mass of 1000 g.

3.10 Sample extractor, such as a jack, lever frame or other suitable device for extruding compacted specimens from the mould.

3.11 Oven of suitable capacity, having a temperature of 45°C to 50°C and complying with AS 1289.0.
3.12 Steel rule, at least 200 mm long and with a resolution of not exceeding 1 mm.

3.13 Water bath of suitable capacity, able to maintain a depth of 10 mm for 72 hours.

4 Materials

The following materials are required:

4.1 Mould oil, a light oil such as Caltex Mould Oil 20 (Note 11.2).

4.2 Potable water.

5 Sample preparation

5.1.1 Prepare the bulk sample as detailed in Section 5 of Test Method Q101 to produce a representative subsample of appropriate size. It may be necessary to partially dry the bulk sample before preparation so that the material is sufficiently dry to allow uniform mixing of the stabilising agent with the host material.

5.1.2 Further prepare the material by screening the subsample on a 19.0 mm sieve as detailed in Test Method Q101, Steps 6.2.1 to 6.2.3. Ensure that any aggregations are broken up to pass a 9.50 mm sieve.

5.1.3 Prepare a capillary rise test portion as well as a single test portion for determining hygroscopic moisture content as detailed in Test Method Q101, Steps 6.2.4 to 6.2.6. The capillary rise test portion must be of sufficient quantity to mould one specimen and provide a subsample for determining the compaction moisture content (Note 11.3).

5.1.4 Where the capillary rise portion moulding moisture content and dry density are not specified, prepare sufficient additional test portions to undertake dry density/moisture relationship (MDR) testing as detailed in Test Method Q142A or Q142B as appropriate (Note 11.4).

5.1.5 Determine the hygroscopic moisture content ($w_1$) of the test portion prepared in Step 5.1.3 as detailed in Test Method Q102A.

6 Moulding

6.1 Determine the quantity of stabilising agent, then mix and condition the capillary rise test portion as detailed in Test Method Q135A.

6.2 Using the procedure detailed in Test Method Q145A, calculate the mass of wet mixture per layer, determine the achieved moisture content, then mould one specimen at optimum moisture content and maximum dry density by compacting in 3 equal layers. Compaction must be complete within 65 minutes timed from when the mixing water was first added to the mixture of host material and stabilising agent (Note 11.5).

7 Conditioning

7.1 If stabilising agents have been used, wrap the compacted specimen in plastic wrapping and condition as detailed in Test Method Q135B.

7.2 Remove the plastic wrapping from the compacted specimen and place in the 45-50°C oven and dry to a constant mass (Note 11.6).

8 Testing

8.1 Following drying, allow the test specimen to cool to room temperature.

8.2 Using the rule, determine the initial height of the test specimen ($H$).
8.3 Place the specimen in the water bath containing potable water and adjust the water level, if necessary, to ensure that 10 mm of the specimen is immersed.

8.4 Record the time of immersion as 0 hours.

8.5 Using the ruler, determine the height from the base of the specimen to the maximum level of capillary rise \((h)\) at 0.25, 0.5, 1.0, 1.5, 2.0, 4.0, 8.0, 24, 48 and 72 hours (Notes 11.7 and 11.8).

9 **Calculations**

9.1 Calculate the capillary rise as follows:

\[
CR = \frac{h-10}{H-10} \times 100
\]

where

- \(CR\) = capillary rise (%)
- \(h\) = maximum level of capillary rise at the termination of the test or 72 hours (mm)
- \(H\) = initial height of the specimen (mm)

9.2 Using the set of capillary rise readings, plot the capillary rise \((h)\) (mm) against time in hours. From the plot determine the time taken for the capillary rise to reach the top of the specimen as the rise time in hours.

10 **Test report**

Report the following:

10.1 Initial height of the specimen to the nearest 1 mm.

10.2 The rise time to the nearest 0.5 hours.

10.3 Capillary rise to the nearest 1%.

11 **Notes on method**

11.1 A material height gauge, which allows monitoring of the height of compacted material relative to the top of a Mould A, can be made from a steel bar and marked as follows:

11.1.1 Mould A: Commencing at one end of the bar, measure and mark distances of:

- a) 5.5 mm for the upper range of the third layer
- b) 33.5 mm and 38.5 mm for the acceptable range of the second layer, and
- c) 72.5 mm and 77.5 mm for the acceptable range of the first layer.

11.1.2 Mark the face with the appropriate mould size (A).

11.2 Before handling oil, the operator must consult the relevant Safety Data Sheet (SDS).

11.3 A test portion mass of 4 kg will be adequate for determining the capillary rise for moist soils. A gravel may, however, require up to 5 kg while it may be possible to use as low as 3 kg for a fine grained soil.

11.4 A test portion mass of 2.5 kg will be adequate for determining MDR for most soils. A gravel may, however require up to 3 kg, while it may be possible to use as low as 2 kg for a fine grained soil.
11.5 When mixing and conditioning more than one test portion, the work must be sequenced such that any time for conditioning and the time to completion of compaction are observed. Both of these times are measured from when the first increment of water is added to the mixture of soil and stabilising agent. Test portions which do not contain stabilising agents are to be compacted at the completion of mixing the soil and mixing water.

11.6 The specimen is considered to have reached a constant mass when the difference between successive weighings, after a further 4 hours drying at 45-50°C, is not more than 1 percent of the total of the previous moisture losses.

11.7 The water level in the water bath should be checked during the 72 hour period to ensure that 10 mm of the specimen remains immersed.

11.8 If the maximum level of capillary rise reaches the top of the specimen before 72 hours record the time and terminate the test.

### Table 1 – Dimensions and tolerances of compaction apparatus

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Dimension</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mould A</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal diameter (mm)</td>
<td>105.0</td>
<td>± 0.5*</td>
</tr>
<tr>
<td>Height (mm)</td>
<td>115.5</td>
<td>± 0.5*</td>
</tr>
<tr>
<td>Nominal volume (cm³)</td>
<td>1000</td>
<td>± 15</td>
</tr>
<tr>
<td><strong>Rammer</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter, round foot (mm)</td>
<td>50</td>
<td>± 0.4</td>
</tr>
<tr>
<td>Area of rammer (mm²)</td>
<td>1964</td>
<td>± 31</td>
</tr>
<tr>
<td><strong>Standard compaction (Mould A)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drop (mm)</td>
<td>300</td>
<td>± 2.0</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>2.7</td>
<td>± 0.01</td>
</tr>
<tr>
<td><strong>Modified compaction (Mould A)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drop (mm)</td>
<td>450</td>
<td>± 2.0</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>4.9</td>
<td>± 0.01</td>
</tr>
</tbody>
</table>

* Either but not both of the tolerances may be exceeded provided that the specified tolerance on volume is not exceeded.
Test Method Q129: Clay index of soils, crushed rock and filler

1 Source
This method was developed in-house with reference to the publication "Recommended Method of Test for Determination of Clay Index Value", Ministry of Works Department Engineering laboratory Auckland, AEL Report No. 83/26, 1983.

2 Scope
This test method describes the procedure for indicating the quantity of expansive clay minerals in natural fines, soil-rock powders or fillers. The method uses methylene blue as an indicator of the amount of expansive clay present.

3 Apparatus
The following apparatus is required:

3.1 Balances:
3.1.1 Balance of suitable capacity, having a resolution of at least 0.1 g and with a limit of performance within the range of ± 0.5 g.
3.1.2 Balance of suitable capacity, having a resolution of at least 0.01 g and with a limit of performance within the range of ± 0.05 g

3.2 Flasks, four identical glass conical flasks of 250 mL capacity.

3.3 Glass rod, about 150 mm long and 5 mm diameter.

3.4 Burette, glass burette of at least 50 mL capacity graduated to 0.1 mL with a burette holder.

3.5 Pipette, glass pipette of 20 mL capacity.

3.6 Cylinders, glass measuring cylinders of 25 mL and 10 mL capacity.

3.7 Volumetric flasks, 200 mL and 1000 mL capacity.

3.8 Bottle, brown glass bottle of 500 mL or 1000 mL capacity.

3.9 Plastic wash bottle.

3.10 Ultrasonic cleaner.

3.11 Hotplate or gas burner with suitable means of supporting a flat bottomed glass flask.

3.12 Sample splitters or rifflers.

3.13 Timer, capable of measuring 30 minute intervals and with a resolution of 1 second.

3.14 Spatula.

4 Reagents
The following reagents of recognised analytical quality are required (Note 11.1):

4.1 Methylene blue solution
   - Dissolve 4.50 ± 0.01 g of methylene blue dihydrate powder in 1 litre of distilled water (Note 11.2).
4.2 Hydrogen peroxide solution
   - Dilute 30% hydrogen peroxide solution at the rate of one part hydrogen peroxide solution to five parts distilled water (Note 11.3).

4.3 Sulfuric acid solution
   - Dilute concentrated sulphuric acid at the rate of one part acid to seventy four parts distilled water (Note 11.4).

5 Materials
   The following materials are required:

5.1 Filter paper of medium filter speed (for example, Whatman No. 2, 40 or 540) or medium-fast filter speed (for example, Whatman No. 1).

5.2 Distilled water.

6 Sample preparation
   The sample shall be prepared as follows:

6.1 Prepare the bulk sample as detailed in Section 5 of Test Method Q101 to obtain a sample which, when dry, will comply with the minimum mass requirement of Table 1.

6.1.1 Where the test is to be performed on a specified fraction of a material, prepare a representative washed, air-dried subsample as detailed in Test Method Q101, Subsection 6.5 for specified fraction subsamples.

6.2 Crush the representative subsample as detailed in Test Method Q101F to produce a fine crushed, air-dried subsample passing the 0.075 mm sieve (Note 11.5).

6.3 Obtain a representative subsample of the material passing the 0.075 mm sieve of approximately 2 g (Note 11.6).

6.4 Determine the mass of a 250 mL conical flask to the nearest 0.01 g ($m_1$).

6.5 Transfer the subsample to the flask.

6.6 Determine the mass of the flask and subsample ($m_2$).

6.7 Add 25 mL of distilled water to the flask, ensuring that all the subsample is contained within the distilled water.

6.8 Place the flask in the ultrasonic cleaner for at least 30 minutes.

6.9 Remove the flask from the ultrasonic cleaner and add 10 mL of hydrogen peroxide solution and 5 mL of sulfuric acid solution to the flask.

6.10 Place the flask on the hotplate and boil the contents gently for 5 minutes.

6.11 Remove the flask from the hotplate and wash any residue carefully from the upper portion of the flask into the suspension using distilled water from a plastic wash bottle. Use the distilled water sparingly.
7 Methylene blue titration

The titration shall be performed as follows:

7.1 Fill the burette with the methylene blue solution and record the initial burette reading (A) (Note 11.7).

7.2 Add 1 mL of the titrant from the burette to the flask and shake the flask and contents vigorously for approximately 5 seconds (Note 11.8).

7.3 Transfer a drop of the suspension in the flask onto a filter paper using the glass rod and observe its colour.

7.4 Repeat Steps 7.2 and 7.3 until a narrow light blue halo first appears between the dark blue centre and the colourless moisture rim (Note 11.9).

7.5 Shake the flask and contents for 30 seconds and perform the drop test (Step 7.3).

7.6 If the halo disappears, add 0.5 mL of the titrant to the flask, shake the flask and contents for 30 seconds and perform the drop test (Step 7.3).

7.7 Repeat Step 7.6 until the halo remains (Note 11.10).

7.8 Record the final reading of the burette (B).

7.9 Allow the flask (F₁) and contents to stand for undisturbed for 30 minutes.

8 Back titration

The back titration shall be performed as follows (Note 11.11):

8.1 Align the four identical conical flasks on a white surface to aid in the comparison of colour intensity.

8.2 Add a volume of distilled water equal to the total volume of liquid in the flask (F₁) to a second conical flask (F₂).

8.3 Using the pipette, carefully remove 20 mL of liquid from F₁, ensuring that the clay particles at the bottom of the flask are not removed or disturbed, and transfer it to a third conical flask (F₃).

8.4 Record the initial burette reading (C).

8.5 Add the methylene blue solution drop by drop from the burette to flask F₂ while agitating the flask.

8.6 Continue the titration until the colour of the liquids in conical flasks F₂ and F₃ appear similar.

8.7 Pipette 20 mL of the solution in flask F₂ into a fourth conical flask (F₄).

8.8 Compare the colour of the liquid in flasks F₃ and F₄ by placing the eyes over the openings of each flask.

8.8.1 If the colour of the liquid in flask F₄ is lighter than that in flask F₃, return the liquid in flask F₄ to flask F₂ and repeat Steps 8.5 to 8.8 until the liquids are deemed to be equal in colour.

8.8.2 If the colour of the liquid in flask F₄ is darker than that in flask F₃:

   a) discard the contents of flasks F₂ and F₄ and clean and dry both flasks
b) add distilled water to flask $F_2$ to the level of the liquid in flask $F_1$.

c) add an additional 20 mL of distilled water to flask $F_2$ and repeat Steps 8.4 to 8.8.

8.9 Record the final burette reading (D).

8.10 Repeat Steps 6.3 to 8.9 for a second subsample.

9 Calculations

9.1 For each subsample calculate the clay index as follows:

$$CI = \frac{(B-A)-(D-C)}{m_2-m_1}$$

where:

- $CI$ = clay index expressed as mL of 4.50 ± 0.01 g/L methylene blue solution absorbed by 1 gram of soil sample.
- $A$ = initial burette reading for methylene blue titration (mL)
- $B$ = final burette reading for methylene blue titration (mL)
- $C$ = initial burette reading for back titration (mL)
- $D$ = final burette reading for back titration (mL)
- $m_1$ = mass of flask (g)
- $m_2$ = mass of flask and subsample (g)

9.2 Average the clay index results from the two subsamples, provided that they do not differ by 0.3 for clay index results from 0.0 to 3.0 and are within ± 10% of the mean value for clay index results > 3.0. Otherwise repeat the test.

10 Reporting

Report the clay index to the nearest 0.1 for results less than 10 and to the nearest 1 for results greater than or equal to 10.

11 Notes on method

11.1 Before handling methylene blue dihydrate, hydrogen peroxide and sulphuric acid, the operator must consult the relevant Safety Data Sheet (SDS).

11.2 A smaller quantity should be made up if tests are few in number and intermittent in occurrence. The solution should be stored in a brown glass bottle in a refrigerator and the bottle marked with the preparation date. The solution shall be discarded after three months.

11.3 This solution should remain stable for several months if stored in a brown glass bottle in a refrigerator.

11.4 Great care must be taken when mixing concentrated sulphuric acid and water. It is imperative that the acid be added slowly to the required volume of distilled water.

11.5 Mechanical grinders which generate temperatures in the material in excess of 50°C while operating shall not be used as they may break down the crystalline structure of the clay minerals.
11.6 To obtain a representative subsample of the passing 0.075 mm material, a small riffle with approximately 2 mm slot widths can be used until the subsample mass has been reduced to 10-20 grams. Use a spatula to obtain the test subsample.

11.7 As the solution is intensely coloured, no meniscus can be read and the top of the solution shall be recorded at all times.

11.8 The initial addition of titrant to the flask should be commenced one minute after removing the flask from the hotplate.

11.9 Prior to the end point being reached, the drop will show a dark blue centre of dyed clay and a colourless moisture rim. As the end point is approached, a narrow light blue halo of unabsorbed dye will appear between the dark blue centre and the colourless moisture rim.

11.10 An example of the drop test for determining the end point of methylene blue titration is included in Figure 1. The details of each drop are listed below:

a) after the addition of 1 mL of methylene blue solution. The drop consists of a blue centre of dyed clay minerals surrounded by a colourless moisture rim.

b) after the addition of 2 mL of methylene blue solution.

c) after the addition of 3 mL of methylene blue solution.

d) after the addition of 4 mL of methylene blue solution.

e) after the addition of 5 mL of methylene blue solution. There is a very faint light blue halo of unabsorbed methylene blue solution.

f) after the addition of 6 mL of methylene blue solution. A light blue halo around the dark blue centre indicates the presence of unabsorbed methylene blue solution. Upon shaking the suspension for 30 seconds, the halo disappears.

g) after the addition of 6.5 mL of methylene blue solution. Upon shaking the suspension for 30 seconds, the halo disappears.

h) after the addition of 7 mL of methylene blue solution. Upon shaking the suspension for 30 seconds, the halo disappears.

i) after the addition of 7.5 mL of methylene blue solution. The halo becomes well marked and is still evident after shaking the suspension for 30 seconds. This represents the end point of the titration. If the titration is continued well past the end point, an over-developed light blue halo of the unabsorbed methylene blue solution will be evident.

11.11 Due to the relatively slow rate of absorption of methylene blue by some clay samples, the excess liquid may become colourless or have a colourless zone forming as further methylene blue solution is absorbed by the clay minerals during the 30 minute standing time after titration. Back titration is not required in such cases.

**Table 1 – Minimum subsample masses**

<table>
<thead>
<tr>
<th>Maximum particle size (mm)</th>
<th>Minimum subsample mass (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>37.5</td>
<td>15,000</td>
</tr>
<tr>
<td>26.5</td>
<td>5,000</td>
</tr>
<tr>
<td>19.0</td>
<td>2,000</td>
</tr>
<tr>
<td>9.50</td>
<td>500</td>
</tr>
<tr>
<td>4.75</td>
<td>200</td>
</tr>
</tbody>
</table>
### Maximum particle size (mm) | Minimum subsample mass (g)
---|---
2.36 | 100
0.425 | 50

*Figure 1 – Example of the drop test for determining the end point of methylene blue titration*
Test Method Q130A: Chloride content of soil and water

1 Source

This method was developed in-house with reference to the procedures described in *A Text-Book of Quantitative Inorganic Analysis including Elementary Instrumental Analysis (3rd Edition)* – Arthur I. Vogel: Section III, 24 – Determination of Chlorides.

2 Scope

This method describes the procedure for determining the chloride content of samples of either soil or water. The chloride ions within soil samples are extracted with water and their concentration within the soil extract or within a water sample is determined by titration with silver nitrate solution.

3 Apparatus

The following apparatus is required:

3.1 Drying oven of suitable capacity, having a temperature of 45 – 50°C and complying with AS 1289.0.

3.2 Balance of suitable capacity, with a resolution of at least 0.1 g and with a limit of performance within the range of ± 0.5 g.

3.3 Balance of suitable capacity, with a resolution of at least 0.0001 g and with a limit of performance within the range of ± 0.0005 g.

3.4 Steam bath.

3.5 Furnace, a furnace capable of maintaining a temperature of 250°C.

3.6 Volumetric flasks, of 1000 mL and 100 mL capacity.

3.7 Conical flasks, of 1000 mL and 125 mL capacity.

3.8 Measuring cylinders, graduated type, of 250 mL capacity and 100 mL capacity (capable of being stoppered).

3.9 Burette, of 50 mL capacity, graduated in 0.1 mL divisions.

3.10 Pipettes, bulb type of 50 mL and 25 mL capacity.

3.11 Pipettes, graduated type of 10 mL and 1 mL capacity (graduated in 0.1 mL divisions).

3.12 Pasteur pipettes.

3.13 Pipette filler.

3.14 Desiccator, containing silica gel desiccant or equivalent.

3.15 Filter funnel, glass filter funnel.

3.16 Beakers, of 600 mL and 250 mL capacity.

3.17 Storage bottles, of 250 mL and 100 mL capacity.

3.18 Storage bottle (amber glass), of 1000 mL capacity.

3.19 Magnetic stirrer and stirring bar.

3.20 Flask shaker.

3.21 Centrifuge.
4 Materials
The following materials are required:

4.1 Distilled water or an equivalent (for example, reverse osmosis water)
4.2 Filter paper, Whatman No. 1 or equivalent.

5 Reagents
All reagents are analytical reagent grade and the following are required (Notes 12.1 and 12.2):

5.1 Standard sodium chloride solution
- Heat sodium chloride in a furnace maintained at 250°C for 2 hours and then cool in the desiccator. Dissolve 1.6485 ± 0.0001 g of dry sodium chloride in distilled water (or equivalent).
- Transfer the solution to a 1000 mL volumetric flask and make up to the mark with distilled water (or equivalent). (1 mL of this solution equals 1 mg of chloride).

5.2 Silver nitrate solution
- Dissolve 4.8 g of silver nitrate in distilled water (or equivalent).
- Transfer the solution to a 1000 mL volumetric flask and make up to the mark with distilled water (or equivalent).
- Transfer the solution to a 1000 mL amber glass storage bottle and store in a dark cupboard (Note 12.3).

5.3 Potassium chromate indicator solution
- Dissolve 5 g of potassium chromate in 80 mL of distilled water (or equivalent). While stirring, add dropwise the silver nitrate solution until a permanent red precipitate is produced.
- Filter the solution and dilute the filtrate by making up to the mark in a 100 mL volumetric flask with distilled water (or equivalent). Transfer the solution to a 100 mL storage bottle.

5.4 Sulfuric acid solution
- Add 0.5 mL of concentrated sulfuric acid by means of a 1 mL pipette to 180 mL of distilled water (or equivalent) in a measuring cylinder.

5.5 Sodium carbonate solution
- Dissolve 1.1 g of sodium carbonate in 200 mL of distilled water (or equivalent) and transfer to a 250 mL storage bottle.

5.6 Phenolphthalein indicator solution
- Dissolve 0.5 g of phenolphthalein in 50 mL of 95% ethanol and then slowly add 50 mL of distilled water (or equivalent), with constant stirring.
- Filter the solution and then transfer to a 100 mL storage bottle.

5.7 Sodium hydroxide solution
- Dissolve 1 g of sodium hydroxide in distilled water (or equivalent).
- Transfer the solution to a 100 mL measuring cylinder and make up to 100 mL with distilled water (or equivalent). Stopper the cylinder when not in use.
5.8 Ammonium nitrate.

6 Standardisation of silver nitrate solution

Perform the following procedure in duplicate.

6.1 Pipette a 25 mL aliquot of standard sodium chloride solution into a 125 mL conical flask.

6.2 Add approximately 1 mL of potassium chromate indicator solution to the flask by pasteur pipette.

6.3 Stir the solution using a magnetic stirring bar and titrate with silver nitrate solution to the first permanent red-brown colour change.

6.4 Record the volume of the silver nitrate solution titrated to the nearest 0.1 mL.

6.5 Calculate the average volume of the duplicate titrations and record to the nearest 0.1 mL (V).

7 Preparation of soil sample

7.1 Prepare a representative subsample of approximately 500 g passing the 9.50 mm sieve as detailed in Test Method Q101, Subsection 6.4 for fine fraction subsamples.

7.2 Dry the subsample in an oven at a temperature of 45-50°C.

7.3 Crush the subsample to pass a 0.425 mm sieve in accordance with the procedure outlined in Test Method Q101F.

8 Preparation of soil-water extract

8.1 Weigh 200 ± 0.1 g of the prepared subsample into a 1000 mL conical flask.

8.2 Add 400 ± 1 mL of distilled water (or equivalent) to the flask, then stopper the flask and shake on the flask shaker for 1 hour.

8.3 Stand the solution for 30 minutes.

8.4 Decant the solution and then centrifuge it for 15 minutes.

8.5 Filter the centrifuged solution into a 600 mL beaker.

8.6 If the solution is clear, proceed to Step 9.1.

8.7 If the solution contains red colloidal clay which will mask the detection of the end point, either:
   - Add 3 mL of sodium hydroxide solution for every 70 mL of filtrate. Place the beaker containing the solution on a steam bath to flocculate the colloid. After flocculation, allow the solution to cool to room temperature and then centrifuge it for 5 minutes before proceeding to Step 9.1, or
   - Add 0.2 g of ammonium nitrate after Step 8.3 and allow the solution to stand for a further 30 minutes. Centrifuge for 5 minutes before proceeding to Step 9.1.

9 Procedure

Perform the following procedure in duplicate.

9.1 Pipette 50 mL of either the soil-water extract or the water sample into a 250 mL beaker.

9.2 Add a few drops of phenolphthalein indicator solution to the beaker by pasteur pipette and stir the contents using the magnetic stirrer and stirring bar.
9.3 While stirring, adjust the pH of the contents to 8.2 (the point at which the indicator just changes from pink to colourless) using sulfuric acid solution and/or sodium carbonate solution dropwise as required.

9.4 Add approximately 1 mL of potassium chromate indicator solution using a pasteur pipette and titrate the contents with the silver nitrate solution to the first permanent red-brown colour change.

9.5 Record the volume of the silver nitrate solution titrated to the nearest 0.1 mL.

9.6 Calculate the average volume of the duplicate titrations of the soil-water extract or water sample and recorded to the nearest 0.1 mL (\(V\)).

10 Calculations

Calculate the chloride content of the sample using one of the following as appropriate:

10.1 Soil samples

\[
C = \frac{1000 \times V_i}{V}
\]

where

- \(C\) = chloride content of sample (mg/kg)
- \(V_i\) = average volume of silver nitrate solution titrated against soil-water extract (mL)
- \(V\) = average volume of silver nitrate solution titrated during standardisation (mL)

10.2 Water samples

\[
C = \frac{500 \times V_i}{V}
\]

where

- \(C\) = chloride content of sample (mg/L)
- \(V_i\) = average volume of silver nitrate solution titrated against the sample (mL)
- \(V\) = average volume of silver nitrate solution titrated during standardisation (mL)

11 Reporting

Report the chloride content of the sample to the nearest 10 mg/kg for soil samples and the nearest 10 mg/L for water samples.

12 Notes on method

12.1 Before handling chemicals and preparing reagents, the operator must consult the relevant Safety Data Sheet (SDS).

12.2 Unless otherwise indicated, all reagents are to conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.
12.3 Silver nitrate should be handled carefully to avoid any spillage of the solution which readily leaves black stains on bench tops, and so on. Should staining occur, it can be removed using a solution prepared by dissolving 75 g of each of thiourea and citric acid in 1 L of distilled water (or equivalent). This reagent is stable indefinitely.
Test Method Q130B: Chloride content of soil - reinforced earth

1 Source

This method was developed in-house with reference to the procedures described in A Text-Book of Quantitative Inorganic Analysis including Elementary Instrumental Analysis (3rd Edition) – Arthur I. Vogel: Section III, 24 – Determination of Chlorides.

2 Scope

This method describes the procedure for determining the chloride content of select backfill material intended for use in reinforced earth structures. Chloride content is determined by water extraction and titrimetric analysis of the chloride ions using silver nitrate solution.

3 Apparatus

The following apparatus is required:

3.1 Drying oven of suitable capacity, having a temperature of 105 – 110°C and complying with AS 1289.0.

3.2 Balance of suitable capacity, with a resolution of at least 0.1 g and with a limit of performance within the range of ± 0.5 g.

3.3 Balance of suitable capacity, with a resolution of at least 0.0001 g and with a limit of performance within the range of ± 0.0005 g.

3.4 Steam bath.

3.5 Furnace, capable of maintaining a temperature of 250°C.

3.6 Hotplate, capable of maintaining a temperature of 150-200°C.

3.7 pH meter or pH indicator paper.

3.8 Volumetric flasks, of 1000 mL and 100 mL capacity.

3.9 Conical flasks, of 125 mL capacity.

3.10 Measuring cylinders, of 1000 mL capacity, 100 mL capacity (capable of being stoppered) and 50 mL capacity.

3.11 Burette, of 25 mL capacity graduated in 0.1 mL divisions.

3.12 Pipettes, bulb type of 50 mL and 25 mL capacity.

3.13 Pasteur pipettes.

3.14 Pipette filler.

3.15 Desiccator, containing silica gel desiccant or equivalent.

3.16 Sintered glass funnel.

3.17 Glass filter funnel.

3.18 Beakers, of 1500 mL, 600 mL and 250 mL capacity.

3.19 Container, mixing container of 2 to 5 litre capacity fitted with an airtight lid.

3.20 Magnetic stirrer and stirring bar.

3.21 Centrifuge.
3.22 Storage bottles (amber glass), of 1000 mL capacity.
3.23 Storage bottles, of 100 mL capacity.

4 Materials

The following materials are required:

4.1 Distilled water or equivalent (for example, reverse osmosis water).
4.2 Filter paper, Whatman No. 542 or equivalent.

5 Reagents

All reagents are analytical reagent grade and the following are required (Notes 11.1 and 11.2):

5.1 Standard sodium chloride solution
   - Heat the sodium chloride in a furnace maintained at 250°C for 2 hours and then cool in the desiccator. Dissolve 1.6485 ± 0.0001 g of dry sodium chloride in distilled water (or equivalent).
   - Transfer the solution to a 1000 mL volumetric flask and make up to the mark with distilled water (or equivalent). (1 mL of this solution equals 1 mg of chloride).

5.2 Silver nitrate solution
   - Dissolve 4.8 g of silver nitrate in distilled water (or equivalent).
   - Transfer the solution to a 1000 mL volumetric flask and make up to the mark with distilled water (or equivalent).
   - Transfer the solution to a 1000 mL amber glass storage bottle and store in a dark cupboard (Note 11.3).

5.3 Potassium chromate indicator solution
   - Dissolve 5 g of potassium chromate in 80 mL of distilled water (or equivalent). While stirring, add dropwise the silver nitrate solution until a permanent red precipitate is produced.
   - Filter the solution and dilute the filtrate by making up to the mark in a 100 mL volumetric flask with distilled water (or equivalent). Transfer the solution to a 100 mL storage bottle.

5.4 Phenolphthalein indicator solution
   - Dissolve 0.5 g of phenolphthalein in 50 mL of 95% ethanol in a beaker and then slowly add 50 mL of distilled water (or equivalent), with constant stirring.
   - Filter the solution and then transfer to a 100 mL storage bottle.

5.5 Potassium permanganate solution
   - Dissolve between 3.2 and 3.25 g of potassium permanganate in 1 litre of distilled water (or equivalent) in a 1500 mL beaker.
   - Place the beaker and contents onto the hotplate and boil gently for 30 minutes. Remove the beaker and contents from the hotplate and allow to cool to room temperature.
   - Filter the solution through a sintered glass funnel into a 1000 mL amber glass storage bottle and store in a dark cupboard.
5.6 Hydrogen peroxide solution
- Decant 10 mL of 30% (W/V) hydrogen peroxide into a 100 mL measuring cylinder and make up to the 100 mL mark with distilled water (or equivalent). Stopper the cylinder when not in use.

5.7 Nitric acid solution
- Decant 60 mL of distilled water (or equivalent) into a 100 mL measuring cylinder and slowly add 10 mL of concentrated nitric acid. Make up to the 100 mL mark with distilled water (or equivalent). Stopper the cylinder when not in use.

5.8 Sodium hydroxide solution
- Dissolve 1 g of sodium hydroxide in distilled water (or equivalent).
- Transfer the solution to a 100 mL measuring cylinder and make up to 100 mL with distilled water (or equivalent). Stopper the cylinder when not in use.

5.9 Calcium carbonate.

5.10 Ammonium nitrate.

6 Standardisation of silver nitrate solution
Perform the following procedure in duplicate.

6.1 Pipette a 25 mL aliquot of standard sodium chloride solution into a 125 mL conical flask.
6.2 Add approximately 1 mL of potassium chromate indicator solution to the flask by pasteur pipette.
6.3 Stir the solution using a magnetic stirring bar and titrate with silver nitrate solution to the first permanent red-brown colour change.
6.4 Record the volume of the silver nitrate solution titrated to the nearest 0.1 mL.
6.5 Calculate the average volume of the duplicate titrations and record to the nearest 0.1 mL (\(V\)).

7 Preparation of sample extract

7.1 Prepare a representative subsample of approximately 1000 g passing the 26.5 mm sieve as detailed in Test Method Q101, Subsection 6.4 for fine fraction subsamples.

7.2 Dry the subsample in an oven maintained at 105 to 110°C.

7.3 Weigh the subsample into the mixing container and record the mass to the nearest 0.1 g (\(m\)).

7.4 Add 1000 mL of distilled water to the container by measuring cylinder.

7.5 Fit the lid to the container and shake by hand for 2 minutes and then allow to stand for 45 minutes.

7.6 Shake the container for a further 2 minutes and then allow to stand for 15 minutes.

7.7 Carefully decant the extract solution from the container, centrifuge to separate fines and then filter.

7.8 If a colloidal precipitate still remains after filtration, either:
- Add 10 mL of the sodium hydroxide solution to the filtrate to flocculate the precipitate and repeat Step 7.7, or
• Add 0.2 g of ammonium nitrate and allow the solution to stand. Centrifuge for 5 minutes and then filter.

8 Procedure
Perform the following procedure in duplicate:

8.1 Pipette 100 mL ($V_s$) of the sample extract into a 250 mL beaker.

8.2 Using a pasteur pipette and the magnetic stirring bar and stirrer, add potassium permanganate solution dropwise to the extract with constant stirring until a permanent pink colour is obtained (Note 11.4).

8.3 Render the solution colourless by adding 1 drop of the hydrogen peroxide solution using a pasteur pipette (Note 11.4).

8.4 Check the neutrality of the solution using pH indicator paper or a pH meter.

8.4.1 If the solution is acidic, neutralise by adding a minimal quantity of calcium carbonate (approximately 0.1 g is usually sufficient) and allowing the solution to stand for a few minutes.

8.4.2 If the solution is alkaline, neutralise by adding 4 to 5 drops of phenolphthalein indicator solution and nitric acid solution dropwise until the colour changes from pink to just colourless.

8.5 Add approximately 1 mL of the potassium chromate indicator to the solution and titrate with the silver nitrate solution to the first permanent red-brown colour change.

8.6 Record the volume of silver nitrate solution titrated to the nearest 0.1 mL ($V_i$).

8.7 Perform a blank titration substituting 100 mL of distilled water (or equivalent) for the sample extract, and repeating Steps 8.1 to 8.5. Record the volume of the blank titration to the nearest 0.1 mL ($V_b$).

8.8 If the chloride content of the sample calculated as described in Step 9.1 is below 5 mg/kg, reject the result and repeat the procedure as follows:

8.8.1 Pipette 200 mL ($V_s$) of the sample extract into a 600 mL beaker and concentrate by evaporation on a steam bath to approximately 100 mL.

8.8.2 Repeat Steps 8.2 to 8.6 on the concentrated sample.

8.9 If the chloride content of the sample calculated as described in Step 9.1 is above 150 mg/kg, reject the result and repeat the procedure as follows:

8.9.1 Pipette 50 mL ($V_s$) of the sample extract into a 250 mL beaker and dilute with distilled water (or equivalent) to approximately 100 mL.

8.9.2 Repeat Steps 8.2 to 8.6, on the diluted sample.

9 Calculations

9.1 Calculate the chloride content of the sample for each run of the procedure to the nearest 1 mg/kg as follows:

$$C = \frac{25 (V_i - V_b) \times 10^6}{V_s \times m}$$

where $C$ = chloride content of sample (mg/kg)
\[ V_t = \text{volume of silver nitrate solution titrated against sample aliquot extract (mL)} \]
\[ V_b = \text{volume of silver nitrate solution titrated against blank (mL)} \]
\[ V = \text{average volume of silver nitrate solution titrated during standardisation (mL)} \]
\[ V_s = \text{volume of sample extract (mL) (the value is 100, 200 or 50 if Step 8.1, 8.8.1 or 8.9.1 is followed respectively)} \]
\[ m = \text{mass of subsample (g)} \]

9.2 Calculate the average of the two results and record as the chloride content of the sample to the nearest 1 mg/kg.

10 Reporting

Report the chloride content of the sample to the nearest 10 mg/kg.

11 Notes on method

11.1 Before handling chemicals and preparing reagents, the operator must consult the relevant Safety Data Sheet (SDS).

11.2 Unless otherwise indicated, all reagents are to conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.

11.3 Silver nitrate should be handled carefully to avoid any spillage of the solution which readily leaves black stains on bench tops and so on. Should staining occur, it can be removed using a reagent prepared by dissolving 75 g of each of thiourea and citric acid in 1 L of distilled water (or equivalent). This reagent is stable indefinitely.

11.4 Potassium permanganate solution and hydrogen peroxide solution are added to the sample extract aliquot to remove any sulphides or sulphites which may be present.
Test Method Q131B: Sulfate content of soil - reinforced earth

1 Source

This method was developed in-house with reference to the procedures described in *A Text-Book of Quantitative Inorganic Analysis including Elementary Instrumental Analysis (3rd Edition)* – Arthur I. Vogel: Section V, 6 – Determination of Sulfate as Barium Sulfate.

2 Scope

This method describes the procedure for determining the sulfate content of select backfill material intended for use in reinforced earth structures. Sulfate content is determined gravimetrically as barium sulfate following water extraction and precipitation of the sulfate with barium chloride solution.

3 Apparatus

The following apparatus is required:

3.1 Drying oven of suitable capacity, having a temperature of 105-110°C and complying with AS 1289.0.

3.2 Balance of suitable capacity, with a resolution of at least 0.1 g and with a limit of performance within the range of ± 0.5 g.

3.3 Balance of suitable capacity, with a resolution of at least 0.0001 g and with a limit of performance within the range of ± 0.0005 g.

3.4 Steam bath.

3.5 Furnace, capable of maintaining temperature up to 800°C.

3.6 Hotplate, capable of maintaining a temperature of 150-200°C.

3.7 Volumetric flasks, of 1000 mL and 100 mL capacity.

3.8 Measuring cylinders, of 1000 mL capacity and 100 mL capacity (capable of being stoppered).

3.9 Pipettes, bulb type of 100 mL and 50 mL capacity, and graduated type of 5 mL capacity.

3.10 Pasteur pipettes.

3.11 Pipette filler.

3.12 Desiccator, containing silica gel desiccant or equivalent.

3.13 Crucibles, silica or platinum crucibles.

3.14 Crucible tongs.

3.15 Glass filter funnels.

3.16 Beakers, of 400 mL capacity.

3.17 Storage bottle (amber glass), of 150 mL capacity.

3.18 Centrifuge.

3.19 Container, mixing container of 2 to 5 litre capacity fitted with an airtight lid.
4 Materials
The following materials are required:
4.1 Distilled water or equivalent (for example, reverse osmosis water).
4.2 Filter paper, Whatman No. 542 or equivalent.

5 Reagents
All reagents are analytical reagent grade and the following are required (Notes 10.1 and 10.2):
5.1 Hydrochloric acid, concentrated (31-32% w/w).
5.2 Nitric acid, concentrated (70% w/w).
5.3 Barium chloride solution
   • Dissolve approximately 100 g of barium chloride in distilled water (or equivalent).
   • Transfer the solution to a 1000 mL volumetric flask and make up to the mark with distilled water (or equivalent).
5.4 Silver nitrate solution
   • Dissolve approximately 1 g of silver nitrate in distilled water (or equivalent).
   • Transfer the solution to a 100 mL volumetric flask and make up to the mark with distilled water (or equivalent).
   • Transfer the solution to a 150 mL amber glass storage bottle and store in a dark cupboard (Note 10.3).
5.5 Sodium hydroxide solution
   • Dissolve approximately 1 g of sodium hydroxide in distilled water (or equivalent).
   • Transfer the solution to a 100 mL measuring cylinder and make up to 100 mL with distilled water (or equivalent). Stopper the cylinder when not in use.

6 Preparation of sample extract
6.1 Prepare a representative subsample of approximately 1000 g passing the 26.5 mm sieve as detailed in Test Method Q101, Subsection 6.4 for fine fraction subsamples.
6.2 Dry the subsample in an oven maintained at 105 to 110°C.
6.3 Weigh the subsample into the mixing container and record the mass to the nearest 0.1 g ($m_1$).
6.4 Add 1000 mL distilled water (or equivalent) to the container by measuring cylinder.
6.5 Fit the lid to the container and shake by hand for 2 minutes then allow to stand for 45 minutes.
6.6 Shake the container for a further 2 minutes and then allow to stand for 15 minutes.
6.7 Carefully decant the extract solution from the container, centrifuge to separate fines and then filter.

7 Procedure
Perform the following procedure in duplicate.
7.1 Pipette 250 mL of the sample extract into a 400 mL beaker.
7.2 Add 2 mL of concentrated hydrochloric acid to the extract by means of the graduated pipette to prevent any subsequent precipitation of carbonates.

7.3 Place the beaker and contents on the hotplate and heat to boiling.

7.4 Remove the beaker from the hotplate and place on the steam bath to maintain gentle boiling of the contents.

7.5 Add barium chloride solution dropwise to the contents, ensuring that no interruption to the boiling occurs and until precipitation appears complete.

7.6 Remove the beaker from the steam bath and allow the precipitate to settle. Add a few drops of barium chloride solution to the clear supernatant liquid to ensure complete precipitation of barium sulfate has occurred.

7.7 If precipitation is incomplete, add additional barium chloride solution and return the beaker to the steam bath for 1 hour, maintaining gentle boiling.

7.8 Remove the beaker from the steam bath and allow to cool to room temperature.

7.9 Filter the contents of the beaker carefully ensuring that all of the precipitate is transferred from the beaker to the filter paper.

7.10 Wash the precipitate several times with approximately 30 mL of boiling distilled water (or equivalent) until the washings are chloride free (Note 10.4).

7.11 Heat a crucible for 1 hour in the furnace at 600-800°C, cool to room temperature in the desiccator and weigh to the nearest 0.0001 g.

7.12 Repeat Step 7.11 until constant mass is attained (Note 10.5). Record the mass of the final weighing to the nearest 0.0001 g (m<sub>2</sub>).

7.13 Carefully transfer the filter paper containing the precipitate to the crucible and dry at approximately 100°C in the furnace.

7.14 Place the lid on the crucible and gradually increase the temperature of the furnace to about 250°C over approximately 1 hour. Further increase the temperature of the furnace to 600-800°C and hold at this temperature for 1 hour.

7.15 Remove the crucible from the furnace and allow to cool in the desiccator.

7.16 Add 3 or 4 drops of concentrated nitric acid to the residue in the crucible and evaporate on the steam bath.

7.17 Heat the crucible in the furnace at 600-800°C for 1 hour, cool to room temperature in the desiccator and weigh to the nearest 0.0001 g.

7.18 Repeat Step 7.17 until constant mass is attained (Note 10.5). Record the mass of the final weighing to the nearest 0.0001 g (m<sub>3</sub>).</p>

8 Calculations

8.1 Calculate the sulfate content for each run of the procedure to the nearest 1 mg/kg as follows:

\[
S = \frac{1.646 \times 10^6 (m_3 - m_2)}{m_1}
\]

where \(S\) = sulfate content (mg/kg)
\[ m_1 = \text{mass of subsample (g)} \]
\[ m_2 = \text{mass of crucible (g)} \]
\[ m_3 = \text{mass of crucible and residue (g)} \]

8.2 Calculate the average of the two results and record as the sulfate content of the sample to the nearest 1 mg/kg.

9 Reporting

Report the sulfate content of the sample to the nearest 1 mg/kg as $\text{SO}_4^{2-}$.

10 Notes on method

10.1 Before handling chemicals and preparing reagents, the operator must consult the relevant Safety Data Sheet (SDS).

10.2 Unless otherwise indicated, all reagents are to conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.

10.3 Silver nitrate should be handled carefully to avoid any spillage of the solution which readily leaves black stains on bench tops and so on. Should staining occur, it can be removed using a reagent prepared by dissolving 75 g of each of thiourea and citric acid in 1 L of distilled water (or equivalent). This reagent is stable indefinitely.

10.4 To ensure the washings are free from chlorides, approximately 10 mL of the washings should be acidified with 3 drops of concentrated nitric acid and silver nitrate added dropwise. If a white precipitate or cloudiness forms, further washing of the precipitate with boiling distilled water (or equivalent) should be carried out until the addition of silver nitrate produces no white discoloration.

10.5 Constant mass shall be achieved when subsequent weighings of the crucible do not vary by more than ± 0.0002 g.
Test Method Q133: Lime demand of soil

1 Source
This method was developed in-house and is based on the procedure described in “A Quick Test to Determine Lime Requirements for Soil Stabilisation”, Eades, J.L., and Grim, R.E. (1966): Highway Research Record No. 139.

2 Scope
This method describes the procedure to determine the degree to which a soil will react with calcium hydroxide through cationic exchange and pozzolanic responses from reactive clay minerals. The method provides for the determination of the lime demand (percent lime), as measured using an extended pH test, and is used as a starting estimate of an optimum in design lime content. The lime demand test as performed by this procedure has been shown to provide lime contents that correspond well with optimum lime contents for long term effective stabilisation.

3 Apparatus
The following apparatus is required:

3.1 pH meter, equipped with combination type high alkaline pH electrode (Note 8.1).
3.2 Balance of suitable capacity, with a resolution of 0.01 g and with a limit of performance within the range ± 0.05 g.
3.3 Sieve, 2.36 mm complying with AS 1152.
3.4 Beakers, 100 mL.
3.5 Watchglasses, of appropriate size to cover the 100 mL beakers.
3.6 Measuring cylinder, of 100 mL capacity.
3.7 Magnetic stirrer.
3.8 Magnetic stirrer bar.
3.9 Wash bottle.
3.10 Glass stirring rod.

4 Materials
The following materials are required:

4.1 Neutral and high pH buffer solutions as recommended by the manufacturer of the pH meter, for example, pH of 7 and pH of 10 to 12 (Note 8.2).
4.2 Fresh sample of hydrated lime of known available lime content expressed in terms of calcium oxide (CaO) (Notes 8.3 and 8.4).
4.3 Distilled water.

Superseded
5 Procedure

The procedure shall be as follows:

5.1 Sample preparation

5.1.1 Prepare the bulk sample as detailed in Section 5 of Test Method Q101 to produce a representative subsample of appropriate size.

5.1.2 Further prepare the material to produce a subsample of approximately 600 g passing the 2.36 mm sieve as detailed in Test Method Q101, Subsection 6.4 for fine fraction subsamples.

5.1.3 Prepare representative test portions as follows:

a) One test portion for hygroscopic moisture content, and

b) One test portion of about 500 g for pH testing and place in an airtight container.

5.1.4 Determine the hygroscopic moisture content (\( w_1 \)) of the test portion prepared in Step 5.1.3 a) as detailed in Test Method Q102A.

5.2 Calculation of test masses

For each lime increment calculate the mass of soil and mass of hydrated lime to be used, based on a combined dry mass of 30 g as follows (Note 8.5):

5.2.1 Mass of Soil Test Portion

\[
m_w = \frac{30}{1 + \frac{p}{100} (1 + \frac{w_1}{100})}
\]

where

- \( m_w \) = mass of soil (g)
- \( w_1 \) = hygroscopic moisture content (%)
- \( p \) = lime content (%)

5.2.2 Mass of hydrated lime

\[
m_i = 30 - \frac{30}{1 + \frac{p}{100}}
\]

where

- \( m_i \) = mass of lime (g)
- \( p \) = lime content (%)

5.3 Calibration of pH meter

5.3.1 Wash the electrode with distilled water and calibrate the pH meter by means of the standard buffer solutions, following the procedure recommended by the manufacturer (Note 8.2).

5.3.2 Wash the electrode with distilled water and leave it in a beaker of distilled water when not in use.
5.4 pH determination

5.4.1 Prepare the required number of test portions with individual masses as calculated in Step 6.2.1 of Test Method Q101B and place the test portions in suitably marked beakers.

5.4.2 Add the corresponding mass of hydrated lime as calculated in Step 5.2.2 to each beaker and thoroughly mix the constituents using a glass stirring rod. Add 5 g of hydrated lime to another beaker, then cover each beaker with a watchglass.

5.4.3 Add 75 mL of distilled water to the beaker containing the hydrated lime only.

5.4.4 Mix the suspension using the magnetic stirrer and then cover the beaker with a watch glass and allow it to stand for 2 hours.

5.4.5 Restart the stirrer and lower the pH electrode into the suspension until the bulb is just covered.

5.4.6 Read the pH meter at 1 minute intervals and continue readings until 3 successive values are within a range of 0.05 pH units. Record these values to the nearest 0.01 units together with the average pH value (Note 8.6).

5.4.7 Remove the electrode from the beaker, wash it with distilled water and check the reading of the meter as detailed in Subsection 5.3 using the higher pH buffer solution. If the reading varies by more than 0.05 pH units from that determined during calibration, repeat Steps 5.3.1 to 5.4.6.

5.4.8 Test each of the soil-lime mixtures in order, commencing with the lowest lime content, by repeating Steps 5.4.4 to 5.4.7 after adding 75 mL of distilled water to the beaker.

5.4.9 Continue testing until the average pH values of the 3 highest lime contents do not vary by more than 0.05 pH units. If this is not achieved with the test portions prepared, calculate the mass of constituents for a further number of higher lime contents and undertake additional testing as detailed in Subsections 5.2 and 5.4.

6 Calculations

6.1 Plot the average pH against its hydrated lime content and join each point. Next, draw a line parallel to the X axis corresponding to the pH for hydrated lime.

6.2 Record the lowest hydrated lime content (HLC) where the pH just reaches a stable peak value, that is, a plateau where the pH values do not vary by more than 0.05 pH units over three successive soil-lime mixtures (Figure 1 and Note 8.7).

7 Reporting

Report the hydrated lime content (HLC) as the lime demand for the soil to the nearest 0.5%.

8 Notes on method

8.1 An electrode manufactured using a medium lithium glass is satisfactory for measuring pH up to 12.4 as required by this method.

8.2 The shelf life of pH of 7 buffer solution is usually 12 months, while that of pH of 10 to 12 buffer solution is about 6 months. Buffer solutions should be refrigerated after use with care being exercised to ensure the solutions do not become contaminated through reuse or are carbonated by exposure to air.

8.3 The available lime content is to be determined as detailed in AS 1672: Limes and Limestones Part 1: Limes for Building.
8.4 Before handling hydrated lime, the operator must consult the relevant Safety Data Sheet (SDS).

8.5 Lime is added at 1 percent increments commencing at a lime content of 1 percent. The number of lime increments used in any test is dependent on the reactivity of soil under consideration. As a guide, some 6 increments are appropriate for a medium plasticity soil, while up to 10 may be necessary for a highly plastic soil.

8.6 The pH readings of the soil-lime suspension should reach a constant value in 2 to 3 minutes.

8.7 The stable pH value of the soil-lime mixture should be the same as the pH of the hydrated lime mixture. The presence of cations such as sodium in the soil pore water may reduce the solubility of the hydrated lime, thus reducing the pH of the solution. It is not uncommon for the soil-lime mixture to plateau at values of 12.2 or even slightly lower, which is below the pH value of 12.4 for hydrated lime under standard conditions.

*Figure 1 – pH/hydrated lime content*
Test Method Q134: Stabilising agent content - heat of neutralisation

1 Source
This method was developed in-house and is based on the procedure described in H.D Taskis: Estimation of Cement Content of Stabilised Crushed Rock; A Method of Eliminating Errors due to Aggregate Reaction, ARRB Conference, Volume 2, 1964.

2 Scope
This method describes the procedure to determine the stabilising agent content of fresh mixtures of soil or crushed rock which have been modified or stabilised with a hydraulic binder. The method relies on the exothermic reaction of free alkalis in the stabilising agent with a buffered acetic acid solution and is limited to stabilising agent types and concentrations which produce an effective temperature rise of at least 3ºC.

The method is generally not suitable for materials which contain significant quantities of carbonate compounds since the carbonate reacts with the buffer solution to produce carbon dioxide and heat.

3 Apparatus
The following apparatus is required:

3.1 Thermometer, a partial immersion thermometer or other suitable temperature measuring device with a temperature range of at least 0-60ºC and graduated to 0.1ºC or less with an uncertainty of no more than 0.5ºC.

3.2 Balance of suitable capacity, with a resolution and limit of performance as specified in Table 1.

3.3 Measuring cylinders, of 1000 mL and 2000 mL capacity.

3.4 Mixing containers, having a capacity approximately 30% larger than the combined volume of solids and liquids used in the test.

3.5 Timer, such as stopwatch.

3.6 Mechanical mixer, motorised or a hand operated tumbler mixer which rotates at a constant rate and provides complete mixing of the constituents. A mixer speed of 20 rpm has been found to be satisfactory.

3.7 Cloth, container and potable water for cleaning thermometer after each measurement.

4 Reagents
All reagents are laboratory reagent quality grade and the following are required:

4.1 Buffer solution:
- Prepare by dissolving 250 g of sodium acetate, 240 g of glacial acetic acid in about 500 mL of potable water (Notes 9.1 and 9.2). Make up to one litre using additional potable water.

5 Calibration
For each combination of stabilising agent, admixture and soil or crushed rock to be stabilised perform the calibration as follows:
5.1 Sample preparation

5.1.1 Prepare the bulk sample as detailed in Section 5 of Test Method Q101 to produce a representative subsample of appropriate size. It may be necessary to partially dry the bulk sample before preparation so that the material is sufficiently dry to allow uniform mixing of the stabilising agent with the host material.

5.1.2 Prepare at least 12 subsamples and a single test portion for determining hygroscopic moisture content as detailed in Test Method Q101, Steps 6.2.4 to 6.2.6, which are of sufficient size to yield the soil masses determined in Subsection 5.2. Refer to Table 1 for minimum test subsample masses.

5.1.3 Determine the moisture content (w) of the hygroscopic moisture test portion prepared in Step 5.1.2 as detailed in Test Method Q102A.

5.1.4 Bring the remaining subsamples, apparatus and buffer solution to the temperature of the test environment at least 2 hours before testing is to commence (Notes 9.3 and 9.4).

5.2 Test portion calculations

5.2.1 Calculate the mass of wet material, mass of water and mass of stabilising agent over the range ± 1.0% of design stabilising agent contents in increments of 0.5% with the minimum content not being less than 0.5%. Where the design stabilising agent content is less than 1.5%, only four contents are to be calculated.

5.2.2 Calculate the mass of wet material for each stabilising agent content as follows:

\[ m_d = \frac{M}{1 + \frac{A}{100} + \frac{OMC}{100} \left(1 + \frac{A}{100}\right)} \]

where

- \( m_d \) = mass of dry material (g)
- \( M \) = mass of test portion (material, water and stabilising agent) to be used in the calibration from Table 1 (g)
- \( A \) = stabilising agent content (%)
- \( OMC \) = optimum moisture content (%)

\[ m_w = m_d \left(1 + \frac{w}{100}\right) \]

where

- \( m_w \) = mass of wet material (g)
- \( m_d \) = mass of dry material (g)
- \( w \) = hygroscopic moisture content (%)

5.2.3 Calculate the mass of stabilising agent for each stabilising agent content as follows:

\[ m_a = \frac{m_d A}{100} \]

where

- \( m_a \) = mass of stabilising agent (g)
- \( m_d \) = mass of dry material (g)
- \( A \) = stabilising agent content (%)
5.2.4 Calculate the mass of water for each stabilising agent content as follows:

\[ m = \left( \frac{m_d + m_a}{100} \right) \cdot \text{OMC} - (m_w - m_d) \]

where:
- \( m \) = mass of water (g)
- \( m_d \) = mass of dry material (g)
- \( m_a \) = mass of stabilising agent (g)
- OMC = optimum moisture content (%)
- \( m_w \) = mass of wet material (g)

5.3 Buffer solution content

Optimise the buffer solution content for the highest stabilising agent content (design plus 1%) as follows:

5.3.1 Using one of the subsamples, obtain a test portion having a wet material mass as calculated in Step 5.2.2 for the highest stabilising agent content.

5.3.2 Weigh the required mass of stabilising agent and thoroughly mix it with the test portion.

5.3.3 Weigh the required mass of water, then mix it with the material and stabilising agent for two minutes using the mechanical mixer or by hand.

5.3.4 Measure out a volume of buffer solution (\( V_b \)) that, when mixed in the mechanical mixer with the material, stabilising agent and water mixture, will have a thick consistency at the completion of four minutes mixing (Note 9.5).

5.3.5 If the mixture either forms a gel or is fluid-like, repeat Steps 5.3.1 to 5.3.4, adjusting the volume of buffer solution until a thick consistency is obtained.

5.4 Procedure

For each of the five stabilising agent contents, undertake the following:

5.4.1 Using one of the subsamples, obtain a test portion of appropriate mass and place it in the mixing container or mixing tray.

5.4.2 Weigh the required mass of stabilising agent and thoroughly mix it with the test portion.

5.4.3 Weigh the required mass of water and mix it with the material and stabilising agent for exactly two minutes using the mechanical mixer or by hand.

5.4.4 At the completion of mixing, insert the thermometer in the mixture and record the temperature \( (T_{c1}) \) after 60 seconds.

5.4.5 Measure out the required volume of buffer solution (\( V_b \)) and insert the thermometer in the solution and record the temperature \( (T_{c2}) \) after 60 seconds.

5.4.6 Add the buffer solution to the material, stabilising agent and water mixture, then immediately mix in the mechanical mixer for exactly four minutes, timed from the start of mixing.

5.4.7 At the completion of mixing, insert the thermometer into the mixture and record the temperature \( (T_{c3}) \) after 60 seconds.
5.4.8 Repeat Steps 5.4.1 to 5.4.7 with the same stabilising agent content.

5.4.9 Repeat Steps 5.4.1 to 5.4.8 for each remaining stabilising agent content.

6 **Test procedure**

Prior to the commencement of each test, ensure all apparatus including the mixing container and the buffer solution has equilibrated to temperature of the test environment (Note 9.3).

6.1 Obtain a representative sample of the mixed material as soon as possible after the completion of mixing.

6.2 Prepare a test portion of the sample by splitting as detailed in Test Method Q101B to produce a test portion within 0.5% of the average mass used in the calibration.

6.3 Place the test portion in the mixing container, insert the thermometer and record the temperature ($T_1$) after 60 seconds.

6.4 Measure out the same volume of buffer solution ($V_c$) as used in the calibration and insert the thermometer in the solution and record the temperature ($T_2$) after 60 seconds.

6.5 If the temperature difference between the sample and the buffer solution exceeds 3°C, heat or cool the test portion as appropriate and repeat Steps 6.3 to 6.4 before continuing (Notes 9.4 and 9.6).

6.6 Add the buffer solution to the test portion, then immediately mix in the mechanical mixer for exactly four minutes timed from the start of mixing.

6.7 At the completion of mixing, insert the thermometer in the mixture and record the temperature ($T_3$) after 60 seconds.

7 **Calculations**

Perform the calculations as follows:

7.1 **Calibration**

7.1.1 Calculate the temperature rise to the nearest 0.01°C for each test portion as follows:

$$\Delta T_c = T_{c3} - \left( \frac{0.0003 M_{c1} + 1.2 V_c T_{c2}}{0.0003 M + 1.2 V_c} \right)$$

where

- $\Delta T_c$ = temperature rise (°C)
- $T_{c3}$ = temperature of the material, stabilising agent, water and buffer solution mixture (°C)
- $M$ = mass of test portion (material, stabilising agent and water) (g)
- $T_{c1}$ = temperature of the material, stabilising agent and water (°C)
- $V_c$ = volume of buffer solution (L)
- $T_{c2}$ = temperature of the buffer solution (°C)
7.1.2 Determine the relationship between the stabilising agent content and temperature rise using linear regression analysis of the following relationship:

\[ y = bx + a \]

where

- \( y \) = stabilising agent content (\( A \)) (%)
- \( b \) = slope of linear relationship
- \( x \) = temperature rise (\( \Delta T_c \)) (°C)
- \( a \) = \( y \) intercept of linear relationship

a) Determine the slope of the linear relationship as follows:

\[ b = \frac{n \sum xy - \sum x \sum y}{n \sum x^2 - (\sum x)^2} \]

where

- \( b \) = slope of linear relationship
- \( \sum x \) = sum of the temperature rise measurements (\( \Delta T_c \))
- \( \sum y \) = sum of the stabilising agent contents
- \( \sum x^2 \) = sum of the squares of the temperature rise measurements (\( \Delta T_c \))
- \( \sum xy \) = sum of the products of the corresponding results from the temperature rise measurements (\( \Delta T_c \)) and the stabilising agent contents
- \( n \) = number of pairs of test measurements

b) Determine the \( y \) intercept of the linear relationship as follows:

\[ a = \frac{1}{n}(\sum y - b \sum x) \]

where

- \( a \) = \( y \) intercept of linear relationship
- \( n \) = number of pairs of test measurements
- \( \sum y \) = sum of the stabilising agent contents
- \( b \) = slope of linear relationship
- \( \sum x \) = sum of the temperature rise measurements (\( \Delta T_c \))

c) Repeat any point which is at variance with the trend of the calibration and re-analyse the test data.

7.1.3 Determine the calibration constant (\( c \)) as follows:

\[ c = \left( \frac{0.0003Mb}{0.0003M + 1.2V_c} \right) \]

where

- \( c \) = calibration constant
- \( M \) = mass of test portion (material, stabilising agent and water) (g)
- \( b \) = slope of linear relationship
\[ V_c = \text{volume of buffer solution (L)} \]

7.1.4 Determine the calibration constant (d) as follows:

\[ d = \frac{1.2V_c b}{0.0003M + 1.2V_c} \]

where
- \( d \) = calibration constant
- \( V_c \) = volume of buffer solution (L)
- \( b \) = slope of linear relationship
- \( M \) = mass of test portion (material, stabilising agent and water) (g)

7.2 Test

7.2.1 Calculate the stabilising agent content using the calibration constants for the combination of stabilising agent, admixture and soil or crushed rock tested as follows:

\[ A = bT_3 - cT_1 - dT_2 + a \]

where
- \( A \) = stabilising agent content (%)
- \( b \) = slope of linear relationship
- \( T_3 \) = temperature of the material, stabilising agent, water and buffer solution mixture (°C)
- \( c \) = calibration constant
- \( T_1 \) = temperature of the test portion (material, stabilising agent and water) (°C)
- \( d \) = calibration constant
- \( T_2 \) = temperature of the buffer solution (°C)
- \( a \) = y intercept of linear relationship

8 Reporting

Report the following values and general information:

8.1 Calibration

8.1.1 The relationship between the stabilising agent content (y) and temperature rise (x) in the form: \( A = bT_3 - cT_1 - dT_2 + a \). Report the values of \( b \), \( c \) and \( d \) to the nearest 0.0001 and \( a \) to the nearest 0.001.

8.1.2 The range of additive contents used in the calibration to the nearest 0.1%.

8.1.3 The combined mass of material, stabilising agent and water used in the calibration to nearest 1 g.

8.1.4 The volume of buffer solution used to the nearest 10 mL.

8.1.5 General information:

a) source and description of the soil or crushed rock.

b) source and type of stabilising agent.
8.2 Test Result

8.2.1 The stabilising agent content to the nearest 0.1%.

9 Notes on method

9.1 Before handling sodium acetate or acetic acid, the operator must consult the relevant Safety Data Sheet (SDS).

9.2 The shelf life of the buffer solution is 90 days when stored at 23°C ± 3°C (air-conditioned environment), otherwise 7 days.

9.3 The test environment is an area that is isolated from drafts and heat sources, that is, a relatively uniform temperature. It is recommended that the calibration and the testing be performed in the same environment.

9.4 Normally test portions and equipment will reach the temperature of the test environment within 30 minutes. The temperature difference between the test portion and the buffer solution should not exceed 3°C.

9.5 The ratio of buffer solution to test portion can vary from 1 litre per 1000 g for a reactive stabilising agent to 1 litre per 5000 g for an unreactive stabilising agent. For a particular stabilising agent composition, the volume of buffer solution increases with increasing design stabilising agent content.

9.6 Techniques for warming or cooling a test portion such as spreading it thinly on a tray and covering the material with a damp cloth, spreading it thinly on a tray, covering with a dry cloth and directing warm air over the material or placing the material in a plastic bag and immersing in a water bath have been found to be suitable.

Table 1 – Test portion and general balance requirements

<table>
<thead>
<tr>
<th>Material type</th>
<th>Test portion minimum mass (g)</th>
<th>Balance resolution (g)</th>
<th>Limit of performance of balance (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium-grained material with 0-20% retained on 19.0 mm sieve</td>
<td>1000</td>
<td>0.1</td>
<td>± 0.5</td>
</tr>
<tr>
<td>Coarse-grained material with 0-20% retained on 37.5 mm sieve</td>
<td>5000</td>
<td>1</td>
<td>± 5</td>
</tr>
<tr>
<td>Stabilising agent for calibration</td>
<td>-</td>
<td>0.1</td>
<td>± 0.5</td>
</tr>
<tr>
<td>Water for calibration</td>
<td>-</td>
<td>0.1</td>
<td>± 0.5</td>
</tr>
</tbody>
</table>
Test Method Q135A: Addition of stabilising agents

1 Source

This method was developed in-house using techniques evolved through internal departmental research investigations.

2 Scope

This method describes the procedure for calculating the quantity of stabilising agent(s) and any specified admixture(s) to be added to a host soil or crushed rock as well as the procedures for mixing the constituent materials and the conditioning of the mixture prior to compaction. The mixing process allows for the incorporation of one or more stabilising agents and provides the techniques for the addition of hydraulic, bituminous or ionic agents.

3 Apparatus

Where appropriate, the working tolerances of particular apparatus are contained in Table 1.

The following apparatus is required:

3.1 Miscellaneous mixing apparatus, such as a tray, trowel or scoop and water spray suitable for mixing stabilising agent and water increments into the material.

3.2 Sealable containers, suitable for curing mixed test portions.

3.3 Balance of suitable capacity, with a resolution of at least 0.1 g and with a limit of performance within the range of 0.5 g (Note 7.1).

3.4 Measuring cylinders of 10 mL or 50 mL capacity as required.

For long term conditioning the following additional apparatus is required:

3.5 Air curing environment as detailed in Test Method Q135B.

3.6 Metal moulds, of a size dependent on the maximum size of material being tested, as follows:

3.6.1 For compaction of material passing a 19.0 mm sieve:

Mould A: A cylindrical metal mould having an internal diameter of 105 mm and effective height of 115.5 mm, fitted with a detachable baseplate and a removable collar assembly about 60 mm high both of which can be firmly attached to the mould.

3.6.2 For compaction of material which has rock material retained on the 19.0 mm sieve:

Mould B: A cylindrical metal mould having an internal diameter of 152 mm and an effective height of 132.5 mm, fitted with a detachable baseplate and a removable collar assembly about 60 mm high both of which can be firmly attached to the mould.

3.7 Steel rammer, or alternatively a mechanical compactor may be used provided that it meets the essential requirements of drop height, mass and energy input (Note 7.2).

3.8 Level rigid foundation on which to compact the specimen, for example a sound concrete floor about 100 mm or more in thickness or a concrete block of at least 100 kg mass.

4 Stabilising agents

Stabilising agents used in laboratory testing must be fresh samples of the same type, manufacturer and supplier as expected for the field application. However, due to safety issues and the need to control compaction parameters, quicklime should not be used for laboratory
testing. Instead, a high quality fresh hydrated lime complying with AS 1672.1: Limes and Limestones should be employed (Note 7.3).

5 Calculation of addition rates

5.1 Calculate the dry mass of each test portion as follows:

$$m_2 = \frac{100m_1}{100+w_1}$$

where

- $m_2$ = mass of dry material in test portion (g)
- $m_1$ = mass of wet material in test portion (g)
- $w_1$ = hygroscopic moisture content (%)

5.2 Calculate the mass or volume of each stabilising agent to be added as follows:

5.2.1 For a system where the agent is specified in terms of percentage by mass:

$$m_s = \frac{m_2 p_1}{100}$$

where

- $m_s$ = mass of each stabilising agent (g)
- $m_2$ = mass of dry material in test portion (g)
- $p_1$ = stabilising agent content (%) 

5.2.2 For a system where the agent is specified in terms of a rate per unit volume:

$$v_s = \frac{m_2 r}{\rho_d 1000}$$

where

- $v_s$ = volume of each stabilising agent (mL)
- $m_2$ = mass of dry material in test portion (g)
- $r$ = application rate (L/m³)
- $\rho_d$ = maximum dry density (t/m³)

5.3 Calculate the mass or volume of each admixture as follows (Note 7.4):

5.3.1 For a system where the admixture is specified in terms of percentage by mass of stabilising agent:

$$m_a = \frac{m_s p_2}{100}$$

where

- $m_a$ = mass of each admixture (g)
- $m_s$ = mass of each stabilising agent (g)
- $p_2$ = admixture content (%)
5.3.2 For a system where the admixture is specified in terms of volume per unit of mass of stabilising agent:

\[ v_a = \frac{m_s p_3}{100000} \]

where

- \( v_a \) = volume of each admixture (mL)
- \( m_s \) = mass of each stabilising agent (g)
- \( p_3 \) = admixture content (mL per 100 kg of stabilising agent)

5.4 Calculate the mass of mixing water to be added as follows (Note 7.5):

5.4.1 For a system containing dry stabilising agent:

\[ m_3 = \frac{m_2 + \sum m_{sd}}{100} w_2 (m_1 - m_2) \]

where

- \( m_3 \) = mass of mixing water to be added (g) (Note 7.6)
- \( m_2 \) = mass of dry material in test portion (g)
- \( \sum m_{sd} \) = sum of dry stabilising agent masses (g) (Note 7.7)
- \( w_2 \) = target compaction moisture content (%)
- \( m_1 \) = mass of wet material in test portion (g)

5.4.2 For a system containing emulsion or slurry stabilising agent:

\[ m_3 = \frac{m_2 + \sum m_{sd} + m_{sw} p_4}{100} w_2 (m_1 - m_2) - \frac{m_{sw} (100-p_4)}{100} \]

where

- \( m_3 \) = mass of mixing water to be added (g) (Note 7.6)
- \( m_2 \) = mass of dry material in test portion (g)
- \( \sum m_{sd} \) = sum of dry stabilising agent masses (g) (Note 7.7)
- \( m_{sw} \) = mass of emulsion or slurry stabilising agent (g)
- \( p_4 \) = solids content of emulsion or slurry stabilising agent (%) (Note 7.7)
- \( w_2 \) = target compaction moisture content (%)
- \( m_1 \) = mass of wet material in test portion (g)
5.5 For a system where a constituent is being diluted, calculate the mass of dilution water and the mass of residual mixing water as follows:

5.5.1 Dilution water for a system where the stabilising agent is specified in terms of percentage by mass:

\[ m_4 = m_s \times DF \]

where
- \( m_4 \) = mass of dilution water (g)
- \( m_s \) = mass of each stabilising agent (g)
- \( DF \) = dilution factor (Note 7.8)

5.5.2 Dilution water for a system where the agent is specified in terms of a rate per unit volume:

\[ m_4 = v_s \times DF \]

where
- \( m_4 \) = mass of dilution water (g)
- \( v_s \) = volume of each stabilising agent (mL)
- \( DF \) = dilution factor (Note 7.8)

5.5.3 Residual mixing water:

\[ m_3 = m_3 - m_4 \]

where
- \( m_3 \) = mass of residual mixing water (g)
- \( m_3 \) = mass of mixing water to be added (g)
- \( m_4 \) = mass of dilution water (g)

6 Procedure

Test portions are to be mixed in turn with the required amount of stabilising agent and any admixture, then conditioned prior to compaction as follows (Note 7.9):

6.1 Weigh or measure the quantity of each stabilising agent separately. Measure out separately the required mass of mixing water, mass of dilution water and mass or volume of admixture. When an admixture is to be used, include this as part of the mixing water. Add any dilution water to the constituent being diluted.

6.2 Lime stabilising agent

This subsection details the process for incorporation of lime where a two day mixing process would be used in the field.

6.2.1 Spread one of the test portions on the mixing tray and distribute half of the lime evenly over its surface. Thoroughly mix the lime to a uniform colour with the host material.

6.2.2 Add half of the mixing water to the material in small increments and combine thoroughly to form a uniform mixture (Note 7.10).
6.2.3 Ameliorate the mixture as follows:
   a) Compact the mixture in an appropriately sized mould in approximately 40 mm layers using one-half standard compactive effort.
   b) Demould the compacted material and seal it in plastic wrapping and place in an air curing environment overnight at 23± 2ºC.

6.2.4 Repeat Steps 6.2.1 to 6.2.3 for each test portion.

6.2.5 At the end of the conditioning period, unwrap the materials, break up the mixture and add the remaining lime and mixing water by repeating Steps 6.2.1 and 6.2.2 for each portion.

6.2.6 Condition the mixture as follows:
   a) Place the mixture into a curing container using hand pressure to consolidate the mixture. Cure the mixture for the expected field delay time, measured from the start of mixing to the commencement of compaction or from mixing of the lime to the incorporation of other stabilising agents.
   b) Otherwise, put the mixture aside to condition for 45 minutes, timed from when the remaining mixing water was first added to the mixture of host material and stabilising agent.

6.2.7 At the end of the conditioning period the mixture is ready for moulding.

6.3 Dry stabilising agent

This subsection details the process for incorporation of dry stabilising agents (such as cement, cement/flyash blends, cement/slag blends, lime/flyash, lime/slag and so on) where a one day mixing process would be used in the field.

6.3.1 Spread one of the test portions on the mixing tray and distribute the stabilising agent evenly over its surface. Thoroughly mix the agent with the material to a uniform colour. Where more than one agent is used, it may be advantageous to mix the stabilising agents together before adding them to the material.

6.3.2 Add any admixture to the mixing water and incorporate the water with the material in small increments, combining thoroughly to form a uniform mixture. If a fluid stabilising agent is also to be added, withhold a small quantity of water to be used in that operation.

6.3.3 Incorporate any fluid stabilising agent as per Subsection 6.4, otherwise place the mixture in an airtight container and put it aside to condition for 45 minutes, timed from when the mixing water was first added to the mixture of host material and stabilising agent(s).

6.3.4 Repeat Steps 6.3.1 to 6.3.3 for each test portion.

6.4 Fluid stabilising agent

6.4.1 Spread one of the test portions on the mixing tray and add most of the residual mixing water to the material in small increments while withholding a small quantity of water for rinsing the stabilising agent container. Combine the water with the material to a uniform mixture.

6.4.2 Again spread the test portion on the mixing tray and pour the diluted stabilising agent evenly over its surface. Rinse the stabilising agent container with the remaining mixing water and thoroughly mix the agent and water with the material to a uniform colour.

6.4.3 Repeat Step 6.4.2 for each fluid stabilising agent, if appropriate.
6.4.4 Place the mixture(s) in an airtight container and put aside to condition for 45 minutes, timed from when the mixing water was first added to the mixture of host material and stabilising agent(s).

6.4.5 Repeat Steps 6.4.1 to 6.4.4 for each test portion.

7 Notes on method

7.1 The balance referred to is suitable for most applications where stabilising agent is being added to material. The balance used must have a resolution which displays to one significant figure more than the mass being weighed and a limit of performance commensurate with the resolution.

7.2 A mechanical form of apparatus may be used provided the essential dimensions are adhered to and the rammer has a free vertical fall of the correct height with blows being uniformly distributed and in keeping with any prescribed cycle of blows. It is also essential that the design of the machine is such that the mould can be attached to a level and rigid support base.

7.3 Before handling any stabilising agents or admixtures, the operator must consult the relevant Safety Data Sheet (SDS).

7.4 Admixtures may be used in conjunction with cementitious stabilising agents such as cement and blended cement. The amount used is normally related to the stabilising agent type and content.

7.5 When non-water based liquid stabilising agents are used, for example, cutback bitumen, no allowance is made here for its contribution to mixture fluidity when determining the mass of mixing water.

7.6 It is necessary to make some allowance for loss of moisture due to hydration and/or during mixing. This allowance will depend on the type of material under test, the stabilising agent content and the ambient conditions in the laboratory. This allowance shall be added to the calculated mass of water ($m_{w}$).

7.7 The formula provides for more than one dry solids stabilising agent as well as one agent which contains both solids and water. If there is more than one stabilising agent containing solids and water, this formula will need to be modified accordingly. Where there are no dry solids, the value of $m_{sd}$ is zero.

7.8 The dilution factor will depend on the mixability of the agent with the material to provide a uniform mixture. A value of about 2 is generally used for bitumen emulsion.

7.9 Before incorporation of the stabilising agent(s), medium and high plasticity materials must be at a significant moisture content (say 50 percent of OMC) to allow thorough and uniform incorporation of the stabilising agent(s).

7.10 Where other stabilising agents are to be added later, use only sufficient water to bring the lime mixture to the approximate optimum moisture content for the mixture.
### Table 1 - Dimensions and tolerances for suitable moulds and rammer

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Dimension</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Moulds</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mould A: 105 diameter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal diameter (mm)</td>
<td>105.0</td>
<td>± 0.5 *</td>
</tr>
<tr>
<td>Effective height (mm)</td>
<td>115.5</td>
<td>± 0.5 *</td>
</tr>
<tr>
<td>Nominal volume (cm³)</td>
<td>1000</td>
<td>± 15</td>
</tr>
<tr>
<td>Mould B: 152 mm diameter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal diameter (mm)</td>
<td>152.0</td>
<td>± 1.0 *</td>
</tr>
<tr>
<td>Effective height (mm)</td>
<td>132.5</td>
<td>± 0.5 *</td>
</tr>
<tr>
<td>Nominal volume (cm³)</td>
<td>2400</td>
<td>± 35</td>
</tr>
<tr>
<td><strong>Rammer</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter, round foot (mm)</td>
<td>50</td>
<td>± 0.4</td>
</tr>
<tr>
<td>Area of rammer (mm²)</td>
<td>1964</td>
<td>± 31</td>
</tr>
<tr>
<td>Drop (mm)</td>
<td>300</td>
<td>± 2.0 ‡</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>2.7</td>
<td>± 0.01 ‡</td>
</tr>
<tr>
<td>Energy delivered per blow (J)</td>
<td>7.94</td>
<td>± 0.08</td>
</tr>
<tr>
<td>Number of layers</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Number of blows/layer: Mould A</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Mould B</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Energy input (kJ/m³)</td>
<td>596</td>
<td>± 14</td>
</tr>
</tbody>
</table>

* Either but not both of the tolerances may be exceeded provided that the specified tolerance on volume is not exceeded.

‡ Either but not both of the tolerances may be exceeded provided that the appropriate tolerance on energy delivered per blow is not exceeded.
Test Method Q135B: Curing moulded specimens of stabilised material

1 **Source**
This method was developed in-house using techniques evolved through internal departmental research investigations.

2 **Scope**
This method describes the procedures for curing laboratory and field moulded specimens containing stabilising agents under standard conditions. The procedure provides for the curing of specimens which are demoulded before testing.

3 **Apparatus**
The following apparatus is required:

3.1 **Air curing environment:**
3.1.1 Cabinet or environmental room for curing unsealed specimens, capable of maintaining a temperature of 23 ± 2°C and a relative humidity ≥ 95%, or
3.1.2 Cabinet or environmental room for curing sealed or moulded specimens, capable of maintaining a temperature of 23 ± 2°C, or
3.1.3 Water bath for curing sealed or moulded specimens, with a lid and raised floor to keep the specimens clear of the water. With the lid closed, the bath must be capable of maintaining a temperature of 23 ± 2°C.

3.2 **Immersed water curing environment:**
3.2.1 Water bath, of sufficient depth to immerse the demoulded specimen in water and capable of maintaining a temperature of 23 ± 2°C during immersion.

3.3 **Air drying environment:**
3.3.1 Cabinet or environmental room for curing specimens, capable of maintaining a temperature of 23 ± 2°C and a relative humidity of 50 ± 5%.

3.4 **Heavy duty plastic wrapping (polyethylene), capable of sealing specimens against moisture loss.**
3.5 **Heavy duty plastic bags (polyethylene), capable of sealing specimens against moisture loss.**
3.6 **Cable ties, elastic bands or other suitable means for sealing the plastic bags.**
3.7 **Paper, wet for wrapping specimens to maintain a moist specimen during curing.**
3.8 **Water and a spray bottle for misting specimens.**
3.9 **Sample extractor, such as a jack, lever frame or other device suitable for extruding compacted specimens from nominal 100 mm and 150 mm diameter moulds.**

4 **Procedure**
The procedure shall be as follows:

4.1 At the completion of moulding, seal all moulds using plastic wrapping or plastic bags to prevent moisture loss (Note 5.1).
4.2 For specimens which are to be demoulded before testing, proceed as follows:

a) Place the moulded specimens in a cabinet, room or bath as specified in Step 3.1 and maintain a temperature of 23 ± 2°C for 18 to 24 hours (Note 5.2).

b) At the completion of this initial curing, carefully demould the specimens ensuring that specimen damage is minimised.

c) For demoulded specimens which are to be air cured as specified in Table 1, prepare as follows:

i. for unsealed specimens to be placed in a cabinet or room specified in Step 3.1.1, place the specimens on a transfer plate for ease of handling

ii. for sealed specimens to be placed in a cabinet, room or bath specified in Step 3.1.2 or 3.1.3
   - lightly mist the specimens with water or wrap in wet paper
   - seal the specimens in plastic wrapping or place in a plastic bag and seal the bags
   - place the specimens on a transfer plate for ease of handling.

4.2.1 Cure both demoulded and moulded specimens at the standard curing conditions specified in Table 1. Where specimens are to be subjected to water curing or air drying, remove any paper, plastic bags or plastic wrapping. For CBR specimens a filter paper is to be placed on the specimen. Place a stem and perforated plate together with a soaking weight on to the filter paper for the duration of the air curing and immersed water curing.

4.2.2 At the completion of curing, remove any paper, plastic bags or wrapping to prepare the specimens for testing (Note 5.3).

5 Notes on method

5.1 The moulded specimens may either be placed in plastic bags and sealed, wrapped in plastic and sealed or plastic placed over the open end of the mould and secured in place using the compaction collar, elastic bands or cable ties.

5.2 If the moulded specimens are not prone to damage during early demoulding and handling, specimens may be demoulded soon after compaction. However, where material loss, delamination or change of shape is likely to occur, specimens must first be initially cured in their moulds for at least 18 to 24 hours. Where longer mould curing is opted for, as in the case of extremely fragile material, the total duration of curing shall not exceed that which is indicated in Table 1.

5.3 Specimens should be tested immediately to prevent moisture loss.

Table 1 – Standard curing conditions

<table>
<thead>
<tr>
<th>Stabilising agent</th>
<th>Test type*</th>
<th>Curing duration and conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement and cementitious blends**</td>
<td>Standard UCS, RLT and CR</td>
<td>(i) 1 day air curing in mould</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(ii) 6 days air curing</td>
</tr>
<tr>
<td></td>
<td>Unsoaked CBR</td>
<td>7 days air curing in mould</td>
</tr>
<tr>
<td></td>
<td>Soaked CBR</td>
<td>(i) 3 days air curing in mould</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(ii) 4 days immersed water curing in mould</td>
</tr>
</tbody>
</table>
### Test Method Q135B: Curing moulded specimens of stabilised material

<table>
<thead>
<tr>
<th>Stabilising agent</th>
<th>Test type*</th>
<th>Curing duration and conditions</th>
</tr>
</thead>
</table>
| Lime, lime/flyash, lime/dlag | Standard UCS, RLT and CR | (i) 1 day air curing in mould  
(ii) 27 days air curing |
|                          | Long term immersion UCS | (i) 1 day air curing in mould  
(ii) 6 days air curing  
(iii) 21 days immersed water curing |
|                          | Unsoaked CBR         | 28 days air curing in mould |
|                          | Soaked CBR           | (i) 24 days air curing in mould  
(ii) 4 days immersed water curing in mould |
| Bituminous emulsion      | Standard UCS, RLT and CR | (i) 1 day air curing in mould  
(ii) 13 days air drying |
| Bituminous emulsion/ cement | Standard UCS, RLT and CR | (i) 1 day air curing in mould  
(ii) 6 days air curing  
(iii) 7 days air drying |

* Test type abbreviations are as follows:  
UCS = Unconfined Compressive Strength (Q115)  
CBR = California Bearing Ratio (Q113C)  
RLT = Repeat Load Triaxial (Q137)  
CR = Capillary Rise (Q125D)

** Blends with supplementary cementitious material, for example, flyash, slag.

*** Lime may be replaced with cement or cement with supplementary cementitious material, for example, flyash, slag.

Superseded
Test Method Q136: Working time of stabilised materials

1 Source

This method applies the principles of Roads and Maritime Services, New South Wales Test Method T147: Working time for road construction materials (Blended in the laboratory with slow setting binders).

2 Scope

This method describes the procedure to determine the allowable working time of compacted specimens of soil and crushed rock materials which have been either modified or stabilised with a stabilising agent or are in their natural state. The method has particular application as part of a laboratory design procedure.

Test specimens are prepared by compacting passing 19.0 mm material by standard or modified compactive effort. Where density/moisture parameters are not directly specified, standard compactive effort is to be used. The additive content used will usually be the design additive content.

3 Definitions

3.1 Allowable working time is the time within which compaction and trimming of the stabilised material is to be completed, measured from the commencement of incorporation (that is, mixing) of stabilising agent into the unstabilised material to completion of compaction and trimming.

4 Apparatus

Where appropriate, the working tolerances of particular apparatus are contained in Table 1.

The following apparatus is required:

4.1 Mould assembly (Mould A), comprising a cylindrical metal mould having an internal diameter of 105 mm and an effective height of 115.5 mm, fitted with a detachable baseplate and a removable collar assembly about 60 mm high, both of which can be firmly attached to the mould.

4.2 Steel rammer or alternatively, a mechanical compactor may be used provided that it meets the essential requirements of drop height, mass and energy input (Note 10.1).

4.3 Level rigid foundation on which to compact the specimen, for example, a sound concrete floor about 100 mm or more in thickness or a concrete block of at least 100 kg mass.

4.4 Balances:

4.4.1 Balance of suitable capacity, with a resolution of at least 1 g and with a limit of performance within the range of ± 5 g.

4.4.2 Balance of suitable capacity to weigh stabilising agents, with a resolution of at least 0.1 g and with a limit of performance within the range of ± 0.5 g (Note 10.2).

4.5 Sieves, 19.0 mm and 9.50 mm complying with AS 1152.

4.6 Material height gauge. A flat steel bar, about 250 mm long, 25 mm wide and 1-3 mm thick is satisfactory (Note 10.3).

4.7 Steel straightedge, about 250 mm long, 25 mm wide and 3 mm thick, preferably with one bevelled edge.
4.8 Sample extractor, such as a jack, lever frame or other suitable device for extruding compacted specimens from the mould.

4.9 Calliper, with a resolution not exceeding 0.1 mm and complying with AS 1984 or JIS B 7507.

4.10 Capping jig, suited to 105 mm diameter specimens and complying with the requirements of AS 1012.9.

4.11 CBR machine, fitted with a moveable lower platen which travels at a uniform vertical upward rate of 1 mm/min when measured loaded and with an upper platen which has a spherical seat.

4.12 Force measuring device, at least Class C as defined in AS 2193 for that part of its operating range which corresponds to the maximum force applied to any test specimen. It shall be equipped with an indicator of a resolution not exceeding 25 N.

4.13 Engineer’s square, with a minimum blade length of 100 mm.

4.14 Mixing apparatus, such as a tray, trowel or scoop and water sprayer.

5 **Materials**

The following materials are required:

5.1 Capping compound, special high-strength cementitious material such as dental plaster or a low heat mortar (Note 10.4).

5.2 Mould oil, a light oil such as Caltex Mould Oil 20 (Note 10.4).

6 **Sample preparation**

The samples shall be prepared as follows:

6.1 Prepare the bulk sample as detailed in Section 5 of Test Method Q101 to produce a representative subsample of appropriate size. It may be necessary to partially dry the bulk sample before preparation so that the material is sufficiently dry to allow uniform mixing of the stabilising agent with the host material.

6.2 Further prepare the material by screening the subsample on a 19.0 mm sieve as detailed in Test Method Q101, Steps 6.2.1 to 6.2.3. Ensure that any aggregations are broken up to pass a 9.50 mm sieve.

6.3 Prepare the required number of unconfined compressive strength (UCS) compaction test portions as well as a single test portion for determining hygroscopic moisture content as detailed in Test Method Q101, Steps 6.2.4 to 6.2.6. Each UCS compaction test portion must be of sufficient quantity to mould three specimens and provide a subsample for determining the compaction moisture content (Note 10.5). Determine the mass of each test portion \( \text{m}_i \).

6.4 Where the working time moulding moisture content and dry density are not specified, prepare sufficient additional test portions to undertake dry density/moisture relationship (MDR) testing as detailed in Test Method Q142A or Q142B as appropriate (Note 10.6).

6.5 Determine the hygroscopic moisture content \( \text{m}_j \) of the single test portion prepared in Step 6.3 as detailed in Test Method Q102A.

7 **Working time**

7.1 **Determination of working time**

7.1.1 Adopt a reference working time of 1 hour \( \text{T}_R \).
7.1.2 Select at least 4 different working times \((T_i)\) greater than 1 hour for each sample that will provide at least two dry density determinations before and after the allowable working time (Note 10.7).

7.2 Compaction of specimens

7.2.1 Using the test portions prepared in Step 6.3 compact three specimens as detailed in Test Method Q115 Subsection 6.2 as follows:

a) record the date and time the mixing of test portion, stabilising agent(s) and water is commenced.

b) condition the mixture in an airtight container for the selected working time \((T_i)\).

c) remove the conditioned mixture from the container and mould the three specimens as detailed in Test method Q115 Subsection 6.2 within ± 15 minutes of the selected working time (Note 9.8).

d) record the time the moulding of the test portion is completed.

e) calculate the achieved dry density for each specimen as detailed in Test Method Q145A Subsection 7.1.

f) calculate the mean achieved dry density for each nominated working time \((MDD_R, MDD_i)\).

g) Retain each test specimen in the mould, de-mould and cure as detailed in Test Method Q135B.

7.2.2 Repeat Step 7.2.1 for each additional working time \((T_i)\).

7.3 Unconfined Compressive Strength

7.3.1 Determine the UCS of each test specimen compacted and cured in Subsection 5.2 for each working time as detailed in Test Method Q115 Sections 8 to 11.

7.3.2 Calculate the mean UCS for each working time \((UCS_R, UCS_i)\).

8 Calculations

8.1 Working time for MDD

8.1.1 Calculate the maximum dry density at the working time as follows:

\[
MDD_{TL} = 0.97 \times MDD_R
\]

where \(MDD_{TL}\) = maximum dry density at the working time \((t/m^3)\)

\(MDD_R\) = reference maximum dry density \((t/m^3)\)

8.1.2 Plot the curing time for the compacted specimens against the corresponding \(MDD_i\). Draw a smooth curve of best fit through the resulting points (Refer to Figure 1).

8.1.3 From the plot determine the time in hours corresponding to and record as the working time for MDD \((WT_{MDD})\).
8.2 Working time for UCS

8.2.1 Calculate the unconfined compressive strength at the working time as follows:

\[ \text{UCS}_{TL} = 0.80 \times \text{UCS}_R \]

where

- \( \text{UCS}_{TL} \): unconfined compressive strength at working time (MPa)
- \( \text{UCS}_R \): reference unconfined compressive strength (MPa)

8.2.2 Plot the curing time for the compacted specimens against the corresponding \( \text{UCS}_I \). Draw a smooth curve of best fit through the resulting points (Refer to Figure 2).

8.2.3 From the plot determine the time in hours corresponding to and record as the Working Time for UCS (\( \text{WT}_{UCS} \)).

8.3 Allowable working time

8.3.1 Calculate the Allowable Working Time (\( \text{AWT} \)) as the lower value of \( \text{WT}_{MDD} \) and \( \text{WT}_{UCS} \).

9 Reporting

Report the following values and general information:

9.1 Working time for MDD to the nearest 0.5 hours.

9.2 Working time for UCS to the nearest 0.5 hours.

9.3 The allowable working time (\( \text{AWT} \)) to the nearest 0.5 hours.

9.4 Compaction standard used, that is, standard or modified.

9.5 General Information:

a) Source and description of the host material.

b) Source and type of the stabilising agent(s).

c) Percentage of stabilising agent(s) used.

10 Notes on method

10.1 A mechanical form of apparatus may be used provided the essential dimensions are adhered to and the rammer has a free vertical fall of the correct height with blows being uniformly distributed and in keeping with any prescribed cycle of blows. It is also essential that the design of the machine is such that the mould can be attached to a level and rigid support base.

10.2 The balance referred to is suitable for most applications where stabilising agent is being added to the material. The balance used must have a resolution which displays to one significant figure more than the mass being weighed and a limit of performance commensurate with the resolution.

10.3 A material height gauge which allows monitoring of the height of compacted material relative to the top of a Mould A can be made from a steel bar and marked as follows:

10.3.1 Commencing at one end of the bar, measure and mark distances of:

a) 5.5 mm for the upper range of the third layer
b) 33.5 to 38.5 mm for the acceptable range of the second layer, and
c) 72.5 to 77.5 mm for the acceptable range of the first layer.

10.3.2 Mark the face with the appropriate mould size (A).

10.4 Before handling capping compounds or oil, the operator must consult the relevant Safety Data Sheet (SDS).

10.5 A test portion mass of 10 kg will be adequate for most materials. A gravel may, however, require up to 12 kg while it may be possible to use as low as 8 kg for a heavy clay.

10.6 Usually four test portions are sufficient for each Q142A or Q142B test. For most materials, 2.5 kg should be adequate for each test portion mass. A gravel may, however, require up to 3 kg while it may be possible to use as low as 2 kg for a heavy clay.

10.7 The usual working times will be 1, 2, 4, 8 and 24 hours. However for slower setting additives such as lime/flyash it may be necessary to use 4, 8, 24, and 48 hours. The principle to be followed in selecting time intervals is they should adequately define the curve and there should be at least two points before and after the allowable working time.

10.8 When mixing and conditioning more than one test portion, the work must be sequenced such that both the time for conditioning and the time to completion of compaction are recognised. These times are measured from when the first increment of water is added to the mixture of material and stabilising agent.

Table 1 - Dimensions and tolerances for suitable mould and rammers

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Dimension</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mould</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mould A: 105 diameter</td>
<td>105.0</td>
<td>± 0.5 *</td>
</tr>
<tr>
<td>Internal diameter (mm)</td>
<td>105.0 ± 0.5 *</td>
<td></td>
</tr>
<tr>
<td>Effective height (mm)</td>
<td>115.5 ± 0.5 *</td>
<td></td>
</tr>
<tr>
<td>Nominal volume (cm³)</td>
<td>1000 ± 15</td>
<td></td>
</tr>
<tr>
<td><strong>Rammer (standard)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter; round foot (mm)</td>
<td>50 ± 0.4</td>
<td></td>
</tr>
<tr>
<td>Area of rammer (mm²)</td>
<td>1964 ± 31</td>
<td></td>
</tr>
<tr>
<td>Drop (mm)</td>
<td>300</td>
<td>± 2.0 ‡</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>2.7 ± 0.01 ‡</td>
<td></td>
</tr>
<tr>
<td>Energy delivered per blow (J)</td>
<td>7.94 ± 0.08</td>
<td></td>
</tr>
<tr>
<td>Number of layers</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Number of blows/layer: Mould A</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Energy input (kJ/m³)</td>
<td>596 ± 14</td>
<td></td>
</tr>
<tr>
<td><strong>Rammer (modified)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter; round foot (mm)</td>
<td>50 ± 0.4</td>
<td></td>
</tr>
<tr>
<td>Area of rammer (mm²)</td>
<td>1964 ± 31</td>
<td></td>
</tr>
<tr>
<td>Drop (mm)</td>
<td>450 ± 2.0 ‡</td>
<td></td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>4.9 ± 0.01 ‡</td>
<td></td>
</tr>
<tr>
<td>Energy delivered per blow (J)</td>
<td>21.62 ± 0.08</td>
<td></td>
</tr>
</tbody>
</table>

*Superseded*
Test Method Q136: Working time of stabilised materials

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Dimension</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of layers</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Number of blows/layer: Mould A</td>
<td>42</td>
<td></td>
</tr>
<tr>
<td>Energy input (kJ/m³)</td>
<td>2703</td>
<td>± 60</td>
</tr>
</tbody>
</table>

* Either but not both of the tolerances may be exceeded provided that the specified tolerance on volume is not exceeded.
‡ Either but not both of the tolerances may be exceeded provided that the appropriate tolerance on energy delivered per blow is not exceeded.

Figure 1 – Working time for Maximum Dry Density
Figure 2 – Working time for Unconfined Compressive Strength
Test Method Q137: Permanent deformation and resilient modulus of unbound material

1 Source

This method applies the principles of AS 1289.6.8.1: Methods of testing soils for engineering purposes - Soil strength and consolidation tests - Determination of the resilient modulus and permanent deformation of unbound pavement materials.

This method was developed in-house using techniques evolved through internal departmental research investigations into the characterization of material performance since 2000. The primary differences between this method and other approaches are:

i) testing three specimens at a nominated density over a range of moisture contents (expressed in terms of the degree of saturation of the specimen). In examining the permanent deformation responses of the specimens at different degrees of saturation, the extent of the sensitivity to moisture changes for a material can be assessed

ii) applying a constant stress ratio of 750/125 kPa to each specimens for 100,000 cycles of load/unload, and

iii) performing the test under undrained conditions with pore pressure measurements.


2 Scope

This method covers the determination of the permanent deformation and the resilient modulus of an unbound material (maximum particle size not exceeding 19 mm) under the action of cyclic vertical loading. This is measured using repeated load triaxial equipment.

A minimum of three specimens of unbound material are prepared to a nominated dry density or relative compaction and to a moisture content corresponding to a target degree of saturation. The degree of saturation (DOS) target values for all three specimens should be selected such that there is an adequate range over which to compare the performance of the specimens.

Each specimen is subjected to 100,000 cycles of loading and unloading using a constant vertical stress, under undrained conditions, at a constant confining pressure. The permanent deformation and pore water pressure responses to loading and the resilient modulus properties of the material are measured under these conditions.

3 Apparatus

The following apparatus is required:

3.1 Dynamic loading equipment capable of applying a vertical dynamic force of up to 10 kN and a static confining pressure of up to 500 kPa (generally an incompressible fluid such as water is used as the confining medium). A general arrangement is shown in Figure 1. The equipment shall meet the following requirements:

3.1.1 The vertical dynamic force loading cycle shall have a period of 3 seconds with rise and fall times of up to 0.3 seconds and load pulse width of 1 second (Figure 2).

3.1.2 The device for vertical load measurement shall meet the requirements of AS 2193 for Class A testing machines. A load measuring device that can be operated from within the triaxial cell is
Test Method Q137: Permanent deformation and resilient modulus of unbound material

recommended for the determination of the modulus for the specimen (for example, internal submersible load cell).

3.1.3 The loading equipment shall be capable of providing at least 100,000 vertical load cycles continuously.

3.1.4 The static confining pressure shall be controllable within 5 kPa of the required applied pressure and shall be measured at the base of the triaxial cell using a device which meets the accuracy requirements of AS 1349 for industrial gauges.

3.1.5 Standard triaxial cell for 100 mm diameter samples, with a working pressure of at least 500 kPa.

3.1.6 A porous plate to be in contact with the specimen and the base pedestal of the standard triaxial cell. The porous plates shall be made of silicon carbide, aluminium oxide, sintered bronze or other materials which are not attacked by soil or soil moisture. The plates shall be sufficiently rigid to withstand the pressures applied without changes in physical properties. The plates shall be sufficiently fine so that soil will not extrude into the pores, but shall be sufficiently coarse so as to have a permeability appreciably greater than the soil sample.

3.1.7 Vertical displacement measuring device with a range of 20 mm meeting the accuracy and repeatability requirements for a Grade B extensometer as defined in AS 1545.

3.1.8 Distance measuring device for measuring the length and diameter of each specimen to an accuracy of ± 0.2%.

3.1.9 Computer and data acquisition equipment capable of recording the data from the load, displacement, and pore water pressure measuring devices to the required accuracy.

3.2 Sieves, 19.0 mm and 9.50 mm complying with AS 1152.

3.3 Compaction apparatus meeting the requirements of Q145A.

3.4 Cylindrical split metal mould capable of producing a specimen 100 ± 1 mm diameter and 200 ± 2 mm high with a collar of sufficient height to permit the filling of the mould in layers with loose soil prior to compaction.

3.5 Seamless rubber membrane in the form of a tube, open at both ends, of internal diameter equal to that of the specimen and length about 50 mm greater than that of the specimen and of 0.3 mm to 0.60 mm thickness. For materials with an appreciable proportion of coarse grained particles, a thickness of 0.6 mm is recommended to reduce the risk of membrane rupture during testing.

3.6 Membrane stretcher to suit the size of specimen.

3.7 Rubber rings of circular cross-section to suit the diameter of the end caps.

3.8 Balance of suitable capacity, having a resolution of at least 0.1 g and with a limit of performance within the range of ± 0.5 g.

3.9 Sealable containers suitable for curing moist samples.

4 Sample preparation

The sample shall be prepared as follows:

4.1 Prepare the bulk sample as detailed in Section 5 of Test Method Q101 to produce a representative subsample of at least 100 kg.
4.2 Further prepare the material by screening the subsample on a 19.0 mm sieve as detailed in Test Method Q101, Steps 6.2.1 to 6.2.3. Ensure that any aggregations are broken up to pass a 9.50 mm sieve and any oversize material is retained.

4.2.1 Where oversize is retained on the 19.0 mm sieve, determine its mass ($m_{ow}$) and the mass of the passing 37.5 mm (undersize) material ($m_{uw}$). Calculate the percentage oversize on a wet mass basis as follows:

$$P_{ow} = \frac{100m_{ow}}{m_{ow} + m_{uw}}$$

where
- $P_{ow}$ = percentage by wet mass of oversize
- $m_{ow}$ = wet mass of oversize (g)
- $m_{uw}$ = wet mass of undersize (g)

4.3 Discard any material retained on the 19.0 mm sieve.

4.4 Prepare representative test portions as follows:
   a) a minimum of 3 test portions of 6000 g for repeated load triaxial testing and determine the mass of each test portion ($m_1$)
   b) a test portion for hygroscopic moisture content
   c) a test portion for apparent particle density
   d) a suitable number of test portions to determine the optimum moisture content (OMC) and maximum dry density (MDD).

4.5 Determine the hygroscopic moisture content ($W_1$) of the test portion prepared in Step 4.4 b) as detailed in Test Method Q102A.

4.6 Determine the apparent particle density ($\rho_{st}$) of the test portion prepared in Step 4.4 c) as detailed in Test Method Q109.

4.7 Determine the optimum moisture content (OMC) and maximum dry density (MDD) of the test portion prepared in Step 4.4 d) as detailed in the relevant test method from Test Methods Q142A or Q142B as appropriate using a Type A mould.

5 Preparation of test specimens

Prepare the test specimens as follows:

5.1 Curing

5.1.1 For each test portion calculate the dry mass of material as follows:

$$m_2 = \frac{100m_1}{100 + W_1}$$

where
- $m_2$ = mass of dry material in test portion (g)
- $m_1$ = mass of wet material in test portion (g)
Test Method Q137: Permanent deformation and resilient modulus of unbound material

\[ w_1 = \text{hygroscopic moisture content (\%)} \]

5.2 Using the procedure detailed in Test Method Q145A, calculate the target compaction moisture content \( (w_2) \) to achieve the nominated relative compaction and nominated relative moisture content or nominated degree of saturation.

5.2.1 For each test portion calculate the mass of mixing water to be added as follows:

\[
m_3 = \frac{(m_2 \times w_2)}{100} - (m_1 - m_2)
\]

where

- \( m_3 \) = mass of mixing water to be added (g)
- \( m_2 \) = mass of dry material in test portion (g)
- \( w_2 \) = target compaction moisture content (\%)
- \( m_1 \) = mass of wet material in test portion (g)

5.2.2 Measure out the required mass of mixing water to be added \( (m_3) \).

5.2.3 Spread out the test portion on the mixing tray and add the mixing water to the material in small increments and combine thoroughly to form a uniform mixture (Note 9.1).

5.2.4 After mixing place the mixture into a curing container to cure for an adequate period of time for the material (Note 9.2).

5.3 Compaction

Compact the test specimens as follows:

5.4 Undertake all necessary calculations, mould preparation and compaction of the test portion as detailed in Test Method Q145A. For portions requiring standard compaction the test portion will be compacted in six layers. For portions requiring modified compaction the test portion will be compacted in ten layers.

5.5 Where the achieved degree of saturation of a compacted specimen varies from the target degree of saturation value by greater than ± 4.0%, discard the specimen and repeat the preparation to Q145A for the required target placement conditions. Similarly, where the achieved dry density varies from the specified target dry density by > 0.02 t/m³, discard the specimen and repeat the preparation to Q145A.

5.6 For non-cohesive material, the specimen is likely to collapse during demoulding (or extrusion) from the mould. For these circumstances, the mould may be lined with a rubber or plastic membrane to hold the sample together after demoulding. Corrections for the mass and volume of the membrane shall be made (Note 9.3). If the membrane is punctured during compaction, a second membrane will be required for the test.

6 Repeat load triaxial testing

Perform the repeat load triaxial testing as follows:

6.1 Specimen assembly

6.1.1 Place the triaxial cell base on the platform of the loading machine.
6.1.2 Ensure the pore water pressure port is filled with water and free of air.

6.1.3 Place a deaired porous plate on the base pedestal of the triaxial cell. A filter paper disc may be placed between the soil specimen and the porous plate.

6.1.4 Initialise the pore water pressure transducer and record the zero measurement ($\mu_1$).

6.1.5 To ensure that the test is performed undrained, ensure the back pressure port valve is closed.

6.1.6 Invert the specimen and mould and place centrally on the base pedestal such that the top face of the specimen is in contact with the pedestal. Remove the specimen from the mould by disassembling the split mould. Ensure that the specimen is not damaged during the demoulding process.

6.1.7 Measure the length ($h_4$) and diameter ($d_4$) of the specimen to the nearest 0.5 mm.

6.1.8 Place the loading cap on top of the specimen. Using the membrane stretcher, place the rubber membrane around the specimen and seal the membrane at both end platens by means of the rubber rings.

6.1.9 Assemble the triaxial cell into position ensuring that the loading ram is seated centrally in the load cap. Adjust the position of the load cell to ensure it is set up within its calibrated range and initialise the reading.

6.1.10 Attach the displacement measuring device to the loading ram so that it is set up to operate within its calibrated range and initialise the reading.

6.1.11 Initialise the confining pressure transducer reading and record the zero measurement ($\sigma_{3(1)}$). Fill the cell with de-aired water to be used for applying the confining pressure and remove any air bubbles.

6.2 Cyclic loading

Perform the cyclic loading as follows:

6.2.1 Apply and hold a confining pressure of 125 kPa to the test specimen. Record the actual confining pressure achieved ($\sigma_{3(2)}$).

6.2.2 Monitor the increase in pore water pressure until a maximum value is reached. Record the maximum pore water pressure observed ($\mu_2$).

6.2.3 Apply loading/unloading cycles (Figures 2 and 3) using a target total vertical stress of 750 kPa to the specimen for 100,000 loading cycles or until the permanent deformation of the specimen exceeds the limitations of the testing system.

6.2.4 Remove the specimen from the cell.

6.2.5 Repeat this procedure for each test specimen.

7 Calculations

7.1 For each specimen calculate as follows:

7.1.1 The achieved compacted dry density, compaction moisture content, relative compaction percentage of OMC and degree of saturation as detailed in Test Method Q145A.
7.1.2 Calculate the cross-sectional area of each specimen as follows:

\[ A = \frac{\pi d_s^2}{4} \times 10^{-6} \]

where 
- \( A \) = cross-sectional area of the specimen (\( m^2 \))
- \( d_s \) = diameter of the specimen (mm)

7.1.3 Calculate the dry density (\( \rho_d \)) of the specimen as follows:

\[ \rho_d = \frac{(m_2 - m_1) \times 10^5}{Ah_s} \times (100 + \omega) \]

where 
- \( \rho_d \) = dry density of the specimen (t/m³)
- \( m_2 \) = the mass of specimen, mould and collar, and baseplate if applicable (g)
- \( m_1 \) = the mass of the mould and collar, and baseplate if applicable (g)
- \( A \) = cross-sectional area of the specimen (m²)
- \( h_s \) = the height of the specimen (mm)
- \( \omega \) = moisture content of the specimen (%)

7.1.4 Calculate the pore pressure coefficient (\( B \)) for the initial application of confining pressure as follows:

\[ B = \frac{\mu_2 - \mu_1}{\sigma_{3(2)} - \sigma_{3(1)}} \]

where 
- \( B \) = pore pressure coefficient
- \( \mu_1 \) = initial pore water pressure (kPa)
- \( \mu_2 \) = maximum pore water pressure after application of confining pressure, prior to the commencement of loading cycles (kPa)
- \( \sigma_{3(1)} \) = initial confining pressure (kPa)
- \( \sigma_{3(2)} \) = maximum applied confining pressure (kPa)

7.1.5 Calculate the deviator stress (\( \sigma_{d(n)} \)) at any loading cycle (n), where recordings are made as follows:

\[ \sigma_{d(n)} = \sigma_{1(n)} - \sigma_{3(n)} = \left( \frac{F}{A} \right) - \sigma_{3(n)} \left[ \frac{1 - (A - a)}{A} \right] \]

where 
- \( \sigma_{d(n)} \) = the deviator stress for that cycle (Notes 9.4, 9.5 and 9.6) (kPa)
\( \sigma_{1(n)} \) = the maximum vertical stress applied to the specimen (Notes 9.4, 9.5 and 9.6) for that cycle (kPa)

\( \sigma_{3(n)} \) = the confining stress applied to the specimen (kPa)

\( F_v \) = the vertical force applied to the loading ram (kN)

\( A \) = the cross-sectional area of the specimen (m²)

\( a \) = the cross-sectional area of the loading ram (m²)

7.2 For the resilient modulus at the completion of each loading cycle \((n)\), calculate as follows:

7.2.1 The gauge length \( l_{g(n)} \) over which the resilient deformation is measured (Note 9.6) for that cycle as follows:

\[
\frac{l_{g(n)}}{l_i} = 1 - \left( \frac{\delta_{4(n-1)}}{\delta_1} \right)
\]

where

- \( l_{g(n)} \) = gauge length over which the deformation is measured for that cycle (mm)
- \( l_i \) = the initial gauge length, that is, the initial height of the specimen \( (h_s) \) (mm)
- \( \delta_{4(n-1)} \) = vertical displacement with the confining stress \( (\sigma_3) \) applied and the vertical force \( F_v \), released for the previous cycle (mm)
- \( \delta_1 \) = vertical displacement at the commencement of the test with no confining stress \( (\sigma_3) \) and no vertical force \( (F_v) \), applied (mm) (Figure 3)
- \( n \) = the cycle number

7.2.2 The resilient vertical strain \( \varepsilon_{r(n)} \) as follows:

\[
\varepsilon_{r(n)} = \frac{\delta_{3(n)} - \delta_{4(n)}}{l_{g(n)}} \times 100
\]

where

- \( \varepsilon_{r(n)} \) = resilient vertical strain (%)
- \( \delta_{3(n)} \) = vertical displacement with the confining stress and the deviator stress applied (mm)
- \( \delta_{4(n)} \) = vertical displacement with the confining stress applied and the deviator stress released (mm) (Figure 3)
- \( l_{g(n)} \) = gauge length over which the deformation is measured for that cycle (mm)

7.2.3 The resilient modulus \( E_{r(n)} \) at the nth cycle as follows:

\[
E_{r(n)} = \frac{\sigma_{\delta_3(n)}}{\varepsilon_{r(n)}} \times 10^{-1}
\]
where \( E_{r(n)} \) = the resilient modulus at that cycle (MPa)
\( \sigma_{d(n)} \) = the deviator stress at that cycle (kPa)
\( \varepsilon_{r(n)} \) = the resilient vertical strain at that cycle (%)

7.3 For the permanent vertical strain (\( \varepsilon_{p(n)} \)) at any loading cycle (n), calculate as follows:

\[
\varepsilon_{p(n)} = \frac{(\delta_{4(n)} - \delta_2)}{l_1} \times 100
\]

where \( \varepsilon_{p(n)} \) = permanent vertical strain at that cycle (%)
\( \delta_{4(n)} \) = vertical displacement with the continuing stress applied and the deviator stress released (mm) (Figure 3)
\( \delta_2 \) = vertical displacement when the confining stress is first applied (mm)
\( l_1 \) = the initial gauge length, that is, the initial height of the specimen (\( h_s \)) (mm)

8 Reporting

Report the following values and general information:

8.1 Specimen preparation details, including the method of placement and drainage conditions.
8.2 The percentage of oversize material retained on 19.0 mm sieve.
8.3 For each specimen, the achieved dry density, achieved moisture content, target relative compaction, achieved relative compaction, nominated relative moisture content as a percentage of OMC, achieved percentage of OMC, nominated degree of saturation and achieved degree of saturation as detailed in Test Method Q145A.
8.4 The nominal vertical stress and the nominal confining stress applied to the specimen to the nearest 1 kPa.
8.5 The pore pressure coefficient to the nearest 0.01.
8.6 The values of the parameters below for the following nominal loading cycle counts; 1, 100, 1000, 5000, 10000, 25000, 50000, 75000, and 100,000:
   - cycle number (n).
   - permanent strain to the nearest 0.01%.
   - resilient strain to the nearest 0.01%.
   - resilient modulus to the nearest 10 MPa.
   - pore water pressure to the nearest 1 kPa.
8.7 Plots of the permanent strain, resilient strain, resilient modulus and pore water pressure as a function of the cycle number (n).
9 Notes on method

9.1 It is important that water is thoroughly mixed into the material and the test portion cured for sufficient time to allow the water to become evenly distributed throughout the material.

9.2 For a material prepared in a moist condition close to optimum moisture content, periods up to 2 hours may be adequate. However, if the material contains dry clay, periods of up to 7 days may be required. Thus, more cohesive materials will need longer curing times.

9.3 Membrane correction - where significant axial strains occur (that is, >2%) or multiple membranes are used, membrane corrections may be significant and should be applied to the calculation of the deviator stress, as detailed in Reference 1.

9.4 Loading system - the contribution of the cell pressure to the vertical stress will be dependent on the loading system used. The calculation for deviator stress is for a rigid loading system. For a flexible loading system, a secondary force may be required throughout the duration of the test to ensure the loading ram is firmly in contact with the top loading cap. This secondary force should be taken into account when calculating the deviator stress.

9.5 Area correction - for samples which suffer significant vertical and lateral deformation (that is >2%) (that is samples prepared near OMC), an area correction (AS 1289:6.4.1) should be applied to accurately calculate the dry stresses applied to the specimen.

9.6 Specimen length - to determine the resilient strain, and hence the resilient modulus, in real time, the gauge length used modulus determination at any cycle \( n \), is the gauge length at the completion of the previous cycle \( n-1 \).

Figure 1 – Schematic of typical repeated load triaxial test apparatus
Figure 2 - Illustration of the vertical force waveform

Figure 3 - Illustration of terms
Test Method Q138: Preparation and compaction of foamed bitumen stabilised material

1 Source

This method was developed in-house but utilises test specimen compaction based on Q305: Stability, Flow and Stiffness of Asphalt (Marshall) and applies it to the preparation and compaction of foamed bitumen stabilised materials.

2 Scope

This method describes the procedure for laboratory preparation, mixing and compaction of foamed bitumen stabilised materials. The method has particular application as a laboratory design procedure but can also be used to prepare test field-mixed specimens in order to check field processes.

In both the laboratory and field, test specimens are compacted using passing 19.0 mm material and the Marshall apparatus.

3 Apparatus

Where appropriate the working tolerances of particular apparatus are contained in Table 1.

The following apparatus is required:

3.1 Foaming equipment

3.1.1 Suitable foaming equipment, capable of manufacturing foamed bitumen able to meet the required specification (Note 8.1).

3.1.2 Metal container for checking the flow of foamed bitumen, having an internal diameter of 300 mm, a depth of 280 mm and a capacity of 15 litres.

3.1.3 Oven of suitable capacity, capable of heating bitumen to 180°C.

3.1.4 Oven of suitable capacity, having a temperature of 35-45°C and complying with AS 1289.0.

3.1.5 Drying oven of suitable capacity, having a temperature of 105-110°C and complying with AS 1289.0.

3.1.6 Mechanical mixing equipment, for example, pugmill or catering style dough mixer capable of mixing foamed bitumen samples.

3.1.7 Suitable tools for removing all materials from mixer such as a mallet, spatula and scoop.

3.2 Compaction equipment

3.2.1 Cylindrical steel or brass compaction mould having an internal diameter of 150 mm, a height of 89 mm and a thickness of 8 mm; a mould base with a thickness of 18 mm and an extension collar having an internal diameter of 150 mm, a height of 70 mm and a thickness of 8 mm. The mould shall have a removable base which fits the compaction pedestal.

3.2.2 Hand compaction hammer, consisting of a flat circular tamping face having a diameter of 149.0 mm, and a sliding weight with a mass of 9.92 kg and a free fall of 460 mm (Note 8.2).

3.2.3 Hand compaction pedestal, consisting of the following:

   a) a wooden block, of approximate dimensions 200 mm square and 450 mm thick, capped by a steel plate of approximate dimensions 300 mm square and 25 mm thick. The air dry density of the wooden block shall be 720 kg/m³. The plate shall be securely attached to the block which shall be secured to a solid concrete floor or slab. Suitable guides for
restraining the compaction mould and locating the compaction hammer centrally during compaction may be attached to the block, or

b) a concrete block, of approximate dimensions 360 mm square and 610 mm thick. Suitable guides for restraining the compaction mould and locating the compaction hammer centrally during compaction may be attached to the block, or

c) a steel post (circular or square cross-section), of approximate dimensions 150 mm diameter/square and 620 mm thick. Suitable guides for restraining the compaction mould and locating the compaction hammer centrally during compaction may be attached to the block.

3.2.4 Specimen extrusion jack, consisting of a hydraulic jack fitted with a plate on the ram and located within a metal frame. The dimensions of the plate shall be 148 mm diameter and 12 mm thick for 150 mm diameter test specimens. The frame shall retain the mould during extrusion of a test specimen.

3.3 Balance of suitable capacity, having a resolution of at least 0.1 g and with a limit of performance within the range of ± 0.5 g.

3.4 Sieves, 19.0 mm and 9.50 mm, complying with AS 1152.

3.5 Stopwatch with a resolution not exceeding 0.1 seconds.

3.6 Riffing equipment.

3.7 Callipers, with a resolution not greater than 0.1 mm complying with AS 1984 or JIS B1904.

3.8 Container for storing manufactured material.

4 Materials

The following materials are required (Note 8.3):

4.1 Bitumen, Class 170 sampled from a bulk supply and free of cutter, flux or other additives.

4.2 Foaming additive (Teric 311 or equivalent).

4.3 Hydrated lime.

4.4 GP Cement.

4.5 Potable water.

4.6 Filter paper (Whatman No. 1 or equivalent).

5 Sample preparation

The sample shall be prepared as follows:

5.1 Laboratory mixing

5.1.1 Prepare the bulk sample as detailed in Section 5 of Test Method Q101 to produce a representative sample of at least 80 kg.

5.1.2 Further prepare the material by screening the subsample on a 19.0 mm sieve as detailed in Test Method Q101, Steps 6.2.1 to 6.2.3. Ensure that any aggregations are broken up to pass a 9.50 mm sieve. Discard any material retained on the 19.0 mm sieve.
5.1.3 Prepare representative test portions as follows:
   a) a minimum of two test portions of 13,000 g for foamed bitumen testing and determine the mass of each test portion \( m_1 \) (Note 8.4)
   b) a test portion for hygroscopic moisture content
   c) a suitable number of test portions to determine the optimum moisture content (OMC) and maximum dry density (MDD).

5.1.4 Determine the hygroscopic moisture content \( w_1 \) of the test portion prepared in Step 5.1.3 b) as detailed in Test Method Q102A.

5.1.5 Determine the optimum moisture content (OMC) and maximum dry density (MDD) using the test portions prepared in Step 5.1.3 c) as detailed in Test Methods Q142A or Q142B as appropriate using a Type A mould.

5.2 Field mixing

5.2.1 Sample the field mixed material as soon as possible after the completion of mixing and seal the bulk sample in an airtight container for transport to the moulding location.

5.2.2 Prepare the sample on a 19.0 mm sieve as detailed in Test Method Q101, Steps 6.2.1 to 6.2.3. Ensure any moisture loss is minimised and any aggregations are broken up to pass a 9.5 mm sieve. Discard the material retained in the 19.0 mm sieve.

5.2.3 Prepare a compaction test portion, as detailed in Test Method Q101, Steps 6.2.4 to 6.2.6, of sufficient quantity to compact three specimens and provide a subsample for determining the compaction moisture content (Note 8.4).

5.2.4 Place the test portion in an airtight container(s) and put aside to condition for 45 minutes, timed from when field mixing was commenced.

5.2.5 Compact the specimens as detailed in Subsection 7.3.

6 Calculation of mix quantities

6.1 For each foamed bitumen test portion:

6.1.1 Using the procedure detailed in Test Method Q135A with nominated dry stabilising agent content \( p_1 \), calculate the dry mass of each test portion \( m_2 \) and mass of stabilising agent (lime or cement) \( m_3 \).

6.1.2 Calculate the target compaction moisture content as follows:

\[
\begin{align*}
    w_2 &= \text{OMC} \frac{\text{RM}_n}{100} \\
    \text{where} & \quad w_2 = \text{target compaction moisture content (\%)} \\
    \text{OMC} &= \text{optimum moisture content (\%)} \\
    \text{RM}_n &= \text{nominated relative moisture content as a percentage of OMC (\%)} \\
    \text{(Note 8.5)}
\end{align*}
\]
6.1.3 Calculate the mass of mixing water to be added as follows:
\[ m_3 = \frac{m_2 w_2}{100} - (m_1 - m_2) + 30p_1 \]

where
- \( m_3 \) = mass of mixing water to be added (g)
- \( m_2 \) = mass of dry material in test portion (g)
- \( w_2 \) = target compaction moisture content (%)
- \( m_1 \) = mass of wet material in test portion (g)
- \( p_1 \) = stabilising agent content (lime and/or cement) (%)

6.1.4 Calculate the mass of bitumen required as follows:
\[ m_b = \frac{(1+LF)m_2 p_2}{100} \]

where
- \( m_b \) = mass of bitumen (g)
- \( LF \) = loss factor (usually 0.0125) (Note 8.6)
- \( m_2 \) = mass of dry material in test portion (g)
- \( p_2 \) = stabilising agent content (bitumen) (%)

6.1.5 Calculate the mass of foaming agent (if required) as follows (Note 8.8):
\[ m_{fa} = 0.005m_b \]

where
- \( m_{fa} \) = mass of foaming agent (g)
- \( m_b \) = mass of bitumen (g)

7 Production of test specimens

The test specimens shall be produced as follows:

7.1 Preparation of foaming apparatus

7.1.1 Before foaming it is necessary to conduct trials for each batch of bitumen to determine the optimum mass flow of bitumen and foamant water flow to achieve a minimum expansion ratio of 10 and half-life of 20 seconds (Note 8.8).

7.1.2 Preheat the bitumen in an oven to 100°C (Note 8.9).

7.1.3 Preheat the foaming apparatus to about 140°C (this usually takes about 20 minutes).

7.1.4 Transfer the hot bitumen from the oven to the foaming apparatus. Turn on the bitumen pump and circulate while heating the bitumen to 180°C.

7.1.5 Add the foaming agent, if required, to the foaming apparatus and continue circulating the bitumen for approximately 10-15 minutes before commencing the production of foamed bitumen.
7.1.6 Using the metal container, check to ensure the foaming apparatus will discharge 500 g of bitumen and adjust the bitumen pump timer if necessary.

7.2 Foaming and mixing

7.2.1 Add the dry material to the mixer and distribute the dry additive (lime or cement) evenly over the surface of the dry materials.

7.2.2 Mix the dry material and dry additive for 2 minutes adding the mixing water gradually to the mixer.

7.2.3 Discharge the material from the mixer and transfer to suitable airtight storage containers and allow to condition for 45 minutes.

7.2.4 Return the material to the mixer and mix the material for a further 2 minutes.

7.2.5 Move the mixer adjacent to the foaming apparatus and add the mass of bitumen as foam to the mixer.

7.2.6 Move the mixer away from the foaming apparatus and continue mixing for a further 2 minutes.

7.2.7 Transfer the material from the mixer to a suitable storage container(s). A rubber mallet, spatula and scoop may be used to assist with loosening material adhering to the interior of the mixer.

7.2.8 Prepare a minimum of three test portions as detailed in Test Method Q101, Steps 6.2.1 to 6.2.3, of sufficient quantity to produce a specimen of 60-80 mm in height (Note 8.10).

7.2.9 Obtain a subsample of the mixture and determine the achieved compaction moisture content \( w \) as detailed in Test Method Q102A.

7.3 Compaction

7.3.1 Position a paper disc on the base plate within the assembled mould and collar.

7.3.2 Transfer the prepared material to the mould and level the surface taking care to avoid segregation.

7.3.3 Position another paper disc on the top surface of the material.

7.3.4 Transfer the compaction mould to the compaction pedestal and compact the mix using 50 blows of the compaction hammer at a rate of 60 to 70 blows per minute with the hammer axis held vertically.

7.3.5 Remove the collar and base plate, discard the filter papers, then reassemble the compaction mould with the test specimen inverted.

7.3.6 Apply a further 50 blows of the compaction hammer at a rate of 60 to 70 blows per minute with the hammer axis held vertically.

7.3.7 Extrude the sample from the mould using the specimen extrusion device.

8 Notes on method

8.1 A Wirtgen WLB 10 S has been found to be suitable.

8.2 Where a mechanical compactor is used instead of the hand compactor, the mass, free fall and design of the hammer foot should be identical to those of the hand compaction hammer and the automatic compactor should be securely anchored to a base.

8.3 Before handling bitumen, foaming additive, hydrated lime or cement, the operator must consult the relevant Safety Data Sheet (SDS).
8.4 The combined test portion mass of 26 kg will be adequate for most materials. This is required to ensure the mixer has sufficient material to mix effectively and ensure the foamed bitumen can be incorporated with minimal loss. For field mixed materials a sample mass of 15 kg will be adequate for most materials.

8.5 A nominated relative moisture content of 70% for standard compaction and 85% for modified compaction have been found to be appropriate.

8.6 The loss factor allows for the binder retained within the mixer.

8.7 Foaming agent volume of 0.5% by mass of bitumen has been found to be adequate for most materials.

8.8 Further information on optimising the mass flow of bitumen and foamant water flow may be found in the Wirtgen GmbH, Cold Recycling Manual, 2012.

8.9 Bitumen may be heated overnight at 100°C before transferring to the foaming machine.

8.10 A compaction portion mass of 2500 g will be adequate for most materials.

*Table 1 - Dimensions and tolerances for suitable moulds*

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Dimension</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal diameter (mm)</td>
<td>149.95</td>
<td>± 0.05</td>
</tr>
<tr>
<td>Effective height (mm)</td>
<td>270</td>
<td>approximate</td>
</tr>
<tr>
<td>Mould finish (μm) (inside)</td>
<td>0.4</td>
<td>maximum</td>
</tr>
<tr>
<td>Mould hardness (Rockwell C)</td>
<td>48</td>
<td>minimum</td>
</tr>
</tbody>
</table>
Test Method Q139: Resilient modulus of stabilised material - indirect tensile method

1 Source
This method was developed in-house but applies the principles of AS/NZS 2891.13.1 – Determination of the resilient modulus of asphalt – Indirect tensile method to the testing of foamed bitumen stabilised materials.

2 Scope
This method describes the procedure for laboratory determination of the resilient modulus using repeat load indirect tensile techniques to determine foamed bitumen mix design properties.

The method may be used to test both field mixed and laboratory mixed specimens prepared using Test Method Q138. It may also be used to test cored specimens removed by dry coring.

3 Definition of terms
Resilient horizontal deformation is defined as the difference between the peak horizontal deformation associated with a load pulse and the horizontal deformation at the end of the rest time of that load pulse.

4 Apparatus
Where appropriate the working tolerances of particular apparatus are contained in Table 1.

The following apparatus is required:

4.1 Testing machine, a pneumatic or hydraulic testing machine that is capable of applying an approximately triangular shaped or haversine load pulse with a rise time (defined as the time required for the load pulse to rise from 10% to 90% of the peak force) in the range of 0.025 to 0.1 seconds with an accuracy of ± 0.005 seconds. The machine shall be capable of applying load pulses with peak load adjustable over the range 0.4 kN to 3.9 kN with an accuracy of ± 0.05 kN. The pulse repetition period shall be adjustable over the range 0.5 seconds to 10 seconds ± 0.005 s (Refer to AS 2891.13.1 Figure 1 for pulse shapes). The machine shall be capable of applying this load pulse for at least 10 cycles for each specimen.

4.2 Temperature cabinet, a temperature-controlled cabinet that is capable of holding the loading frame, at least three test specimens and a dummy specimen and with sufficient internal space to permit adjustment of the frame, displacement measuring devices and specimens. The cabinet shall be capable of maintaining a temperature of 25°C ± 0.5°C and shall be fitted with an external device which indicates the temperature inside the cabinet.

4.3 Measuring and recording apparatus, consisting of:

a) A load-measuring device of at least 3.9 kN capacity, meeting the requirements of an AS 2193 Class B testing machine when calibrated statically.

b) A displacement measuring device meeting the requirements of an AS 1545 Grade B extensometer for gauge lengths equal to the diameter of the specimen, with a range of at least 100 μm for measurement of horizontal displacements for each pulse and capable of being held in contact with the specimen during the complete test. The device shall be capable of being anchored to the specimen through 114” UNF bolts to which a torque of approximately 250 mN.m will be applied.
c) A recorder able to read and record the individual measurements of load, temperature and the peak horizontal deformation after application of a pulse and the horizontal deformation at the end of the pulse.

4.4 Plano-cylindrical-concave steel loading blocks, 125 mm long blocks which are flat on the loading surface, and curved on the surface in contact with the specimen. The thickness of the blocks, measured at the thinnest section, between the concave surface and the flat surface on the other side shall be not less than 18 mm. The width of the loading blocks as measured from tip to tip of the concave face, and the radius of curvature are shown in Table 1. At each end of the blocks there shall be a hole to accommodate the locating bolts.

4.5 Callipers, with a resolution not greater than 0.1 mm complying with AS 1984 or JIS B1904.

4.6 Temperature measuring devices, readable to 0.1°C with an uncertainty not greater than 0.2°C at the required test temperature.

4.7 Torque screwdriver, complying with AS 4115, with minimum range 0.1 N.m to 1 N.m and readable to 10 mN.m.

4.8 Oven, of suitable capacity, having a temperature of 40 ± 5.0°C and complying with AS 1289.0.

4.9 Environmental cabinet, a temperature-controlled cabinet that is capable of holding at least three test specimens. The cabinet shall be capable of maintaining a temperature of 25°C ± 0.5°C and shall be fitted with an external device which indicates the temperature inside the cabinet.

4.10 Vacuum apparatus and chamber.

4.11 Container for soaking specimens.

5 Materials

The following materials are required:

5.1 Potable water.

5.2 Cloths for removing excess water from vacuum soaked specimens.

6 Specimen preparation

6.1 Laboratory mixed specimens

6.1.1 Prepare the material as detailed in Test Method Q138 to obtain at least three specimens (Note 10.1) for testing as follows:

- Initial modulus – Three specimens, to be stored in the environmental cabinet at 25 ± 0.5°C after compaction for 3 ± 0.5 hours. After the air curing, measure and test as detailed in Steps 7.1 to 7.5.

- Three day cured modulus – Three specimens, retained after the determination of initial modulus, to be stored at 40 ± 5.0°C for 72 ± 2.0 hours. Remove specimens from the oven and allow them to equilibrate to the test temperature in the environmental cabinet at 25 ± 0.5°C for 2 hours. Test as detailed in Steps 7.1.4 to 7.5.

- Soaked modulus – Three specimens, retained after the determination of three day cured modulus, to be placed in a container and covered with potable water at 25 ± 0.5°C. Place in the vacuum chamber and apply a partial vacuum of 13 kPa or less absolute pressure for 10 minutes (Note 10.2). After the vacuum soaking remove the specimens from the water and remove excess water. Test as detailed in Steps 7.1.4 to 7.5.
6.2 Field mixed specimens
6.2.1 Prepare the material as detailed in Test Method Q138 to obtain at least three specimens (Note 10.1) for testing as follows:
   • As received modulus – Specimens, to be stored in the environmental cabinet at 25 ± 0.5°C after preparation for 3 ± 0.5 hours. After the air curing, measure and test as detailed in Steps 7.1 to 7.5 (Note 10.1).
   • Three day cured modulus (optional) – Three specimens, retained after compaction, to be stored at 40 ± 5.0°C for 72 ± 2.0 hours. Remove specimens from the oven and allow them to equilibrate to the test temperature in the environmental cabinet at 25 ± 0.5°C for 2 hours. Test as detailed in Steps 7.1.4 to 7.5.
   • Soaked modulus – Three specimens, retained after the determination of three day cured modulus, to be placed in a container and covered with potable water at 25 ± 0.5°C. Place in the vacuum chamber and apply a partial vacuum of 13 kPa or less absolute pressure for 10 minutes (Note 10.2). After the vacuum soaking remove the specimens from the water and remove excess water. Test as detailed in Steps 7.1.4 to 7.5.

6.3 Core specimens
6.3.1 Obtain at least three core samples about 150 mm diameter from the pavement as detailed in Test Method Q070.
6.3.2 Prepare the core sample as detailed in Q303A Subsection 4.2 without air drying to obtain three specimens between 60.0 to 80.0 mm in height for testing as follows:
   • As received modulus – Specimens, to be stored in the environmental cabinet at 25 ± 0.5°C after preparation for 3 ± 0.5 hours. After the air curing, measure and test as detailed in Steps 7.1 to 7.5 (Note 10.1).
   • Soaked modulus – Specimens, retained after the determination of initial modulus, to be placed in a container and covered with potable water at 25 ± 0.5°C. Place in the vacuum chamber and apply a partial vacuum of 13 kPa or less absolute pressure for 10 minutes (Note 10.2). After the vacuum soaking remove the specimens from the water and remove excess water. Test as detailed in Steps 7.1.4 to 7.5.

7 Testing of specimens

Measure and test the specimens as follows:

7.1 Initial measurements and conditioning
7.1.1 Mark two diameter lines at right angles to each other on one end of the specimen and a corresponding pair on the opposite end of the specimen.
7.1.2 Measure the two marked diameters of the specimen at each end of the specimen ($d_1$). Calculate the mean diameter of the specimen ($D$).
7.1.3 Measure the height of the specimen at each of the four marked locations where the diameter markings intersect the circumference ($h_1$). Calculate the mean height of the specimen ($h$).
7.1.4 Place the first specimen in the loading apparatus, ensuring that the diametral markings are vertical and horizontal.
7.1.5 Place the displacement measuring apparatus on the specimen along the horizontal diametral marking to measure the horizontal deformation of the curved surfaces.
7.1.6 Anchor the apparatus on the flat surfaces of the specimen with a clamping torque of approximately 250 mN.m applied to each anchoring bolt.

7.2 **Standard test conditions – laboratory and field mixed specimens**

7.2.1 Unless otherwise specified, use the following standard test conditions:
   a) Test temperature: 25°C ± 0.5°C.
   b) Rise time (10% to 90%): 0.04 ± 0.005 seconds.
   c) Pulse repetition period (10% to 10%): 3.0 ± 0.005 seconds.
   d) Recovered horizontal strain: 50 ± 20.

7.3 **Standard test conditions – cored specimens**

7.3.1 Unless otherwise specified, use the following standard test conditions:
   a) Test temperature: 25°C ± 0.5°C.
   b) Rise time (10% to 90%): 0.04 ± 0.005 seconds.
   c) Pulse repetition period (10% to 10%): 3.0 ± 0.005 seconds.
   d) Recovered horizontal strain: 20 ± 5 με.

7.4 **Preconditioning and test setting determination**

7.4.1 The test shall be performed within the range of the specified recovered horizontal strain. Calculate the peak load required to deform the specimen within that range as follows:

\[
P_c = \frac{E D h_c \varepsilon}{(\nu + 0.27)10^6}
\]

where
- \( P_c \) = peak estimated load (N)
- \( E \) = estimated resilient modulus of the specimen (MPa)
- \( D \) = mean diameter of the specimen (mm)
- \( \varepsilon \) = recovered horizontal strain (με), usually 50 ± 20
- \( h_c \) = mean height of the specimen (mm)
- \( \nu \) = Poisson ratio (estimated as 0.4)

7.4.2 Ensure that the temperature of the specimen has reached equilibrium after attaching the displacement apparatus.

7.4.3 Apply a single pulse with the specified rise time to the estimated peak load calculated above, then remove the load. Measure the recovered horizontal deformation at the end of the pulse and calculate the recovered horizontal strain as follows:

\[
\varepsilon = \frac{H}{D}
\]

where
- \( \varepsilon \) = recovered horizontal strain (με)
- \( H \) = recovered horizontal deformation (mm)
7.4.4 If the recovered horizontal strain is within the specified range, apply further preconditioning pulses at the same estimated peak load until five pulses of preconditioning have been completed.

7.4.5 If the recovered horizontal strain is not within the specified range, adjust the estimated peak load so that the recovered horizontal strain will fall within the specified range.

7.4.6 Repeat Step 7.4.3 until the specified range is obtained or until five preconditioning pulses have been completed. Record the peak load and the recovered horizontal strain for each pulse.

7.4.7 If the specified range of recovered strain is not achieved after five pulses, the resilient modulus test may be performed using the value of peak load which had a corresponding value of recovered strain closest to the specified range.

7.4.8 Report the variation from the test conditions and the values of recovered strain and resilient modulus from each of the five preconditioning pulses.

7.5 Resilient modulus test

Resilient modulus shall be determined by testing three specimens. For each specimen, the procedure shall be as follows:

7.5.1 Apply five load pulses with the specified rise time to the peak load determined from Clause 7.4 at the specified pulse repetition period.

7.5.2 Measure and record the recovered horizontal deformation after each pulse (H).

8 Calculations

8.1 Calculate the initial modulus (M_I), three day cured modulus (M_C), soaked modulus (M_s) and as received modulus (M_AR) as follows (Note 10.3):

\[ M = P \frac{(\nu + 0.27)}{H \bar{h}_c} \]

where
- M = resilient modulus (initial, three day cured, soaked, as received) (MPa)
- P = peak load (N)
- \( \nu \) = Poisson ratio (estimated as 0.4)
- H = recovered horizontal deformation (mm)
- \( \bar{h}_c \) = mean height of the specimen (mm)

8.2 Calculate the retained modulus as follows (Note 10.3):

\[ M_R = \frac{M_s}{M_C} \times 100 \]

where
- M_R = retained modulus (%)
\[ M_s = \text{soaked modulus (MPa)} \]
\[ M_C = \text{three day cured modulus (MPa)} \]

8.2.1 Calculate the average initial modulus, three day cured modulus, soaked modulus, as received and retained modulus as appropriate.

9 Reporting

Report the following values and general information:

9.1 Description of specimens, that is cores, field mixed specimens, laboratory mixed specimens.

9.2 Description of test conditions, that is test temperature, rise time, pulse repetition period and recovered horizontal strain and any variations to the standard conditions.

9.3 Test temperature to the nearest 1°C.

9.4 Mean height of each specimen to the nearest 0.1 mm.

9.5 Mean diameter of each specimen to the nearest 0.1 mm.

9.6 For laboratory mixed specimens:

9.6.1 Resilient modulus for each specimen and an average of all specimens as follows:

- Initial modulus to the nearest 1 MPa.
- Three day cured modulus to the nearest 1 MPa.
- Soaked modulus to the nearest 1 MPa.
- Retained modulus for each specimen to the nearest 1%.

9.7 For field mixed specimens:

9.7.1 Resilient modulus for each specimen and an average of all specimens as follows:

- As received modulus to the nearest 1 MPa.
- Three day cured modulus to the nearest 1 MPa (if required).
- Soaked modulus to the nearest 1 MPa.
- Retained modulus for each specimen to the nearest 1% (if required).

9.8 For core specimens:

9.8.1 Resilient modulus for each specimen and an average of all specimens as follows:

- As received modulus to the nearest 1 MPa.
- Soaked modulus to the nearest 1 MPa.

10 Notes on method

10.1 Additional specimens may be required to allow replacement of specimens damaged during the preconditioning and test setting determination.

10.2 A partial vacuum of 13 kPa absolute pressure is approximately equivalent to a -88 kPa reading on a vacuum gauge at sea level.

**Table 1 - Test equipment requirements**

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Requirement</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Loading blocks (150 mm dia. specimen)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Width (mm)</td>
<td>19.0</td>
<td>± 2.0</td>
</tr>
<tr>
<td>Radius of curvature of concave face (mm)</td>
<td>75.0</td>
<td>± 2.0</td>
</tr>
</tbody>
</table>

*Superseded*
Test Method Q140A: Relative compaction of soils and crushed rock

1 Source
This method applies the principles of AS 1289.5.4.1: Soil compaction and density tests - Dry density ratio, moisture variation and moisture ratio. It differs from this standard by an allowance for the determination of laboratory reference density on uncompacted material, the provision for oversize contents of up to 35% and providing for relative compaction calculation as a wet density ratio in addition to a dry density ratio.

2 Scope
This method sets out the procedure for the determination of the relative compaction of soil and crushed rock materials, including mixtures containing stabilising agent, having not more than 35% of oversize rock material retained on the 37.5 mm sieve.

The relative compaction is the ratio of compacted density of soil and crushed rock compared with a laboratory reference density and is calculated as either a wet density ratio or a dry density ratio.

Where oversize is present in the soil or crushed rock, the laboratory reference density and optimum moisture content is adjusted for this oversize component. The adjustment to the reference density is based upon the oversize content from the oversize within the laboratory sample(s) used to determine the reference density.

3 Definitions
3.1 Relative compaction (dry density ratio) is the ratio of compacted dry density to laboratory reference dry density expressed as a percentage.
3.2 Relative compaction (wet density ratio) is the ratio of compacted wet density to laboratory reference wet density expressed as a percentage.
3.3 Relative moisture content is the ratio of in situ moisture content to the laboratory optimum moisture content expressed as a percentage.
3.4 Allowable working time is the time within which compaction and trimming of the stabilised material is to be completed, measured from the commencement of incorporation (that is, mixing) of stabilising agent into the unstabilised material to completion of compaction and trimming.

4 Procedure
Determine the laboratory reference density and compacted density as follows:

4.1 Laboratory reference density
Assign or use previously assigned values of maximum dry density, optimum moisture content and, where appropriate, the density and percentage of oversize.

Where assigned values have either not been developed or are impractical, sample and test for laboratory reference density as detailed in Step 4.1.3.

4.1.1 New assigned values
Obtain samples of uncompacted material and if necessary, stabilising agents and assign values of maximum dry density, optimum moisture content and the density and percentage of any oversize as detailed in Test Method Q144A.
4.1.2 Previously assigned values

Confirm and monitor the applicability of previously assigned values using the Assigned Values Check procedure detailed in Test Method Q144A.

4.1.3 One-for-one testing

a) Select sampling and test locations within the lot under consideration using Random Stratified Sampling: Selection of Location – Available Area (unless otherwise specified) as detailed in Test Method Q050.

b) Obtain samples as detailed in Test Method Q061 and test for laboratory reference density, percentage of oversize and oversize density as follows:

i. For pavement materials excluding stabilised materials:
   • Obtain samples of compacted material following the field testing operations for the compacted density test (refer to Subsection 4.2).
   • Determine the laboratory reference density for each sample as detailed in Test Method Q142A or Q142B as appropriate.

ii. For earthworks materials excluding stabilised materials:
   • Obtain samples of compacted material following the field testing operations for the compacted density test (refer to Subsection 4.2).
   • Determine the laboratory reference density for each sample as detailed in Test Method Q142A, Q142B or Q142C as appropriate.

iii. Stabilised materials:
   • Obtain samples of uncompacted material after spreading and the incorporation of all stabilising agents and water, but before the start of compaction.
   • Determine the laboratory reference density for each sample as detailed in Test Method Q142A or Q142B as appropriate.
   • The process of obtaining the sample, preparation and compaction of the test portions must be completed within the allowable working time for the stabilising agent (Note 7.1 and Table 1).

4.2 Compacted density

4.2.1 Select test locations within the lot under consideration using Random Stratified Sampling: Selection of Location – Available Area (unless otherwise specified) as detailed in Test Method Q050. Where one-for-one testing is being performed, use the locations determined in Step 4.1.3.

4.2.2 At each of the test locations determine the in situ moisture content and/or compacted density as detailed in Test Method Q141A or Q141B as appropriate.
5 Calculations

5.1 Where a reference dry density is used, calculate as follows:

5.1.1 Adjust the laboratory reference density for oversize material as follows (Note 7.2):

\[
LRD_{da} = \frac{100}{\frac{100-P_{ad}}{\rho_{ad}} + \frac{P_{ad}}{\rho_{ad}}} \frac{\rho}{r LRD_d}
\]

where
- \( LRD_{da} \) = adjusted laboratory reference dry density (t/m³)
- \( P_{ad} \) = percentage of oversize (dry basis)
- \( r \) = interference factor (Table 2)
- \( LRD_d \) = laboratory reference dry density, either maximum dry density or assigned maximum dry density (t/m³)
- \( \rho_{ad} \) = density of oversize (dry basis) (t/m³)

5.1.2 Adjust the laboratory optimum moisture content for oversize material as follows (Note 7.3):

\[
OMC_a = OMC \left(1 - \frac{P_{ad}}{100}\right)
\]

where
- \( OMC_a \) = adjusted laboratory optimum moisture content (%)
- \( OMC \) = optimum moisture content assigned or obtained in the laboratory reference test (%)
- \( P_{ad} \) = percentage of oversize (dry basis)

5.1.3 Determine the relative compaction as follows:

\[
RC_d = \frac{100\rho_d}{LRD_{da}}
\]

where
- \( RC_d \) = relative compaction (dry density ratio) (%)
- \( \rho_d \) = compacted dry density (t/m³)
- \( LRD_{da} \) = adjusted laboratory reference dry density (t/m³) (Note 7.2)

5.1.4 Determine the relative moisture content as follows:

\[
RM_d = \frac{100w}{OMC_a}
\]

where
- \( RM_d \) = relative moisture content (%)
- \( w \) = in situ moisture content (%) 
- \( OMC_a \) = adjusted laboratory optimum moisture content (%) (Note 7.3)

5.1.5 Where a number of tests have been performed on a lot, calculate the minimum characteristic relative compaction as detailed in Test Method Q020.
5.2 Where a reference wet density is used, calculate as follows:

5.2.1 Adjust the laboratory reference density for oversize material as follows (Note 7.2):

\[
LRD_{wa} = \frac{100}{100-P_{ow} + P_{ow} + r} \frac{\rho_{mcw}}{\rho_{ow}}
\]

where

- \( LRD_{wa} \) = adjusted laboratory reference wet density (t/m³)
- \( P_{ow} \) = percentage of oversize (wet basis)
- \( r \) = interference factor (Table 2)
- \( \rho_{mcw} \) = maximum converted wet density (t/m³)
- \( \rho_{ow} \) = density of oversize (wet basis) (t/m³)

5.2.2 Adjust the laboratory optimum moisture content for oversize material as follows (Note 7.3):

\[
OMC_a = OMC_e \frac{100-P_{ow}}{100}
\]

where

- \( OMC_a \) = adjusted laboratory optimum moisture content (%)
- \( OMC_e \) = estimated optimum moisture obtained in the laboratory reference test (%)
- \( P_{ow} \) = percentage of oversize (wet basis)

5.2.3 Determine the relative compaction as follows:

\[
RC_w = \frac{100 \rho_w}{LRD_{wa}}
\]

where

- \( RC_w \) = relative compaction (wet density ratio) (%)
- \( \rho_w \) = compacted wet density (t/m³)
- \( LRD_{wa} \) = adjusted laboratory reference wet density (t/m³) (Note 7.2)

5.2.4 Determine the relative moisture content as follows:

\[
RM_w = \frac{100w}{OMC_a}
\]

where

- \( RM_w \) = relative moisture content (%)
- \( w \) = in situ moisture content (%)
- \( OMC_a \) = adjusted laboratory optimum moisture content (%) (Note 7.3)

5.2.5 Where a number of tests have been performed on a lot, calculate the minimum characteristic relative compaction as detailed in Test Method Q020.
6 Reporting

Report the following values and general information for each test location within the lot:

6.1 Relative compaction in terms of dry density ratio or wet density ratio to the nearest 0.1%.
6.2 Relative moisture content to the nearest 1%, if required.
6.3 Adjusted laboratory reference dry or wet density to the nearest 0.001 t/m³.
6.4 The maximum dry density or maximum converted wet density to the nearest 0.001 t/m³ and, in the case of maximum dry density, whether the value was assigned.
6.5 The optimum moisture content or estimated optimum moisture content to the nearest 0.1% and whether the value was assigned.
6.6 Density of dry or wet oversize to the nearest 0.001 t/m³ and, when calculated on a dry basis, whether the value was assigned.
6.7 Percentage of dry or wet oversize to the nearest 1% and, when calculated on a dry basis, whether the value was assigned.
6.8 The sieve on which the oversize material is retained (19.0 mm or 37.5 mm).
6.9 Date when the laboratory reference density (maximum dry density or maximum converted wet density) was either assigned or determined.
6.10 Compacted dry or wet density to the nearest 0.001 t/m³.
6.11 In situ moisture content to the nearest 0.1%, if required.
6.12 The minimum characteristic relative compaction as detailed in Test Method Q020, if required.
6.13 The maximum characteristic relative compaction as detailed in Test Method Q020, if required.

7 Notes on method

7.1 For a stabilising agent not listed in Table 1 or where a project specific allowable working time is required, determine the allowable working time as detailed in Test Method Q136.
7.2 Where there is no oversize present in the material, \( \text{LRD}_{da} = \text{LRD}_d \) and \( \text{LRD}_{wa} = \text{LRD}_w \), as applicable.
7.3 Where there is no oversize present in the material, \( \text{OMC}_a = \text{OMC} \) and \( \text{OMC}_a = \text{OMC}_c \), as applicable.

Table 1 - Allowable working time for stabilising agents

<table>
<thead>
<tr>
<th>Stabilising agent</th>
<th>Allowable working time (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GP cement</td>
<td>2</td>
</tr>
<tr>
<td>GB cement (flyash)</td>
<td>4</td>
</tr>
<tr>
<td>Foamed bitumen/Lime</td>
<td>6.5</td>
</tr>
<tr>
<td>Lime</td>
<td>8</td>
</tr>
<tr>
<td>Lime/flyash</td>
<td>40</td>
</tr>
<tr>
<td>Foamed bitumen/GB cement</td>
<td>2.5</td>
</tr>
</tbody>
</table>
Table 2 - Oversize content and interference factor (r)

<table>
<thead>
<tr>
<th>Percentage oversize</th>
<th>Interference factor (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-20</td>
<td>1.00</td>
</tr>
<tr>
<td>21-25</td>
<td>0.99</td>
</tr>
<tr>
<td>26-30</td>
<td>0.98</td>
</tr>
<tr>
<td>31-35</td>
<td>0.97</td>
</tr>
</tbody>
</table>
Test Method Q141A: Compacted density of soils and crushed rock - nuclear gauge

This test shall be performed in accordance with Test Method N01: Compacted Density of Soils and Crushed Rock (Nuclear Gauge) contained within the department's Nuclear Gauge Testing Manual.
Test Method Q141B: Compacted density of soils and crushed rock - sand replacement

1 Source

This method is based on AS 1289.5.3.1: Soil compaction and density tests - Determination of the field density of a soil - Sand replacement method using a sand-cone pouring apparatus. It differs from this standard in the coarseness of material at which the larger template diameter is used, the range of materials tested by the method and calibration cylinder requirements.

2 Scope

The method sets out the procedure for determining the compacted wet density and, when required, the compacted dry density of fine-grained, medium-grained and coarse-grained soils and crushed rock, including mixtures containing stabilising agent, by the sand replacement method using a sand-cone pouring apparatus.

The compacted dry density for the total material of the test site is determined from measured values of compacted wet density and insitu moisture content.

3 Apparatus

Where appropriate, the working tolerances of particular apparatus are contained in Table 1.

The following apparatus is required:

3.1 Sand-cone pouring apparatus: either a sand-cone or a windshielded sand-cone comprised of a conical funnel, tap and cone with the cone being either 150 mm or 200 mm in diameter.

3.2 Template, a circular or square flat rigid metal template with raised sides and a central hole, either 150 mm or 200 mm in diameter, surrounded by a border at least 50 mm wide. The template border shall contain at least two holes for pins to secure the template.

3.3 Pins, two or more metal pins with a length and diameter that allows the template to be firmly secured to the surface under test.

3.4 Excavation equipment - hand tools such as scoop, spoon, brush, trowel, chisel and mallet. A lightweight electric hammer can be used in place of or in conjunction with a chisel and mallet.

3.5 Calibration cylinder, a metal cylinder with the same diameter as the central hole in the template. The depth of the calibration cylinder must align with the depth of hole to be excavated to within 50 mm. The minimum depth of an acceptable calibration cylinder is 40 mm.

3.6 Balance of suitable capacity, having a resolution of at least 1 g and with a limit of performance within the range of $\pm 5$ g.

3.7 Flat plate, approximately 300 mm square.

3.8 Soil containers, sealable containers of appropriate capacity.

3.9 Sand containers, translucent sealable containers of appropriate capacity.

3.10 Rule, a 300 mm long rule will service all requirements.
4 **Materials**

The following materials are required:

4.1 Density sand, clean dry one-size sand with particles approximately uniform in size, for example, 90% passing a 1.18 mm sieve and 90% retained on a 0.600 mm sieve (Note 12.1).

4.2 Modelling plasticine or other suitable material (if required).

5 **Definitions**

5.1 Fine-grained soils – soils that contain not more than 20% retained on a 2.36 mm sieve.

5.2 Medium-grained soils – soils that contain not more than 20% retained on a 19.0 mm sieve.

5.3 Coarse-grained soils – soils that contain not more than 20% retained on a 37.5 mm sieve.

6 **Test hole and significant apparatus requirements**

In order to determine the dimensions of the test hole to be excavated in the lot under test and the appropriate sizes of the template, sand-cone pouring apparatus and calibration cylinder, it is necessary to consider the following:

- Specification requirements and/or the depth of the layer
- Apparatus limitations, and
- Maximum particle size of the soil within the lot.

6.1 Determine the depth to be tested from the appropriate specification or testing methodology. Where the depth is not specified, test to the full depth of the layer up to a maximum practical test depth of 250 mm. Refer to Table 1.

6.2 Determine the test hole diameter and template size based on the particle size of the soil within the lot and the test hole depth by referring to Table 1.

6.3 Select a matched template and sand-cone pouring apparatus set having the same diameter as the test hole diameter and template size determined in Step 6.2.

6.4 Select a calibration cylinder having the same diameter as the template hole and a depth that is within 50 mm of the depth of the test hole.

7 **Calibration of apparatus**

Calibrate the sand-cone pouring apparatus and template set as well as determine the sand pouring density for the batch of density sand as follows:

7.1 **Density sand sampling**

Sample the batch of density sand by taking at least three representative samples randomly throughout the batch or one sample per 500 kg, whichever yields the greater number of samples. Record the batch identification details.

7.2 **Mass of sand in the cone and template**

7.2.1 Obtain a subsample from one of the representative density sand samples sufficient to fill the central hole in the template, the inverted cone and tap of the sand-cone pouring apparatus plus a small quantity which will remain in the funnel after pouring.

7.2.2 Transfer the sand to a sand container and determine the mass of the sand and the container ($m_1$).
7.2.3 Place the template on the flat plate and position the sand-cone pouring apparatus and sand centrally over the hole in the template.

7.2.4 Open the tap on the sand-cone pouring apparatus and allow the sand to run. When no further movement of sand takes place, close the tap. Take care that the apparatus is not disturbed or vibrated while the tap is open. There must be sand still remaining in the funnel after pouring. Remove the sand-cone pouring apparatus and return the surplus sand in the tap and funnel to the container.

7.2.5 Determine the mass of the residual sand and the container (m₂).

7.2.6 Repeat Steps 7.2.1 to 7.2.5 for each of the remaining representative samples of density sand using the same initial total mass of sand and container each time.

7.2.7 Calculate the mass of sand in the cone and template for each of the determinations as follows:

\[ m_3 = m_1 - m_2 \]

where

- \( m_3 \) = mass of sand in the cone and template (g)
- \( m_1 \) = initial total mass of sand and container (g)
- \( m_2 \) = mass of residual sand and container (g)

7.2.8 Calculate the average mass of sand in the cone and template (\( \bar{m}_3 \)) to the nearest 1 g.

7.3 Sand pouring density

7.3.1 Obtain a subsample from one of the representative density sand samples which is sufficient to fill the calibrating cylinder, central hole in the template, the inverted cone and tap of the sand-cone pouring apparatus plus a small quantity which will remain in the funnel after pouring.

7.3.2 Transfer the sand to a sand container and determine the mass of the sand and the container (m₄).

7.3.3 Place the template over the calibration cylinder such that the two holes are concentric. Position the sand-cone pouring apparatus and sand centrally over the hole in the template.

7.3.4 Open the tap on the sand-cone pouring apparatus and allow the sand to run. When no further movement of sand takes place, close the tap. Take care that the apparatus is not disturbed or vibrated while the tap is open. There must be sand still remaining in the funnel after pouring (Note 12.2). Remove the sand-cone pouring apparatus and return the sand in the tap and funnel to the container.

7.3.5 Determine the mass of the residual sand and the container (m₅).

7.3.6 Repeat Steps 7.3.1 to 7.3.5 for each of the remaining representative samples of density sand using the same initial total mass of sand and container each time.

7.3.7 Calculate the pouring density of the sand for each of the determinations as follows:

\[ \rho_s = \frac{(m_4 - m_3) - \bar{m}_3}{V} \]

where

- \( \rho_s \) = sand pouring density (t/m³)
- \( m_4 \) = initial mass of sand and container (g)
7.3.8 If the maximum variation in sand pouring densities for the batch of sand does not exceed 0.020 t/m³, calculate the average sand pouring density (ρ̅s) and record to the nearest 0.001 t/m³.

8 Test site preparation

Prepare the test site as follows:

8.1 At the designated test location, use the template to define a test site which is flat and free from large depressions such as roller marks. For earthworks, it may be necessary to trim the surface flat.

8.2 Sweep all loose material from the test site and place the template on the prepared test site. If the surface is so irregular that the sand is likely to escape under the template, fill the irregularities under the tray with modelling plasticine or other suitable material to prevent sand escaping.

8.3 Mark the location of the template on the test site.

9 Testing

Undertake testing at the prepared test site as follows:

9.1 Surface correction

9.1.1 Fill a sand container with sufficient sand to fill the surface irregularities, the central hole in the template, cone and tap of the sand-cone pouring apparatus plus a quantity which will remain in the funnel after pouring.

9.1.2 Determine the mass of sand and the container (m₁).

9.1.3 Place the sand-cone pouring apparatus and sand centrally over the hole in the template.

9.1.4 Open the tap on the sand-cone pouring apparatus and allow the sand to run. When no further movement takes place, close the tap. Take care that the apparatus is not disturbed or vibrated while the tap is open. There must be sand still remaining in the funnel after pouring.

9.1.5 Remove the sand-cone pouring apparatus and return the sand in the tap and funnel to the container.

9.1.6 Determine the mass of the residual sand and the container (mᵢ).

9.1.7 Carefully remove the template from the test site and sweep all sand from the surface occupied by the template. Ensure the test surface is not disturbed during this process.

9.1.8 Place the template on the test surface ensuring that it is in the same position and orientation as that used for the surface correction. Pin the template to the surface of the test site ensuring that it is firmly held in place.
9.2 Hole excavation

9.2.1 Fill a container with sufficient sand to fill the excavated hole, the central hole in the template, the cone and tap of the sand-cone pouring apparatus plus a quantity which will remain in the funnel after pouring.

9.2.2 Determine the mass of sand and the container \( (m_s) \).

9.2.3 Excavate a cylindrical hole to the required depth using the procedure and observing the precautions detailed below:
   a) Excavate a hole, using the hole of the template as a pattern and working from the centre. The sides of the hole must be essentially vertical.
   b) Remove all loose soil from the sides and bottom of the hole with the appropriate tools and carefully deposit the excavated soil in a sealable container, keeping it closed when not in use.
   c) During the excavation process, protect the hole and soil deposited in the container from wind and rain in order to minimise moisture change.
   d) At the completion of the excavation, seal the container and ensure that it is protected to prevent moisture and soil loss during transport and storage.

9.2.4 Measure and record the depth of the hole.

9.2.5 Position the sand pouring cone and sand centrally over the hole in the template.

9.2.6 Open the tap on the sand-cone pouring apparatus and allow the sand to run. When no further movement of sand takes place, close the tap. Take care that the apparatus is not disturbed or vibrated while the tap is open. There must be sand still remaining in the funnel after pouring (Note 12.2). Remove the apparatus and return the sand in the tap and funnel to the container.

9.2.7 Determine the mass of residual sand and the container \( (m_{1o}) \).

9.2.8 Determine the mass \( (m_{10}) \) of the excavated soil.

9.3 Foreign material

9.3.1 If foreign material, including up to two occasional large stones which are not representative of the bulk of the material being tested, are found to be included in the soil excavated from the hole, they are to be removed and an adjustment for their mass and volume made to the calculated wet density as follows:
   a) Remove each large stone, brush any fine material from the stone surface and return the fines to the container holding the excavated material.
   b) Determine the mass of foreign material \( (m_{12}) \).
   c) Determine the volume of the foreign material \( (V_s) \) directly by displacement of water in a siphon can as detailed in Test Method Q143.

9.4 Moisture content

9.4.1 Where the compacted dry density or relative moisture content is required, determine the insitu moisture content \( (w) \) in accordance with Test Method Q102A or one of the subsidiary Test Methods Q102B or Q102D for which a relationship with Test Method Q102A has been established and used in accordance with Test Method Q010.
10 Calculations

10.1 Calculate the insitu wet density to the nearest 0.001 t/m³ as follows:

\[ \rho_w = \frac{\bar{\rho}_s m_{11}}{(m_s - m_{10}) + (m_s - m_8)} \]

where
- \( \rho_w \) = insitu wet density (t/m³)
- \( \bar{\rho}_s \) = average sand pouring density (t/m³)
- \( m_{11} \) = mass of excavated soil (g)
- \( m_9 \) = mass of the sand and container before excavation (g)
- \( m_{10} \) = mass of the sand and container after excavating (g)
- \( m_7 \) = mass of the sand and container before surface correction (g)
- \( m_8 \) = mass of the sand and container after surface correction (g)

10.2 Where there is any foreign material such as occasional large stones, calculate the insitu wet density to the nearest 0.001 t/m³ as follows:

\[ \rho_w = \frac{m_{11} - m_{12}}{(m_s - m_{10}) + (m_s - m_8) - V_s} \bar{\rho}_s \]

where
- \( \rho_w \) = insitu wet density (t/m³)
- \( m_{11} \) = mass of excavated soil (g)
- \( m_{12} \) = mass of foreign material (g)
- \( m_9 \) = mass of the sand and container before excavation (g)
- \( m_{10} \) = mass of the sand and container after excavating (g)
- \( m_7 \) = mass of the sand and container before surface correction (g)
- \( m_8 \) = mass of the sand and container after surface correction (g)
- \( \bar{\rho}_s \) = average sand pouring density (t/m³)
- \( V_s \) = volume of foreign material (cm³)

10.3 Calculate the compacted dry density, as required, to the nearest 0.001 t/m³ as follows:

\[ \rho_d = \frac{100 \rho_w}{100 + w} \]

where
- \( \rho_d \) = compacted dry density (t/m³)
- \( \rho_w \) = insitu wet density (t/m³)
- \( w \) = insitu moisture content (%)
11 Reporting
Report the following values and general information:

11.1 Compacted wet density and/or compacted dry density, as appropriate, to the nearest 0.001 t/m³.

11.2 Insitu moisture content, if required, to the nearest 0.1%, the test method used and any moisture correlation report number.

11.3 Depth of hole (mm).

11.4 Layer type and depth (if known).

12 Notes on method

12.1 Alternative Sand – Other sand or grits with particles approximately uniform in size, for example, 2.36 mm to 1.18 mm or 0.600 mm to 0.300 mm sizes, may be used. The particle size of the sand used in a field density test should exceed the size of voids within the compacted material which is mostly related to the size of the largest particles compacted. The sand should be shielded at all times from any moistening, for example, rain, as the resultant bulking would invalidate volume calculations.

12.2 When using a windshielded sand-cone, it may be necessary to add more sand from the container to the funnel during pouring as the storage capacity of some windshielded sand-cones is limited.

Table 1 – Test hole and template hole diameter

<table>
<thead>
<tr>
<th>Particle size</th>
<th>Test hole and template hole diameter (mm)</th>
<th>Test hole depth (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fine, medium and coarse-grained without retained 37.5 mm stone</td>
<td>150</td>
<td>50-175*</td>
</tr>
<tr>
<td>Fine, medium and coarse-grained with retained 37.5 mm stone</td>
<td>200</td>
<td>&gt;50-250#</td>
</tr>
</tbody>
</table>

* Maximum practical depth for 150 mm template
# Maximum practical depth for 200 mm template

Superseded
Test Method Q142A: Dry density–moisture relationship of soils and crushed rock - standard

1 Source
This method is based on AS 1289.5.1.1: Soil compaction and density tests - Determination of the dry density/moisture content relation of a soil using standard compactive effort. It differs from this standard in the coarseness of material permitted and provision for the addition of stabilising agents.

2 Scope
This method sets out a procedure for the determination of the relationship between the moisture content and the dry density of a soil or a crushed rock material, including mixtures containing stabilising agents, when compacted using standard compactive effort (596 kJ/m³). Compaction is conducted over a range of moisture contents so as to establish the maximum mass of dry material per unit volume achievable for this compactive effort and its corresponding moisture content.

The procedure is applicable to that portion of a material that passes the 37.5 mm sieve. Material that all passes the 19.0 mm sieve is compacted in a 105 mm diameter mould. Material that has more than 20% rock retained on the 19.0 mm sieve is compacted in a 152 mm diameter mould. Corrections for oversize are not directly included in this method but may be made as detailed in Test Method Q140A when required for compaction control.

3 Apparatus
Where appropriate, the working tolerances of particular apparatus are contained in Table 1.

The following apparatus is required:

3.1 Metal moulds, of a size dependent on the maximum size of material being tested, as follows:

3.1.1 For compaction of material passing a 19.0 mm sieve:
Mould A: A cylindrical metal mould having an internal diameter of 105 mm and effective height of 115.5 mm, fitted with a detachable baseplate and a removable collar assembly about 60 mm high both of which can be firmly attached to the mould.

3.1.2 For compaction of material which has rock material retained on the 19.0 mm sieve:
Mould B: A cylindrical metal mould having an internal diameter of 152 mm and an effective height of 132.5 mm, fitted with a detachable baseplate and a removable collar assembly about 60 mm high both of which can be firmly attached to the mould.

3.2 Steel rammer, or alternatively a mechanical compactor may be used provided that it meets the essential requirements of drop height, mass and energy input (Note 9.1).

3.3 Level rigid foundation on which to compact the specimen, for example a sound concrete floor about 100 mm or more in thickness or a concrete block of at least 100 kg mass.

3.4 Balances:

3.4.1 Balance of suitable capacity, with a resolution of at least 1 g and with a limit of performance within the range of ± 5 g.

3.4.2 Balance of suitable capacity to weigh stabilising agents, with a resolution of at least 0.1 g and with a limit of performance within the range of ± 0.5 g (Note 9.2).

3.5 Sieves, 37.5 mm, 19.0 mm and 9.5 mm complying with AS 1152.
3.6 Strong spatula or a suitable knife.

3.7 Steel straightedge, about 250 mm long, 25 mm wide and 3 mm thick, preferably with one bevelled edge.

3.8 Miscellaneous mixing apparatus, such as a tray, trowel or scoop and water spray suitable for mixing increments of water into the material.

3.9 Material height gauge. A flat steel bar, about 250 mm long, 25 mm wide and 1-3 mm thick is satisfactory (Note 9.3).

3.10 Sealable containers, suitable for curing the material samples.

3.11 Sample extractor, such as a jack, lever frame or other device for extruding compacted specimens from the mould.

4 Materials

The following material is required:

4.1 Mould oil, a light oil such as Caltex Mould Oil 20 (Note 9.4).

5 Procedure

The procedure shall be as follows:

5.1 Prepare the bulk sample as detailed in Section 5 of Test Method Q101 to produce a representative subsample of appropriate size. For fresh mixtures of insitu stabilised materials, limit both moisture loss and time loss during preparation.

5.2 Further prepare the material by screening the subsample on a 19.0 mm sieve as detailed in Test Method Q101, Steps 6.2.1 to 6.2.3. Ensure that any aggregations are broken up to pass a 9.5 mm sieve and keep any retained 37.5 mm (oversize) rock material.

5.3 Determine the approximate percentage retained on the 19.0 mm sieve and whether any material is retained on the 37.5 mm sieve to allow the selection of the appropriate mould size as follows:

5.3.1 Where oversize is retained on the 19.0 mm sieve, determine its mass \( m_{ow} \) and the mass of the passing 19.0 mm (undersize) material \( m_{uw} \). Calculate the wet mass of material as follows:

\[
  m_w = m_{ow} + m_{uw}
\]

where

- \( m_w \) = wet mass of material (g)
- \( m_{ow} \) = wet mass of > 19.0 mm oversize material (g)
- \( m_{uw} \) = wet mass of < 19.0 mm undersize material (g)

5.3.2 Where oversize is retained on the 19.0 mm sieve, calculate the percentage oversize on a wet mass basis as follows:

\[
  p_{ow} = \frac{100 m_{ow}}{m_w}
\]

where

- \( p_{ow} \) = percentage by wet mass of > 19.0 mm oversize material
\[ m_{ow} = \text{wet mass of } > 19.0 \text{ mm oversize material (g)} \]
\[ m_w = \text{wet mass of material (g)} \]

5.3.3 If the calculated percentage oversize (\( P_{ow} \)) is greater than 20\%, screen the material retained on the 19.0 mm sieve on the 37.5 mm sieve. Where oversize is retained on the 37.5 mm sieve, determine its mass of (\( m_{ow} \)). Calculate the percentage oversize on a wet basis as follows:

\[ P_{ow} = \frac{100m_{ow}}{m_w} \]

where
\[ P_{ow} = \text{percentage by wet mass of } > 37.5 \text{ mm oversize material} \]
\[ m_{ow} = \text{wet mass of } > 37.5 \text{ mm oversize material (g)} \]
\[ m_w = \text{wet mass of material (g)} \]

5.4 If required, retain the material retained on the 19.0 mm or 37.5 mm sieve for determining the density and percentage of oversize.

5.5 Select the size fraction and mould size to be used in the compaction test using the criteria in Table 2. Record the mould used (A or B). When necessary recombine the material passing 37.5 mm portion with the material passing the 19.0 mm portion and thoroughly remix.

5.6 Prepare four or more representative portions of the sieved material as detailed in Test Method Q101, Steps 6.2.4 to 6.2.6 as follows:

5.6.1 Each test portion is to be of sufficient quantity to produce a compacted specimen in excess of the volume of the mould (Notes 9.5 and 9.6).

5.6.2 Where oversize is present and a correction to the laboratory reference dry density or optimum moisture content is required as detailed in Test Method Q140A, prepare an additional portion of the sieved material and determine its moisture content of undersize material (\( w_u \)) in accordance with Test Method Q102A or one of the subsidiary Test Methods Q102B or Q102D for which a relationship with Test Method Q102A has been established and used in accordance with Test Method Q010.

5.6.3 Where a correction to the laboratory reference dry density or optimum moisture content is required as detailed in Test Method Q140A, determine the density and percentage of any oversize as detailed in Test Method Q143, using the wet mass of oversize (\( m_{ow} \)) and wet mass of material (\( m_w \)) determined at Step 5.3.2 (Mould A) or Step 5.3.3 (Mould B) and the moisture content of undersize material (\( w_u \)) of the undersize from Step 5.6.2.

5.7 Take the portions of material prepared in Step 5.6, mix them with the stabilising agent if appropriate, and prepare each portion for compaction as follows:

5.7.1 Material only
   a) Thoroughly mix each test portion, adding or removing water so that the optimum moisture content is judged to be straddled. Use essentially equal increments of moisture between portions and ensure that the moisture steps are not excessive for the material type (Note 9.7).
b) Place the mixed test portions in separate sealable containers and allow the portions to cure for an appropriate time for the material type (Note 9.8).

c) Record the time of curing.

5.7.2 Material with stabilising agent incorporated in the laboratory

a) Incorporate the stabilising agent with the material and precondition the mixture as detailed in Test Method Q135A. When selecting compaction moisture contents, ensure that the optimum moisture is judged to be straddled. Use essentially equal increments of moisture between test portions and ensure that the moisture steps are not excessive for the material type (Note 9.7).

b) Record the time of curing.

5.7.3 Material with stabilising agent incorporated in situ

a) Thoroughly mix each test portion, adding or removing water so that the optimum moisture content is judged to be straddled. Use essentially equal increments of moisture between portions and ensure that the moisture steps are not excessive for the material type (Note 9.7).

b) Place the mixed test portions in separate sealable containers.

c) Record the time of curing.

5.8 Clean and assemble the mould and baseplate, lightly oiling the internal surfaces. Inspect and clean the rammer or mechanical compactor and ensure that it is free in the guide.

5.9 Determine the mass \( m_1 \) of the mould and baseplate, attach the collar and place the assembly on the rigid support base, checking to ensure that the mould is firmly seated and will not rock due to distortion of the mould baseplate or deterioration of the support base.

5.10 Compact the test portions as follows; ensuring the compaction of each portion containing stabilising agent is completed within 65 minutes, timed from when the mixing water was first added to the mixture of host material and stabilising agent.

5.10.1 Material passing the 19.0 mm sieve only (Mould A):

a) Take one test portion, mix it thoroughly and compact it into the assembled mould in three layers so that the compacted height of the material in the mould is from 38 mm to 43 mm in the first layer, from 77 mm to 82 mm in the second layer and from 116 mm to 120 mm in the third layer. Specimens that do not meet one or more of these height tolerances must be discarded.

b) Compact each layer by 25 uniformly distributed blows of the rammer falling freely from a height of 300 mm (Note 9.9). Use only sufficient material, which is representative of the portion, to meet the layer heights above (Note 9.10).

5.10.2 Material passing the 37.5 mm sieve (Mould B):

a) Take one test portion, mix it thoroughly and compact it into the assembled mould in three layers so that the compacted height of the material in the mould is from 44 mm to 49 mm in the first layer, from 89 mm to 94 mm in the second layer and from 133 mm to 138 mm in the third layer. Specimens that do not meet one or more of these height tolerances must be discarded.

b) Compact each layer by 60 uniformly distributed blows of the rammer falling freely from a height of 300 mm. Deliver the first 55 blows as 5 cycles of 11 blows each, with 8...
5.11 Free the material from around the inside of the collar and then carefully remove the collar.

5.12 Trim the surface of the specimen while the mould is still attached to the baseplate. This operation depends upon the characteristics of the material as follows:

5.12.1 For an essentially fine-grained material, trim the compacted material level with the top of the mould by means of the straightedge. Use smaller sized material to patch any hollows developed in the surface from removal of coarse material during trimming.

5.12.2 For a material containing stones, trim the compacted material in the mould ensuring that portions of stones standing above the top of the mould are compensated by hollows of about the equivalent volume below the top of the mould.

5.13 Determine the mass \( m_2 \) of the mould, baseplate and compacted material.

5.14 Immediately remove the compacted specimen from the mould and either use the whole specimen or obtain a representative sample from its full height. Determine the moisture content \( w \) of this sample in accordance with Test Method Q102A or one of the subsidiary Test Methods Q102B or Q102D for which a relationship with Test Method Q102A has been established and used in accordance with Test Method Q010.

5.15 Discard the used material. Do not reuse material from a previously compacted specimen.

5.16 Repeat Steps 5.8 to 5.15 for the other test portions of prepared material to obtain a minimum of four points, at least two of which must be drier and one wetter than optimum moisture content, to satisfactorily define the dry density/moisture content relationship.

5.17 If the optimum moisture content has not been straddled or is imprecisely defined, use additional test portions prepared and cured at appropriate moisture contents in the same manner as in Steps 5.6 to 5.7, and compacted as in Steps 5.8 to 5.15 (Note 9.11).

### 6 Calculations

Calculate as follows:

6.1 For each specimen, wet density of material \( \rho_w \) as follows:

\[
\rho_w = \frac{m_2 - m_1}{V}
\]

where \( \rho_w \) = wet density of material (t/m³)

\( m_2 \) = mass of mould, baseplate and compacted material (g)

\( m_1 \) = mass of mould and baseplate (g)

\( V \) = mould volume (cm³)

6.2 For each specimen, dry density of material \( \rho_d \) as follows:

\[
\rho_d = \frac{100\rho_w}{100+w}
\]
where \( \rho_d \) = dry density of material (t/m\(^3\))
\( \rho_w \) = wet density of material (t/m\(^3\))
\( w \) = moisture content of the specimen (%)

6.3 Moisture content points for the chosen air voids line, from the apparent particle density (Note 9.12) by using dry density values corresponding to the lowest and highest values determined in Step 6.2 as follows:

\[
w = \frac{100 - V_a}{\rho_d} - 100 \left( \frac{\rho_d}{\rho_s} \right)
\]

where
\( w \) = moisture content, expressed as a percentage of the mass of dry material
\( V_a \) = volume of chosen air voids, expressed as a percentage of the volume of undried material
\( \rho_d \) = dry density of material (t/m\(^3\))
\( \rho_s \) = apparent particle density (t/m\(^3\))

6.4 Plot the dry densities obtained for the compacted specimens against their corresponding moisture contents. Draw a smooth curve of best fit through the resulting points with the wet leg of the curve tending parallel to the air voids line.

6.5 Plot the air voids line on the graph constructed at Step 6.4.

7 Reporting

Report the following values and general information:

7.1 The plot of dry density against moisture content together with the plot of the chosen air voids line.

7.2 The dry density corresponding to the maximum point on the moisture content/dry density curve as the standard maximum dry density to the nearest 0.001 t/m\(^3\).

7.3 The percentage moisture content corresponding to the maximum dry density on the moisture content/dry density curve as the standard optimum moisture content to the nearest 0.1%.

7.4 The method used to determine the moisture content of the compacted material.

7.5 When measured, the density and percentage of any oversize as determined by Test Method Q143 and the sieve on which the material is retained (19.0 mm or 37.5 mm).

7.6 For stabilised materials, source, type and quantity of the stabilising agent(s).

7.7 Sender’s number, if assigned values of maximum dry density and optimum moisture content are to be assigned as detailed in Test Method Q144A.

8 Precision

The precision of the test is shown in Table 3. These values, in 95% of cases, should not be exceeded by the difference between any two results, expressed as a percentage of the average value. The values shown are based on test results from a wide variety of materials.
but, in some cases such as heavy clays, these values may be exceeded. Precision may be enhanced by employing fractionation as the preferred option for test portion preparation.

9 Notes on method

9.1 A mechanical form of apparatus may be used provided the essential dimensions are adhered to and the rammer has a free vertical fall of the correct height with blows being uniformly distributed and in keeping with any prescribed cycle of blows. It is also essential that the design of the machine is such that the mould can be attached to a level and rigid support base.

9.2 The balance referred to is suitable for most applications where stabilising agent is being added to the material. The balance used must have a resolution which displays to one significant figure more than the mass being weighed and a limit of performance commensurate with the resolution.

9.3 A material height gauge, which allows monitoring of the height of compacted material relative to the top of either a Mould A or a Mould B, can be made from a steel bar and marked as follows:

9.3.1 Mould A: Commencing at one end of the bar, measure and mark distances of:
   a) 5.5 mm for the upper range of the third layer
   b) 33.5 mm and 38.5 mm for the acceptable range of the second layer, and
   c) 72.5 mm and 77.5 mm for the acceptable range of the first layer.

9.3.2 Mould B: Using another face and commencing at one end of the bar, measure and mark distances of:
   a) 5.5 mm for the upper range of the third layer
   b) 38.5 mm and 43.5 mm for the acceptable range of the second layer, and
   c) 83.5 mm and 88.5 mm for the acceptable range of the first layer.

9.3.3 Mark each face with the appropriate mould size (A or B).

9.4 Before handling oils, the operator must consult the relevant Safety Data Sheet (SDS).

9.5 For material compacted in Mould A, a mass of 2.5 kg will be adequate for most materials. A gravel may however, require up to 3 kg, while it may be possible to use as low as 2 kg for a heavy clay. For material compacted in Mould B, about 2.5 times the mass of the material required for Mould A will be required.

9.6 When a stabilising agent is to be added in the laboratory, it may be necessary to partly dry the soil sample before preparation. The material must be sufficiently dry to allow uniform mixing of the stabilising agent into the material in order to minimise variability within the mixture.

9.7 As a guide, suitable intervals of moisture content range between 1% for crushed rock or gravel and 2% to 3% for clays.

9.8 It is important that the water is thoroughly mixed into and uniformly distributed throughout the material since inadequate mixing gives rise to variable test results. It is desirable to keep the mixed material in a sealed container to allow the water to become more uniformly distributed before compaction. For materials of low plasticity and high permeability prepared in a moist condition close to optimum moisture content, little or no curing is required but if the material is a dry heavy clay, up to seven days curing may be required before testing.
9.9 During compaction, material can build up on the surface of the rammer. This is particularly evident at moisture contents near to and above optimum moisture content. In order to prevent the cushioning effect caused by this build up, the rammer face must be inspected and cleaned if necessary during the compaction process.

9.10 It is necessary to control the total amount of mixture compacted since, if the amount of material struck off after removing the collar is too great, the test results will be inaccurate as the energy input will not be within the required tolerances of Table 1. Some large particles may protrude a little more than 5 mm above the surface for the passing 37.5 mm material. Suitable allowances in the trimming process must be made for these particles but the average height of the compacted specimen before trimming should not exceed 5 mm above the mould.

9.11 If, with increasing moisture content, the wet mass of compacted material markedly increases and then starts to decrease, the optimum moisture content probably has been straddled adequately. For materials with low plasticity and high permeability, points significantly wetter than optimum moisture content may not be reliable due to loss of water during compaction.

9.12 The value of the material's apparent particle density for calculating the air voids lines may be obtained using the method described in Q109 or assumed on the basis of previous tests. A rough check on the material particle density is to select the dry density and moisture content of the wettest data point, nominate a percent air voids (2% often gives a satisfactory result) and calculate an apparent particle density as follows:

\[
\rho_a = \frac{100\rho_d}{(100-V_a)\rho_w}
\]

where

- \( \rho_a \) = apparent particle density (t/m³)
- \( \rho_d \) = dry density of material (t/m³)
- \( V_a \) = nominated air voids (%)
- \( w \) = moisture content expressed as a percentage of the mass of dry material

The material's apparent particle density so derived is taken as the assumed value.

**Table 1 - Dimensions and tolerances for suitable moulds and rammer**

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Dimension</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Moulds</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mould A: 105 diameter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal diameter (mm)</td>
<td>105.0</td>
<td>± 0.5 *</td>
</tr>
<tr>
<td>Effective height (mm)</td>
<td>115.5</td>
<td>± 0.5 *</td>
</tr>
<tr>
<td>Nominal volume (cm³)</td>
<td>1000</td>
<td>± 15</td>
</tr>
<tr>
<td>Mould B: 152 mm diameter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal diameter (mm)</td>
<td>152.0</td>
<td>± 1.0 *</td>
</tr>
<tr>
<td>Effective height (mm)</td>
<td>132.5</td>
<td>± 0.5 *</td>
</tr>
<tr>
<td>Nominal volume (cm³)</td>
<td>2400</td>
<td>± 35</td>
</tr>
</tbody>
</table>
Apparatus | Dimension | Tolerance
--- | --- | ---
Rammer | | |
Diameter; round foot (mm) | 50 | ± 0.4
Area of rammer (mm²) | 1964 | ± 31
Drop (mm) | 300 | ± 2.0 ‡
Mass (kg) | 2.7 | ± 0.01 ‡
Energy delivered per blow (J) | 7.94 | ± 0.08
Number of layers | 3 | |
Number of blows/layer: Mould A | 25 | |
mould B | 60 | |
Energy input (kJ/m³) | 596 | ± 14
* Either but not both of the tolerances may be exceeded provided that the specified tolerance on volume is not exceeded.
‡ Either but not both of the tolerances may be exceeded provided that the appropriate tolerance on energy delivered per blow is not exceeded.

Table 2 - Size fraction and mould size

<table>
<thead>
<tr>
<th>Percentage retained</th>
<th>Test mould</th>
<th>Portion to be tested</th>
</tr>
</thead>
<tbody>
<tr>
<td>37.5 mm sieve</td>
<td>19.0 mm sieve</td>
<td></td>
</tr>
<tr>
<td>&gt; 35</td>
<td>-</td>
<td>Not tested by this method</td>
</tr>
<tr>
<td>≤ 35</td>
<td>&gt; 20</td>
<td>B All material passing 37.5 mm sieve</td>
</tr>
<tr>
<td>-</td>
<td>≤ 20</td>
<td>A All material passing 19.0 mm sieve</td>
</tr>
</tbody>
</table>

Table 3 - Acceptable range of two results expressed as a percentage of mean value

<table>
<thead>
<tr>
<th>Precision measure</th>
<th>Maximum density</th>
<th>Optimum moisture content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repeatability</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Reproducibility</td>
<td>4</td>
<td>20</td>
</tr>
</tbody>
</table>
Test Method Q142B: Dry density–moisture relationship of soils and crushed rock - modified

1 Source

This method is based on AS 1289.5.2.1: Soil compaction and density tests - Determination of the dry density/moisture content relation of a soil using modified compactive effort. It differs from this standard in the coarseness of material permitted and provision for the addition of stabilising agents.

2 Scope

This method sets out a procedure for the determination of the relationship between the moisture content and the dry density of a soil or a crushed rock material, including mixtures containing stabilising agent, when compacted using modified compactive effort (2703 kJ/m³). Compaction is conducted over a range of moisture contents so as to establish the maximum mass of dry material per unit volume achievable for this compactive effort and its corresponding moisture content.

The procedure is applicable to that portion of a material that passes the 37.5 mm sieve. Material that all passes the 19.0 mm sieve is compacted in a 105 mm diameter mould. Material that has more than 20% rock retained on the 19.0 mm sieve is compacted in a 152 mm diameter mould. Corrections for oversize are not directly included in this method but may be made as detailed in Test Method Q140A when required for compaction control.

3 Apparatus

Where appropriate, the working tolerances of particular apparatus are contained in Table 1.

The following apparatus is required:

3.1 Metal moulds, of a size dependent on the maximum size of material being tested, as follows:

3.1.1 For compaction of material passing a 19.0 mm sieve:

Mould A: A cylindrical metal mould having an internal diameter of 105 mm and effective height of 115.5 mm, fitted with a detachable baseplate and a removable collar assembly about 60 mm high both of which can be firmly attached to the mould.

3.1.2 For compaction of material which has rock material retained on the 19.0 mm sieve:

Mould B: A cylindrical metal mould having an internal diameter of 152 mm and an effective height of 132.5 mm, fitted with a detachable baseplate and a removable collar assembly about 60 mm high both of which can be firmly attached to the mould.

3.2 Steel rammer, or alternatively a mechanical compactor may be used provided that it meets the essential requirements of drop height, mass and energy input (Note 9.1).

3.3 Level rigid foundation on which to compact the specimen, for example a sound concrete floor about 100 mm or more in thickness or a concrete block of at least 100 kg mass.

3.4 Balances:

3.4.1 Balance of suitable capacity, with a resolution of at least 1 g and with a limit of performance within the range of ± 5 g.

3.4.2 Balance of suitable capacity to weigh stabilising agents, with a resolution of at least 0.1 g and with a limit of performance within the range of ± 0.5 g (Note 9.2).

3.5 Sieves, 37.5 mm, 19.0 mm and 9.5 mm complying with AS 1152.
3.6 Strong spatula or a suitable knife.

3.7 Steel straightedge, about 250 mm long, 25 mm wide and 3 mm thick, preferably with one bevelled edge.

3.8 Miscellaneous mixing apparatus, such as a tray, trowel or scoop and water spray suitable for mixing increments of water into the material.

3.9 Material height gauge. A flat steel bar, about 250 mm long, 25 mm wide and 1-3 mm thick is satisfactory (Note 9.3).

3.10 Sealable containers, suitable for curing the material samples.

3.11 Sample extractor, such as a jack, lever frame or other device for extruding compacted specimens from the mould.

4 Materials

The following material is required:

4.1 Mould oil, a light oil such as Caltex Mould Oil 20 (Note 9.4).

5 Procedure

The procedure shall be as follows:

5.1 Prepare the bulk sample as detailed in Section 5 of Test Method Q101 to produce a representative subsample of appropriate size. For fresh mixtures of insitu stabilised materials, limit both moisture loss and time loss during preparation.

5.2 Further prepare the material by screening the subsample on a 19.0 mm sieve as detailed in Test Method Q101, Steps 6.2.1 to 6.2.3. Ensure that any aggregations are broken up to pass a 9.5 mm sieve and keep any retained 37.5 mm (oversize) rock material.

5.3 Determine the approximate percentage retained on the 19.0 mm sieve and whether any material is retained on the 37.5 mm sieve to allow the selection of the appropriate mould size as follows:

5.3.1 Where oversize is retained on the 19.0 mm sieve, determine its mass \( m_{ow} \) and the mass of the passing 19.0 mm (undersize) material \( m_{uw} \). Calculate the wet mass of material as follows:

\[
\begin{align*}
\text{wew} &= m_{ow} + m_{uw} \\
\text{where} &\quad m_{w} = \text{wet mass of material (g)} \\
&\quad m_{ow} = \text{wet mass of > 19.0 mm oversize material (g)} \\
&\quad m_{uw} = \text{wet mass of < 19.0 mm undersize material (g)}
\end{align*}
\]

5.3.2 Where oversize is retained on the 19.0 mm sieve, calculate the percentage oversize on a wet mass basis as follows:

\[
\begin{align*}
p_{ow} &= \frac{100m_{ow}}{m_{w}} \\
\text{where} &\quad p_{ow} = \text{percentage by wet mass of > 19.0 mm oversize material}
\end{align*}
\]
5.3.3 If the calculated percentage oversize \( P_{ow} \) is greater than 20%, screen the material retained on the 19.0 mm sieve on the 37.5 mm sieve. Where oversize is retained on the 37.5 mm sieve, determine its mass of \( m_{ow} \). Calculate the percentage oversize on a wet basis as follows:

\[
P_{ow} = \frac{100m_{ow}}{m_w}
\]

where

\( P_{ow} \) = percentage by wet mass of > 37.5 mm oversize material

\( m_{ow} \) = wet mass of > 37.5 mm oversize material (g)

\( m_w \) = wet mass of material (g)

5.4 If required, retain the material retained on the 19.0 mm or 37.5 mm sieve for determining the density and percentage of oversize.

5.5 Select the size fraction and mould size to be used in the compaction test using the criteria in Table 2. Record the mould used (A or B). When necessary recombine the material passing 37.5 mm portion with the material passing the 19.0 mm portion and thoroughly remix.

5.6 Prepare four or more representative portions of the sieved material as detailed in Test Method Q101, Steps 6.2.4 to 6.2.6 as follows:

5.6.1 Each test portion is to be of sufficient quantity to produce a compacted specimen in excess of the volume of the mould (Notes 9.5 and 9.6).

5.6.2 Where oversize is present and a correction to the laboratory reference dry density or optimum moisture content is required as detailed in Test Method Q140A, prepare an additional portion of the sieved material and determine its moisture content of undersize material \( w_u \) in accordance with Test Method Q102A or one of the subsidiary Test Methods Q102B or Q102D for which a relationship with Test Method Q102A has been established and used in accordance with Test Method Q010.

5.6.3 Where a correction to the laboratory reference dry density or optimum moisture content is required as detailed in Test Method Q140A, determine the density and percentage of any oversize as detailed in Test Method Q143, using the wet mass of oversize \( m_{ow} \) and wet mass of material \( m_w \) determined at Step 5.3.2 (Mould A) or Step 5.3.3 (Mould B) and the moisture content of undersize material \( w_u \) of the undersize from Step 5.6.2.

5.7 Take the portions of material prepared in Step 5.6, mix them with the stabilising agent if appropriate, and prepare each portion for compaction as follows:

5.7.1 Material only

a) Thoroughly mix each test portion, adding or removing water so that the optimum moisture content is judged to be straddled. Use essentially equal increments of moisture between portions and ensure that the moisture steps are not excessive for the material type (Note 9.7).
b) Place the mixed test portions in separate sealable containers and allow the portions to
cure for an appropriate time for the material type (Note 9.8).

c) Record the time of curing.

5.7.2 Material with stabilising agent incorporated in the laboratory

a) Incorporate the stabilising agent with the material and precondition the mixture as
detailed in Test Method Q135A. When selecting compaction moisture contents, ensure
that the optimum moisture is judged to be straddled. Use essentially equal increments of
moisture between test portions and ensure that the moisture steps are not excessive for
the material type (Note 9.7).

b) Record the time of curing.

5.7.3 Material with stabilising agent incorporated in situ

a) Thoroughly mix each test portion, adding or removing water so that the optimum moisture
content is judged to be straddled. Use essentially equal increments of moisture between
portions and ensure that the moisture steps are not excessive for the material type
(Note 9.7).

b) Place the mixed test portions in separate sealable containers.

c) Record the time of curing.

5.8 Clean and assemble the mould and baseplate, lightly oiling the internal surfaces. Inspect and
clean the rammer or mechanical compactor and ensure that it is free in the guide.

5.9 Determine the mass \( m_1 \) of the mould and baseplate, attach the collar and place the
assembly on the rigid support base, checking to ensure that the mould is firmly seated and will
not rock due to distortion of the mould baseplate or deterioration of the support base.

5.10 Compact the test portions as follows, ensuring the compaction of each portion containing
stabilising agent is completed within 65 minutes, timed from when the mixing water was first
added to the mixture of host material and stabilising agent.

5.10.1 Material passing the 19.0 mm sieve only (Mould A):

a) Take one test portion, mix it thoroughly and compact it into the assembled mould in three
layers so that the compacted height of the material in the mould is from 38 mm to 43 mm
in the first layer, from 77 mm to 82 mm in the second layer and from 116 mm to 120 mm
in the third layer. Specimens that do not meet one or more of these height tolerances
must be discarded.

b) Compact each layer by 42 uniformly distributed blows of the rammer falling freely from a
height of 450 mm (Note 9.9). Use only sufficient material, which is representative of the
portion, to meet the layer heights above (Note 9.10).

5.10.2 Material passing the 37.5 mm sieve (Mould B):

a) Take one test portion, mix it thoroughly and compact it into the assembled mould in three
layers so that the compacted height of the material in the mould is from 44 mm to 49 mm
in the first layer, from 89 mm to 94 mm in the second layer and from 133 mm to 138 mm
in the third layer. Specimens that do not meet one or more of these height tolerances
must be discarded.

b) Compact each layer by 100 uniformly distributed blows of the rammer falling freely from a
height of 450 mm. Deliver the first 99 blows as 9 cycles of 11 blows each, with 8
distributed around the mould circumference and 3 within the central area. Deliver the remaining blow in the central area (Note 9.9). Use only sufficient material, which is representative of the portion, to meet the layer heights above (Note 9.10).

5.11 Free the material from around the inside of the collar and then carefully remove the collar.

5.12 Trim the surface of the specimen while the mould is still attached to the baseplate. This operation depends upon the characteristics of the material as follows:

5.12.1 For an essentially fine-grained material, trim the compacted material level with the top of the mould by means of the straightedge. Use smaller sized material to patch any hollows developed in the surface from removal of coarse material during trimming.

5.12.2 For a material containing stones, trim the compacted material in the mould ensuring that portions of stones standing above the top of the mould are compensated by hollows of about the equivalent volume below the top of the mould.

5.13 Determine the mass ($m_2$) of the mould, baseplate and compacted material.

5.14 Immediately remove the compacted specimen from the mould and either use the whole specimen or obtain a representative sample from its full height. Determine the moisture content ($w$) of this sample in accordance with Test Method Q102A or one of the subsidiary Test Methods Q102B or Q102D for which a relationship with Test Method Q102A has been established and used in accordance with Test Method Q010.

5.15 Discard the used material. Do not reuse material from a previously compacted specimen.

5.16 Repeat Steps 5.8 to 5.15 for the other test portions of prepared material to obtain a minimum of four points, at least two of which must be drier and one wetter than optimum moisture content, to satisfactorily define the dry density/moisture content relationship.

5.17 If the optimum moisture content has not been straddled or is imprecisely defined, use additional test portions prepared and cured at appropriate moisture contents in the same manner as in Steps 5.6 to 5.7, and compacted as in Steps 5.8 to 5.15 (Note 9.11).

6 Calculations

Calculate as follows:

6.1 For each specimen, wet density of material ($\rho_w$) as follows:

$$\rho_w = \frac{m_2 - m_1}{V}$$

where $\rho_w$ = wet density of material (t/m³)  
$m_2$ = mass of mould, baseplate and compacted material (g)  
$m_1$ = mass of mould and baseplate (g)  
$V$ = mould volume (cm³)

6.2 For each specimen, density of dry material ($\rho_d$) as follows:

$$\rho_d = \frac{100\rho_w}{100+w}$$
where

\[ \rho_d = \text{dry density of material (t/m}^3) \]
\[ \rho_w = \text{wet density of material (t/m}^3) \]
\[ w = \text{moisture content of the specimen (\%)} \]

6.3 Moisture content points for the chosen air voids line, from the apparent particle density (Note 9.12) by using dry density values corresponding to the lowest and highest values determined in Step 6.2 as follows:

\[ w = \frac{100 - V_a}{\rho_d} \cdot \frac{100}{\rho_s} \]

where

\[ w = \text{moisture content, expressed as a percentage of the mass of the dry material (\%)} \]
\[ V_a = \text{volume of chosen air voids, expressed as a percentage of the volume of the un-dried material} \]
\[ \rho_d = \text{dry density of material (t/m}^3) \]
\[ \rho_s = \text{apparent particle density (t/m}^3) \]

6.4 Plot the dry densities obtained for the compacted specimens against their corresponding moisture contents. Draw a smooth curve of best fit through the resulting points with the wet leg of the curve tending parallel to the air voids line.

6.5 Plot the air voids line on the graph constructed at Step 6.4.

7 Reporting

Report the following values and general information:

7.1 The plot of dry density against moisture content together with the plot of the chosen air voids line.

7.2 The dry density corresponding to the maximum point on the moisture content/dry density curve as the modified maximum dry density to the nearest 0.001 t/m³.

7.3 The percentage moisture content corresponding to the maximum dry density on the moisture content/dry density curve as the modified optimum moisture content to the nearest 0.1%.

7.4 The method used to determine the moisture content of the compacted material.

7.5 When measured, the density and percentage of any oversize as determined by Test Method Q143 and the sieve on which the material is retained (19.0 mm or 37.5 mm).

7.6 For stabilised materials, source, type and quantity of the stabilising agent(s).

7.7 Sender's number, if assigned values of maximum dry density and optimum moisture content are to be assigned as detailed in Test Method Q144A.

8 Precision

The precision of the test is shown in Table 3. These values, in 95% of cases, should not be exceeded by the difference between any two results, expressed as a percentage of the average value. The values shown are based on test results from a wide variety of materials.
but, in some cases such as heavy clays, these values may be exceeded. Precision may be enhanced by employing fractionation as the preferred option for test portion preparation.

9 Notes on method

9.1 A mechanical form of apparatus may be used provided the essential dimensions are adhered to and the rammer has a free vertical fall of the correct height with blows being uniformly distributed and in keeping with any prescribed cycle of blows. It is also essential that the design of the machine is such that the mould can be attached to a level and rigid support base.

9.2 The balance referred to is suitable for most applications where stabilising agent is being added to material. The balance used must have a resolution which displays to one significant figure more than the mass being weighed and a limit of performance commensurate with the resolution.

9.3 A material height gauge, which allows monitoring of the height of compacted material relative to the top of either a Mould A or a Mould B, can be made from a steel bar and marked as follows:

9.3.1 Mould A: Commencing at one end of the bar, measure and mark distances of:
   a) 5.5 mm for the upper range of the third layer
   b) 33.5 mm and 38.5 mm for the acceptable range of the second layer, and
   c) 72.5 mm and 77.5 mm for the acceptable range of the first layer.

9.3.2 Mould B: Using another face and commencing at one end of the bar, measure and mark distances of:
   a) 5.5 mm for the upper range of the third layer
   b) 38.5 mm and 43.5 mm for the acceptable range of the second layer, and
   c) 83.5 mm and 88.5 mm for the acceptable range of the first layer.

9.3.3 Mark each face with the appropriate mould size (A or B).

9.4 Before handling oils, the operator must consult the relevant Safety Data Sheet (SDS).

9.5 For material compacted in Mould A, a mass of 2.5 kg will be adequate for most materials. A gravel may however, require up to 3 kg, while it may be possible to use as low as 2 kg for a heavy clay. For material compacted in Mould B, about 2.5 times the mass of the material required for Mould A will be required.

9.6 When a stabilising agent is to be added in the laboratory, it may be necessary to partly dry the bulk sample before preparation. The material must be sufficiently dry to allow uniform mixing of the stabilising agent into the material in order to minimise variability within the mixture.

9.7 As a guide, suitable intervals of moisture content range between 1% for crushed rock or gravel and 2% to 3% for clays.

9.8 It is important that the water is thoroughly mixed into and uniformly distributed throughout the material since inadequate mixing gives rise to variable test results. It is desirable to keep the mixed soil in a sealed container to allow the water to become more uniformly distributed before compaction. For materials of low plasticity and high permeability prepared in a moist condition close to optimum moisture content, little or no curing is required but if the material is a dry heavy clay, up to seven days curing may be required before testing.
9.9 During compaction, material can build up on the surface of the rammer. This is particularly evident at moisture contents near to and above optimum moisture content. In order to prevent the cushioning effect caused by this build-up, the rammer face must be inspected and cleaned if necessary during the compaction process.

9.10 It is necessary to control the total amount of mixture compacted since, if the amount of material struck off after removing the collar is too great, the test results will be inaccurate as the energy input will not be within the required tolerances of Table 1. Some large particles may protrude a little more than 5 mm above the surface for the passing 37.5 mm material. Suitable allowances in the trimming process must be made for these particles but the average height of the compacted specimen before trimming should not exceed 5 mm above the mould.

9.11 If, with increasing moisture content, the wet mass of compacted material markedly increases and then starts to decrease, the optimum moisture content probably has been straddled adequately. For materials with low plasticity and high permeability, points significantly wetter than optimum moisture content may not be reliable due to loss of water during compaction.

9.12 The value of the material's particle density for calculating the air voids lines may be obtained using the method described in Q109 or assumed on the basis of previous tests. A rough check on the apparent particle density is to select the dry density and moisture content of the wettest data point, nominate a percent air voids (2% often gives a satisfactory result) and calculate an apparent particle density as follows:

$$\rho_s = \frac{100\rho_d}{(100-V_a)\rho_w}$$

where

- $\rho_s$ = apparent particle density (t/m³)
- $\rho_d$ = dry density of material (t/m³)
- $V_a$ = nominated air voids (%)
- $w$ = moisture content expressed as moisture content expressed as a percentage of the mass of dry

The material's apparent particle density so derived is taken as the assumed value.

**Table 1 - Dimensions and tolerances for suitable moulds and rammer**

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Dimension</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Moulds</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mould A: 105 diameter</td>
<td>105.0</td>
<td>± 0.5 *</td>
</tr>
<tr>
<td>Internal diameter (mm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effective height (mm)</td>
<td>115.5</td>
<td>± 0.5 *</td>
</tr>
<tr>
<td>Nominal volume (cm³)</td>
<td>1000</td>
<td>± 15</td>
</tr>
<tr>
<td>Mould B: 152 mm diameter</td>
<td>152.0</td>
<td>± 1.0 *</td>
</tr>
<tr>
<td>Internal diameter (mm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effective height (mm)</td>
<td>132.5</td>
<td>± 0.5 *</td>
</tr>
<tr>
<td>Nominal volume (cm³)</td>
<td>2400</td>
<td>± 35</td>
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</tbody>
</table>
### Apparatus Dimension Tolerance

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Dimension</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rammer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter; round foot (mm)</td>
<td>50</td>
<td>± 0.4</td>
</tr>
<tr>
<td>Area of rammer (mm²)</td>
<td>1964</td>
<td>± 31</td>
</tr>
<tr>
<td>Drop (mm)</td>
<td>450</td>
<td>± 2.0 ‡</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>4.9</td>
<td>± 0.01 ‡</td>
</tr>
<tr>
<td>Energy delivered per blow (J)</td>
<td>21.62</td>
<td>± 0.08</td>
</tr>
<tr>
<td>Number of layers</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Number of blows/layer: Mould A</td>
<td>42</td>
<td></td>
</tr>
<tr>
<td>Mould B</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Energy input (kJ/m³)</td>
<td>2703</td>
<td>± 60</td>
</tr>
</tbody>
</table>

* Either but not both of the tolerances may be exceeded provided that the specified tolerance on volume is not exceeded.

‡ Either but not both of the tolerances may be exceeded provided that the appropriate tolerance on energy delivered per blow is not exceeded.

### Table 2 - Size fraction and mould size

<table>
<thead>
<tr>
<th>Percentage retained</th>
<th>Test mould</th>
<th>Portion to be tested</th>
</tr>
</thead>
<tbody>
<tr>
<td>37.5 mm sieve</td>
<td>19.0 mm sieve</td>
<td></td>
</tr>
<tr>
<td>&gt; 35</td>
<td>-</td>
<td>Not tested by this method</td>
</tr>
<tr>
<td>≤ 35</td>
<td>&gt; 20</td>
<td>B All material passing 37.5 mm sieve</td>
</tr>
<tr>
<td>-</td>
<td>≤ 20</td>
<td>A All material passing 19.0 mm sieve</td>
</tr>
</tbody>
</table>

### Table 3 - Acceptable range of two results expressed as a percentage of mean value

<table>
<thead>
<tr>
<th>Precision measure</th>
<th>Maximum density</th>
<th>Optimum moisture content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repeatability</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Reproducibility</td>
<td>4</td>
<td>20</td>
</tr>
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</table>
Test Method Q142C: Density – moisture relationship of soils by rapid method - standard

1 Source
This method is based on AS 1289.5.7.1: Soil compaction and density tests – Compaction control test - Hilf density ratio and Hilf moisture variation (rapid method). This method differs from this standard in the coarseness of material permitted.

2 Scope
This method sets out a procedure for the rapid determination of the relationship between the added moisture and the wet density of a soil, when compacted using standard compactive effort (596 kJ/m³). Compaction is conducted over a range of moisture contents so as to establish the maximum mass of wet material per unit volume achievable for this compactive effort and its corresponding added/removed moisture.

The procedure is applicable to that portion of a material that passes the 37.5 mm sieve. Material that all passes the 19.0 mm sieve is compacted in a 105 mm diameter mould. Material that has more than 20% rock retained on the 19.0 mm sieve is compacted in a 152 mm diameter mould. Corrections for oversize are not directly included in this method but may be made as detailed in Test Method Q140A when required for compaction control.

The absence of curing following the addition or removal of water may produce minor differences in results when this method is compared to Test Method Q142A.

The procedure is not applicable to stabilised materials or where the percentage added/removed moisture is outside the range -4 to +6.

3 Apparatus

Where appropriate, the working tolerances of particular apparatus are contained in Table 1.

The following apparatus is required:

3.1 Metal moulds, of a size dependent on the maximum size of material being tested, as follows:

3.1.1 For compaction of material passing a 19.0 mm sieve:
Mould A: A cylindrical metal mould having an internal diameter of 105 mm and effective height of 115.5 mm, fitted with a detachable baseplate and a removable collar assembly about 60 mm high both of which can be firmly attached to the mould.

3.1.2 For compaction of material which has rock material retained on the 19.0 mm sieve:
Mould B: A cylindrical metal mould having an internal diameter of 152 mm and an effective height of 132.5 mm, fitted with a detachable baseplate and a removable collar assembly about 60 mm high both of which can be firmly attached to the mould.

3.2 Steel rammer, or alternatively a mechanical compactor may be used provided that it meets the essential requirements of drop height, mass and energy input (Note 8.1).

3.3 Level rigid foundation on which to compact the specimen, for example, a sound concrete floor about 100 mm or more in thickness or a concrete block of at least 100 kg mass.

3.4 Balance of suitable capacity, with a resolution of at least 1 g and with a limit of performance within the range of ± 5 g.

3.5 Sieves, 37.5 mm, 19.0 mm and 9.5 mm complying with AS 1152.
3.6 Strong spatula or a suitable knife.
3.7 Steel straightedge, about 250 mm long, 25 mm wide and 3 mm thick, preferably with one bevelled edge.
3.8 Miscellaneous mixing apparatus, such as a tray, trowel or scoop and water spray suitable for mixing increments of water into the material.
3.9 Material height gauge. A flat steel bar, about 250 mm long, 25 mm wide and 1-3 mm thick is satisfactory (Note 8.2).
3.10 Sealable containers, suitable for storing material subsamples.
3.11 Sample extractor, such as a jack, lever frame or other device for extruding compacted specimens from the mould.

4 Materials

The following material is required:

4.1 Mould oil, a light oil such as Caltex Mould Oil 20 (Note 8.3).

5 Procedure

The procedure shall be as follows:

5.1 Prepare the bulk sample as detailed in Section 5 of Test Method Q101 to produce a representative subsample of appropriate size taking care to limit moisture loss during preparation.

5.2 Further prepare the material by screening the subsample on a 19.0 mm sieve as detailed in Test Method Q101, Steps 6.2.1 to 6.2.3. Ensure that any aggregations are broken up to pass a 9.5 mm sieve and keep any retained 37.5 mm (oversize) rock material (Note 8.4).

5.3 Determine the approximate percentage retained on the 19.0 mm sieve and whether any material is retained on the 37.5 mm sieve to allow the selection of the appropriate mould size as follows:

5.3.1 Where oversize is retained on the 19.0 mm sieve, determine its mass \( m_{ow} \) and the mass of the passing 19.0 mm (undersize) material \( m_{uw} \). Calculate the wet mass of material as follows:

\[
\text{w} = m_{ow} + m_{uw}
\]

where

\( m_{w} \) = wet mass of material (g)

\( m_{ow} \) = wet mass of > 19.0 mm oversize material (g)

\( m_{uw} \) = wet mass of < 19.0 mm undersize material (g)

5.3.2 Where oversize is retained on the 19.0 mm sieve, calculate the percentage oversize on a wet mass basis as follows:

\[
\text{p}_{ow} = \frac{100 m_{ow}}{m_{w}}
\]

where \( \text{p}_{ow} \) = percentage by wet mass of > 19.0 mm oversize material
\[ m_{ow} = \text{wet mass of } > 19.0 \text{ mm oversize material (g)} \]
\[ m_{w} = \text{wet mass of material (g)} \]

5.3.3 If the calculated percentage oversize (\( P_{ow} \)) is greater than 20%, screen the material retained on the 19.0 mm sieve on the 37.5 mm sieve. Where oversize is retained on the 37.5 mm sieve, determine its mass of (\( m_{ow} \)). Calculate the percentage oversize on a wet basis as follows:

\[ P_{ow} = \frac{100m_{ow}}{m_{w}} \]

where 
\[ P_{ow} = \text{percentage by wet mass of } > 37.5 \text{ mm oversize material} \]
\[ m_{ow} = \text{wet mass of } > 37.5 \text{ mm oversize material (g)} \]
\[ m_{w} = \text{wet mass of material (g)} \]

5.4 If required, retain the material retained on the 19.0 mm or 37.5 mm sieve for determining the density and percentage of oversize.

5.5 Select the size fraction and mould size to be used in the compaction test using the criteria in Table 2. Record the mould used (A or B). When necessary recombine the material passing 37.5 mm portion with the material passing the 19.0 mm portion and thoroughly remix.

5.6 Prepare three or more representative portions of the sieved material as detailed in Test Method Q101, Steps 6.2.4 to 6.2.6 but excluding Appendix 3, as follows:

5.6.1 Each test portion is to be of sufficient quantity to produce a compacted specimen in excess of the volume of the mould (Note 8.5).

5.6.2 Where oversize is present and a correction to the laboratory reference wet density or optimum moisture content is required as detailed in Test Method Q140A, prepare an additional portion of the sieved material and determine the insitu moisture content (\( w \)) in accordance with Test Method Q102A or one of the subsidiary Test Methods Q102B or Q102D for which a relationship with Test Method Q102A has been established and used in accordance with Test Method Q010.

5.6.3 Where a correction to the laboratory reference wet density or optimum moisture content is required as detailed in Test Method Q140A, determine the density and percentage of any oversize as detailed in Test Method Q143, using the wet mass of oversize (\( m_{ow} \)) and wet mass of material (\( m_{w} \)) determined at Step 5.3.2 (Mould A) or Step 5.3.3 (Mould B).

5.7 Take the portions of material prepared in Step 5.6 and thoroughly mix each test portion, adding or removing water so that the optimum moisture content is judged to be straddled. Use essentially equal increments of moisture between portions and ensure that the moisture steps are not excessive for the material type (Note 8.6).

5.8 To remove moisture from a portion, place the moist material on a large flat tray of known mass and determine the mass of the tray and material. Spread the material over the base of the tray in a uniform layer and stir frequently to assist in the removal of moisture. Monitor the moisture loss by determining the mass of tray and material until the desired mass of test portion is achieved.
5.9 Clean and assemble the mould and baseplate, lightly oiling the internal surfaces. Inspect and
        clean the rammer or mechanical compactor and ensure that it is free in the guide.

5.10 Determine the mass \( (m_1) \) of the mould and baseplate, attach the collar and place the
        assembly on the rigid support base, checking to ensure that the mould is firmly seated and will
        not rock due to distortion of the mould baseplate or deterioration of the support base.

5.11 Compact the test portions as follows, ensuring that moisture loss is minimised during
        compaction:

5.11.1 Material passing the 19.0 mm sieve only (Mould A):
        a) Take one test portion, adding or removing moisture until it is judged to be at optimum
           moisture content. Mix it thoroughly and compact it into the assembled mould in three
           layers so that the compacted height of the material in the mould is from 38 mm to 43 mm
           in the first layer, from 77 mm to 82 mm in the second layer and from 116 mm to 120 mm
           in the third layer. Specimens that have a compacted height of material for any layer
           outside these height limits must be discarded.
        b) Compact each layer by 25 uniformly distributed blows of the rammer falling freely from a
           height of 300 mm (Note 8.7). Use only sufficient material, which is representative of the
           portion, to meet the layer heights above (Note 8.8).

5.11.2 Material passing the 37.5 mm sieve (Mould B):
        a) Take one test portion, adding or removing moisture until it is judged to be at optimum
           moisture content. Mix it thoroughly and compact it into the assembled mould in three
           layers so that the compacted height of the material in the mould is from 44 mm to 49 mm
           in the first layer, from 89 mm to 94 mm in the second layer and from 133 mm to 138 mm
           in the third layer. Specimens that have a compacted height of material for any layer
           outside these height limits must be discarded.
        b) Compact each layer by 60 uniformly distributed blows of the rammer falling freely from a
           height of 300 mm. Deliver the first 55 blows as 5 cycles of 11 blows each, with 8
           distributed around the mould circumference and 3 within the central area. Deliver the
           remaining 5 blows as 4 around the circumference and 1 in the central area (Note 8.7).
           Use only sufficient material, which is representative of the portion, to meet the layer
           heights above (Note 8.8).

5.12 Free the material from around the inside of the collar and then carefully remove the collar.

5.13 Trim the surface of the specimen while the mould is still attached to the baseplate. This
        operation depends upon the characteristics of the material as follows:

5.13.1 For an essentially fine-grained material, trim the compacted material level with the top of the
        mould by means of the straightedge. Use smaller sized material to patch any hollows
        developed in the surface from removal of coarse material during trimming.

5.13.2 For a material containing stones, trim the compacted material in the mould ensuring that
        portions of stones standing above the top of the mould are compensated by hollows of about
        the equivalent volume below the top of the mould.

5.14 Determine the mass \( (m_2) \) of the mould, baseplate and compacted material.

5.15 Calculate the converted wet density as detailed in Steps 6.1 and 6.2 and plot the converted
        wet density \( (\rho_{ow}) \) against the percentage added/removed moisture \( (\text{w}_{ar}) \). The value of \( \text{w}_{ar} \)
is positive if moisture is added, zero if the material is at field moisture content and negative, if moisture is removed.

5.16 Discard the used material. Do not reuse material from a previously compacted specimen.

5.17 Repeat Steps 5.9 to 5.16 for the other test portions to obtain a minimum of three points, at least one of which must be drier and one wetter than optimum moisture content, to satisfactorily define the converted wet density/percentage added/removed moisture relationship.

5.18 If the optimum moisture content has not been straddled or is imprecisely defined, use additional test portions prepared in the same manner as in Steps 5.6 to 5.8, and compacted as in Steps 5.9 to 5.16.

6 Calculations

Calculate as follows:

6.1 For each specimen, wet density of material \( \rho_w \) as follows:

\[
\rho_w = \frac{m_2 - m_1}{V}
\]

where

\( \rho_w \) = wet density of material (t/m³)
\( m_2 \) = mass of mould, baseplate and compacted material (g)
\( m_1 \) = mass of mould and baseplate (g)
\( V \) = volume of mould (cm³)

6.2 For each specimen, converted wet density of material \( \rho_{ow} \) as follows:

\[
\rho_{ow} = \frac{100\rho_w}{100+w_{a/r}}
\]

where

\( \rho_{ow} \) = converted wet density of material (t/m³)
\( \rho_w \) = wet density of material (t/m³)
\( w_{a/r} \) = percentage added/removed moisture

The value of \( w_{a/r} \) is positive if moisture is added, zero if the material is at field moisture content and negative if moisture is removed.

6.3 Plot the converted wet densities obtained for the compacted specimens against their corresponding percentage added/removed moisture. Draw a smooth curve of best fit through the resulting points.

6.4 Determine the converted wet density corresponding to the maximum point on the converted wet density/percentage added/removed moisture curve as the maximum converted wet density \( \rho_{mcw} \).
6.5  Determine the percentage added/removed moisture corresponding to the maximum point on the converted wet density/percentage added/removed moisture curve as the optimum added/removed moisture content (\(w_{oa/r}\)).

6.6  Where required, the estimated optimum moisture content:

\[
OMC_e = w + \frac{w_{oa/r}}{100} + w_w
\]

where

- \(OMC_e\) = estimated optimum moisture content (%)
- \(w\) = insitu moisture content (%)
- \(w_{oa/r}\) = optimum added/removed moisture content (%)

7  Reporting

Report the following as appropriate:

7.1  The plot of converted wet density against the percentage added/removed moisture.

7.2  The maximum converted wet density to the nearest 0.001 t/m³.

7.3  The optimum added/removed moisture content to the nearest 0.1%.

7.4  The estimated optimum moisture content to the nearest 0.1%, if required.

7.5  The method used to determine the insitu moisture content of the compacted material, if required.

7.6  When measured, the density and percentage of any oversize as determined by Test Method Q143.

8  Notes on method

8.1  A mechanical form of apparatus may be used provided the essential dimensions are adhered to and the rammer has a free vertical fall of the correct height with blows being uniformly distributed and in keeping with any prescribed cycle of blows. It is also essential that the design of the machine is such that the mould can be attached to a level and rigid support base.

8.2  A material height gauge, which allows monitoring of the height of compacted material relative to the top of either a Mould A or a Mould B, can be made from a steel bar and marked as follows:

8.2.1  Mould A: Commencing at one end of the bar, measure and mark distances of:

   a)  5.5 mm for the upper range of the third layer
   b)  33.5 mm and 38.5 mm for the acceptable range of the second layer, and
   c)  72.5 mm and 77.5 mm for the acceptable range of the first layer.

8.2.2  Mould B: Using another face and commencing at one end of the bar, measure and mark distances of:

   a)  5.5 mm for the upper range of the third layer
   b)  38.5 mm and 43.5 mm for the acceptable range of the second layer, and
c) 83.5 mm and 88.5 mm for the acceptable range of the first layer.

8.2.3 Mark each face with the appropriate mould size (A or B).

8.3 Before handling oils, the operator must consult the relevant Safety Data Sheet (SDS).

8.4 The validity of this method depends upon the field moisture content and the moisture content of the split test portions, prior to wetting or drying, being substantially the same. Therefore care must be taken to ensure moisture loss is minimized during sampling, preparation and compaction procedures.

8.5 For material compacted in Mould A, a mass of 2.5 kg will be adequate for most materials. A gravel may however, require up to 3 kg, while it may be possible to use as low as 2 kg for a heavy clay. For material compacted in Mould B, about 2.5 times the mass of the material required for Mould A will be required.

8.6 As a guide, suitable intervals of moisture content range between 1% for crushed rock or gravel and 2% to 3% for clays.

8.7 During compaction, material can build up on the surface of the rammer. This is particularly evident at moisture contents near to and above optimum moisture content. In order to prevent the cushioning effect caused by this build up, the rammer face must be inspected and cleaned if necessary during the compaction process.

8.8 It is necessary to control the total amount of mixture compacted since, if the amount of material struck off after removing the collar is too great, the test results will be inaccurate as the energy input will not be within the required tolerances in Table 1. Some stone particles may protrude a little more than 5 mm above the surface for the passing 37.5 mm material. Suitable allowances in the trimming process must be made for these particles but the average height of the compacted specimen before trimming should not exceed 5 mm above the mould.

Table 1 - Dimensions and tolerances for suitable moulds and rammer

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Dimension</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Moulds</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mould A: 105 diameter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal diameter (mm)</td>
<td>105.0</td>
<td>± 0.5 *</td>
</tr>
<tr>
<td>Effective height (mm)</td>
<td>115.5</td>
<td>± 0.5 *</td>
</tr>
<tr>
<td>Nominal volume (cm³)</td>
<td>1000</td>
<td>± 15</td>
</tr>
<tr>
<td>Mould B: 152 mm diameter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal diameter (mm)</td>
<td>152.0</td>
<td>± 1.0 *</td>
</tr>
<tr>
<td>Effective height (mm)</td>
<td>132.5</td>
<td>± 0.5 *</td>
</tr>
<tr>
<td>Nominal volume (cm³)</td>
<td>2400</td>
<td>± 35</td>
</tr>
<tr>
<td><strong>Rammer</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter; round foot (mm)</td>
<td>50</td>
<td>± 0.4</td>
</tr>
<tr>
<td>Area of rammer (mm²)</td>
<td>1964</td>
<td>± 31</td>
</tr>
<tr>
<td>Drop (mm)</td>
<td>300</td>
<td>± 2.0 ‡</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>2.7</td>
<td>± 0.01 ‡</td>
</tr>
<tr>
<td>Energy delivered per blow (J)</td>
<td>7.94</td>
<td>± 0.08</td>
</tr>
<tr>
<td>Number of layers</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>
Table 2 - Size fraction and mould size

<table>
<thead>
<tr>
<th>Percentage retained</th>
<th>Test mould</th>
<th>Portion to be tested</th>
</tr>
</thead>
<tbody>
<tr>
<td>37.5 mm sieve</td>
<td>19.0 mm sieve</td>
<td></td>
</tr>
<tr>
<td>&gt; 35</td>
<td>-</td>
<td>Not tested by this method</td>
</tr>
<tr>
<td>≤ 35</td>
<td>&gt; 20</td>
<td>B</td>
</tr>
<tr>
<td>-</td>
<td>≤ 20</td>
<td>A</td>
</tr>
</tbody>
</table>

Notes:
* Either but not both of the tolerances may be exceeded provided that the specified tolerance on volume is not exceeded.
‡ Either but not both of the tolerances may be exceeded provided that the appropriate tolerance on energy delivered per blow is not exceeded.
Test Method Q143: Treatment of oversize material

1 Source
This method applies the principles of Section 4(c) of AS 1289.5.4.1: Soil compaction and density tests – Compaction control test - Dry density ratio, moisture variation and moisture ratio. It differs from this standard in that the density and percentage of oversize can be determined on either a dry or wet basis and in the apparatus and techniques used for determining the oversize volume.

2 Scope
This method sets out the procedure for the determination of the density and percentage of oversize for a material on either a dry or wet basis. It assumes that the masses of the oversize and undersize material have been determined by other test methods.

The method provides for the volume of oversize to be measured either by using a siphon can or directly by below balance weighing.

3 Apparatus
The apparatus required for this test depends on the technique used to determine the volume of oversize.

3.1 Siphon can
3.1.1 A siphon can of suitable capacity.
3.1.2 A water container, having a volume in excess of the oversize material under test.
3.1.3 Balance of suitable capacity, having a resolution of at least 1 g and with a limit of performance within the range of ± 5 g.

3.2 Below balance weighing
3.2.1 Balance of suitable capacity equipped for below balance weighing, having a resolution of at least 1 g and with a limit of performance within the range of ± 5 g.
3.2.2 Balance bench, equipped with a hole for below balance weighing.
3.2.3 Wire basket of suitable capacity to contain the oversize and a thin wire to suspend the basket.
3.2.4 Container equipped with an overflow and of suitable capacity to accommodate the suspended basket.
3.3 Drying oven of suitable capacity, having a temperature of 105 - 110°C and complying with AS 1289.0.

4 Procedure
The volume of oversize can be determined using the siphon can technique or using below balance weighing.

4.1 Siphon can
4.1.1 Determine the mass of the water container (m_1).
4.1.2 Place the siphon can on a stable level surface and fill the can with water above the level of the overflow and allow the excess water to run to waste.
4.1.3 When water has ceased flowing (dripping), stopper the overflow and place the oversize material in the can, avoiding any water loss.

4.1.4 Remove the stopper from the overflow and collect the excess water in the container.

4.1.5 When the water has ceased flowing (dripping), weigh the container and water (\( m_2 \)).

4.2 **Below balance weighing**

4.2.1 Place the container directly below the hole in the balance bench and fill it until water escapes from the overflow and allow the excess water to run to waste.

4.2.2 When water has ceased flowing (dripping), suspend the basket from the balance using the thin wire so that the basket is completely immersed in water.

4.2.3 When the water has ceased flowing (dripping), record the mass of the basket immersed in water (\( m_3 \)).

4.2.4 Transfer the oversize to the basket and agitate the basket to remove any entrapped air from the oversize.

4.2.5 Add additional water if necessary until water escapes from the overflow and allow the excess water to run to waste.

4.2.6 When the water has ceased flowing (dripping), record the mass of the oversize and basket (\( m_4 \)).

4.3 If the dry mass of the oversize is not known and is required, oven dry the oversize to a constant mass (\( m_{od} \)) (Note 7.1).

5 **Calculations**

Calculate as follows:

5.1 The volume of oversize as follows:

For the siphon can technique:

\[
V_o = m_2 - m_1
\]

where

- \( V_o \) = volume of oversize (cm³)
- \( m_2 \) = mass of container and water (g)
- \( m_1 \) = mass of container (g)

For the below balance weighing technique:

\[
V_o = m_{od} - (m_4 - m_3)
\]

where

- \( V_o \) = volume of oversize (cm³)
- \( m_{od} \) = dry mass of oversize (g)
- \( m_4 \) = mass of fully immersed basket and oversize (g)
- \( m_3 \) = mass of fully immersed basket (g)
5.2 Determine the density of oversize on either a dry or wet basis as follows:

On a dry basis:

\[ \rho_{od} = \frac{m_{od}}{V_o} \]

where \( \rho_{od} \) = density of oversize (dry basis) (t/m³)

\( m_{od} \) = dry mass of oversize (g)

\( V_o \) = volume of oversize (cm³)

On a wet basis:

\[ \rho_{ow} = \frac{m_{ow}}{V_o} \]

where \( \rho_{ow} \) = density of oversize (wet basis) (t/m³)

\( m_{ow} \) = wet mass of oversize (g), obtained from Q142C

\( V_o \) = volume of oversize (cm³)

5.3 Determine the percentage of oversize on either a dry or wet basis as follows:

On a dry basis:

\[ P_{od} = \frac{100m_{od}}{m_{od} + m_{ud}} \]

where \( P_{od} \) = percentage of oversize (dry basis)

\( m_{od} \) = dry mass of oversize (g)

\( m_{ud} \) = dry mass of undersize (g) (Note 7.2), obtained from Q142A or Q142B

On a wet basis:

\[ P_{ow} = \frac{100m_{ow}}{m_w} \]

where \( P_{ow} \) = percentage of oversize (wet basis)

\( m_{ow} \) = wet mass of oversize (g), obtained from Q142C

\( m_w \) = wet mass of material (g), obtained from Q142C

6 Reporting

Report the following values:

6.1 The density of oversize to the nearest 0.001 t/m³, including whether it was determined on a dry or wet basis.
6.2 The percentage oversize to the nearest 1%, including whether it was determined on a dry or wet basis.

7 Notes on method

7.1 The oversize is considered to have reached a constant mass when the difference between successive weighings, after a further 1 hour drying at 105 - 110°C, is not more than 1 percent of the total of the previous moisture losses.

7.2 Where the undersize is not dry, use the wet mass of material (\(m_w\)), wet mass of oversize (\(m_{ow}\)) and moisture content of undersize material (\(w_u\)) to calculate the dry mass of undersize (\(m_{ud}\)) as follows:

\[
m_{ud} = \frac{100(m_w - m_{ow})}{100 + w_u}
\]

where
- \(m_{ud}\) = dry mass of undersize (g)
- \(m_w\) = wet mass of material (g), obtained from Q142A or Q142B
- \(m_{ow}\) = wet mass of oversize (g), obtained from Q142C.
- \(w_u\) = moisture content of undersize material (%), obtained from Q142A or Q142B
Test Method Q144A: Assignment of maximum dry density and optimum moisture content for soils and crushed rock

1 Source
This method is based on AS 1289.5.4.2: Soil compaction and density tests – Compaction control test - Assignment of maximum dry density and optimum moisture content values.

2 Scope
This method sets out the procedure for assigning values of maximum dry density, optimum moisture content and the density and percentage of oversize.

The method is applicable only to essentially uniform materials and is usually confined to pavement materials produced under controlled conditions, such as unbound materials from quarries or plant-mixed stabilised materials. It may be applicable to in situ stabilised materials where the in situ material is essentially uniform or where additional imported material is the majority of the material to be stabilised. Occasionally, earthworks materials such as natural gravels will be found to meet the criteria for assigning values.

3 Procedure
The procedure shall be as follows:

3.1 For quarry materials and plant-mixed stabilised materials:
3.1.1 Obtain six samples of uncompacted material, as detailed in Test Method Q060, from not less than three days production or from stockpiled material to be used in at least three lots. Number each sample and any subsequent sample in chronological order with a sample number at the time of sampling.

3.2 For in situ stabilised materials:
3.2.1 Obtain six samples of uncompacted material after spreading and the incorporation of all stabilising agent, but before the start of compaction, as detailed in Test Method Q061. Number each sample and any subsequent sample in chronological order with a sample number at the time of sampling.

3.3 For earthworks materials excluding stabilised materials:
3.3.1 Obtain six samples of compacted material following the field testing operations for compacted density testing. Number each sample and any subsequent sample in chronological order with a sample number at the time of sampling.

3.4 Test each sample separately and determine the following:
3.4.1 Maximum dry density and optimum moisture content as detailed in Test Method Q142A or Q142B as appropriate.
3.4.2 Density and percentage oversize as detailed in Test Method Q143.

4 Calculations
4.1 Calculate the mean values for the maximum dry density, optimum moisture content and, where appropriate, the density and percentage of oversize from each set of six test results.
4.2 Compare the maximum dry density and optimum moisture content values for each of the six samples to the calculated mean for that property as follows:

4.2.1 If all results obtained for a property from the six samples do not differ from the mean by more than the limits shown in Table 1 for that property, the mean value for that property as calculated in Step 4.1 is designated as the assigned maximum dry density or assigned optimum moisture content, as appropriate (Note 7.1).

4.2.2 If any single result obtained for a property from the six samples differs from the calculated mean for that property by more than the limits shown in Table 1, the determined mean values shall not be assigned for either property for the set of samples. Either obtain and test six further samples as detailed in Section 3 or undertake one-for-one testing as detailed in Test Method Q140A.

4.3 Where values of maximum dry density and optimum moisture content are assigned as detailed in Step 4.2.1, designate any mean values of density and percentage oversize calculated in Step 4.1 as assigned oversize density and assigned percentage oversize (Note 7.1).

5 **Assigned values check**

5.1 Monitor the assigned values by sampling and testing as detailed in Section 3, in accordance with the following frequencies:

5.1.1 Quarry materials and plant-mixed stabilised materials are to be checked by obtaining at least one sample at the following frequency:

   a) after the supply of every 10,000 tonnes of material, such that the check is in the lot that contains the last of the 10,000 tonnes
   
   b) if the assigned values have not been used for 2 months or more, or
   
   c) if the assigned values have not been used on the project being tested.

5.1.2 In situ stabilised materials are to be checked by obtaining at least one sample from every lot.

5.1.3 Earthworks materials excluding stabilised materials are to be checked by obtaining at least one sample from every lot.

5.2 Add the new data to the previous data while removing an equal number of existing and consecutive values commencing at the lowest sample number.

5.3 Calculate new mean values for each property and review the maximum dry density and optimum moisture content data as detailed within Section 4.

5.4 If the criteria in Table 1 are not infringed, report new assigned values for maximum dry density, optimum moisture content and, if appropriate, the density and percentage of oversize (Note 7.1).

5.5 Should the criteria of Table 1 now be infringed:

5.5.1 For quarry materials and plant-mixed stabilised materials:

   a) Either re-determine the assigned values by obtaining and testing six further samples as detailed in Section 3 or undertake one-for-one testing as detailed in Test Method Q140A.

5.5.2 For in situ stabilised materials:

   a) Continue using the assigned maximum dry density, optimum moisture and, if appropriate, the density and percentage of oversize as determined in Section 4 for the remainder of the lot.
b) For subsequent lots either re-determine the assigned values by obtaining and testing six further samples as detailed in Section 3 from the next lot or undertake one-for-one testing as detailed in Test Method Q140A.

5.5.3 For Earthworks materials excluding stabilised materials:

a) Continue using the assigned maximum dry density, optimum moisture and, if appropriate, the density and percentage of oversize as determined in Section 4 for the remainder of the lot.

b) For subsequent lots either re-determine the assigned values by obtaining and testing six further samples as detailed in Section 3 from the next lot or undertake one-for-one testing as detailed in Test Method Q140A.

6 Reporting

Report the following values and general information:

6.1 The assigned value of standard or modified maximum dry density to the nearest 0.001 t/m³.

6.2 The assigned value of standard or modified optimum moisture content to the nearest 0.1%.

6.3 Where required, the assigned value of oversize density to the nearest 0.001 t/m³.

6.4 Where required, the assigned value of percentage oversize to the nearest 1%.

6.5 The date at which the values were assigned and the sender's numbers corresponding to the data sets used.

6.6 For stabilised materials, source, type and quantity of the stabilising agent(s).

7 Notes on method

7.1 Control charts of the progressively assigned values may be plotted to assess whether there is drift in the values being used, and if so, new values may need to be assigned.

Table 1 – Limits for assigning maximum dry density and optimum moisture content

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit</th>
<th>Range</th>
<th>Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum dry density</td>
<td>t/m³</td>
<td>All values</td>
<td>± 0.05</td>
</tr>
<tr>
<td>Optimum moisture content</td>
<td>%</td>
<td>2.0 to 10.0</td>
<td>± 1.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10.1 to 15.0</td>
<td>± 1.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt; 15.0</td>
<td>± 2.0</td>
</tr>
</tbody>
</table>
Test Method Q145A: Laboratory compaction to nominated levels of dry density and moisture content

1 Source
This method was developed in-house using techniques evolved through internal departmental research investigations.

2 Scope
This method describes the procedure for compacting specimens to a nominated dry density and nominated moisture content when such specimens are required by a particular reference test method for further testing. The nominated levels of dry density and/or moisture content often relate to some percentage of the Maximum Dry Density (MDD) and/or Optimum Moisture Content (OMC) or Degree of Saturation (DOS) respectively.

The procedure relies on the reference method to provide essential procedural information such as apparatus and compaction details.

3 Apparatus
Refer to the apparatus section of the reference method.

4 Calculation of target compaction values
4.1 Calculate target compacted dry density if specified as a percentage of MDD as follows:

\[ \rho_t = \frac{\text{MDD} \times \text{RC}_n}{100} \]

where
\[ \rho_t = \text{target compacted dry density (t/m}^3) \]
\[ \text{MDD} = \text{maximum dry density (t/m}^3) \]
\[ \text{RC}_n = \text{nominated relative compaction (％)} \]

4.2 Calculate the target compaction moisture content, if specified, as a percentage of OMC as follows:

\[ w_2 = \frac{\text{OMC} \times \text{RM}_n}{100} \]

where
\[ w_2 = \text{target compaction moisture content (％)} \]
\[ \text{OMC} = \text{optimum moisture content (％)} \]
\[ \text{RM}_n = \text{nominated relative moisture content as a percentage of OMC (％)} \]

4.3 Calculate the target compaction moisture if specified, as a nominated degree of saturation as follows:

\[ w_2 = \frac{\rho_w - 1}{\rho_t - \rho_{sat}} \]

where
\[ w_2 = \text{target compaction moisture content (％)} \]
S = nominated degree of saturation (%)  
\( \rho_w \) = water density (t/m³) (taken as 1.000 t/m³)  
\( \rho_t \) = target compacted dry density (t/m³)  
\( \rho_{st} \) = apparent particle density (t/m³), obtained from Q109

5 Calculation of mass of material per layer

5.1 Calculate the required mass of mixed and cured/conditioned wet material per layer as follows:

\[ M_i = \frac{V \rho_t (100 + w_i)}{100 N} \]

where  
\( M_i \) = mass of wet material per layer (g)  
\( V \) = mould volume (cm³)  
\( \rho_t \) = target compacted dry density (t/m³)  
\( w_i \) = target compaction moisture content (%)  
\( N \) = number of layers.

6 Procedure

6.1 Clean and assemble the mould and baseplate, lightly oiling the internal surfaces. Inspect and clean the rammer or mechanical compactor and ensure that it is free in the guide.

6.2 Determine the mass (\( m_1 \)) of the mould and baseplate, attach the collar and place the assembly on a rigid foundation.

6.3 At the end of the required curing/conditioning period, spread the test portion on the mixing tray and thoroughly remix. Take a subsample and determine the achieved compaction moisture content (\( w_a \)) as detailed in Test Method Q102A.

6.4 Weigh out the required mass of wet material for a layer and evenly distribute the material within the mould (Note 8.1).

6.5 Compact the material to the required height using rammer blows effected from the complete drop of the rammer. Distribute the blows uniformly over the layer surface (Note 8.2). As the required layer height is approached, it may be necessary to use partial blows.

6.6 Repeat Steps 6.4 to 6.5 for each subsequent layer with the final layer being compacted until its height is approximately 1 - 2 mm greater than the required height.

6.7 Level the final layer by lightly scarifying the surface if necessary, and redistributing the loose material.

6.8 Place a suitable levelling plate on the surface and use the steel rammer or a rubber mallet to further compact the layer until the required height is reached.

6.9 Remove the levelling plate together with any collar and/or spacer.

6.10 Determine the mass (\( m_2 \)) of the mould, baseplate and compacted material.
7 Calculations

7.1 Calculate the achieved compacted dry density to the nearest 0.001 t/m³ as follows:

\[ \rho_a = \frac{100(m_2 - m_1)}{V(100 + w_a)} \]

where
\[ \rho_a \] = achieved compacted dry density (t/m³)
\[ m_2 \] = mass of mould, baseplate and compacted material (g)
\[ m_1 \] = mass of mould and baseplate (g)
\[ V \] = volume of mould (cm³)
\[ w_a \] = achieved compaction moisture content (%)

7.2 When the target compacted dry density is specified as a percentage of MDD, calculate the achieved relative compaction to the nearest 0.1 % as follows:

\[ RC_a = \frac{\rho_a 100}{MDD} \]

where
\[ RC_a \] = achieved relative compaction (%)
\[ \rho_a \] = achieved compacted dry density (t/m³)
\[ MDD \] = maximum dry density (t/m³)

7.3 When the target compaction moisture content is specified as a percentage of OMC, calculate the achieved percentage of OMC to the nearest 1 % as follows:

\[ p_m = \frac{w_a 100}{OMC} \]

where
\[ p_m \] = achieved percentage of OMC (%)
\[ w_a \] = achieved compaction moisture content (%)
\[ OMC \] = optimum moisture content (%)

7.4 When the target compaction moisture content is specified as a percentage of DOS, calculate the achieved percentage of DOS to the nearest 1 % as follows:

\[ S = \frac{w_a}{\frac{\rho_w}{\rho_a} - 1} \]

where
\[ S \] = achieved degree of saturation (%)
\[ w_a \] = achieved compaction moisture content (%)
\[ \rho_w \] = water density (t/m³) (taken as 1.000 t/m³)
\[ \rho_a \] = achieved compacted dry density (t/m³)
\[ \rho_{st} = \text{apparent particle density (t/m}^3\text{)} \]

8 Reporting

Report the following values as appropriate:

8.1 Target compacted dry density to the nearest 0.001 t/m³.

8.2 Nominated relative compaction to the nearest 0.1%, if appropriate.

8.3 Target compaction moisture content to the nearest 0.1%.

8.4 Nominated relative moisture content as a percentage of OMC to the nearest 1%.

8.5 Nominated degree of saturation to the nearest 1%.

8.6 Achieved compacted dry density to the nearest 0.001 t/m³.

8.7 Achieved relative compaction to the nearest 0.1%.

8.8 Achieved compaction moisture content to the nearest 0.1%.

8.9 Achieved percentage of OMC to the nearest 1%.

8.10 Achieved DOS to the nearest 1%.

9 Notes on method

9.1 When compacting multiple specimens from the same test portion, it is preferable that these are moulded simultaneously. This is accomplished by compacting the same layer in each mould one after the other.

9.2 When compacting using a 150 mm nominal diameter mould, deliver the blows in cycles of 11, with 8 distributed around the mould circumference and 3 in the central area.
Test Method Q146: Degree of saturation of soils and crushed rock

1 Source
This procedure was developed in-house using information contained within technical references.

2 Scope
This method describes the procedure for determining the degree of saturation of compacted layers of pavements consisting of unbound materials.

3 Procedure
3.1 Select test locations within the lot under consideration using Random Stratified Sampling: Selection of Location – Available Area as detailed in Test Method Q050 (unless otherwise specified).

3.2 Determine the insitu dry density and the insitu moisture content of the compacted pavement material as detailed in Test Method Q141A preferably, or Q141B (Note 6.1).

3.3 Determine the apparent particle density of the pavement material as detailed in Test Method Q109, re-establishing an updated value at the following frequency:

3.3.1 Undertake one test per 10,000 tonnes supply or one test per fortnight, whichever produces the greater number of tests where an assigned maximum dry density applies.

3.3.2 Undertake one test per 5,000 tonnes supply or one test per week, whichever produces the greater number of tests where one-for-one testing applies.

3.4 Determine the degree of saturation as described in Section 4.

3.5 Where the degree of saturation has necessitated further drying of the pavement material, retest to determine the compacted density and insitu moisture content as detailed in Steps 3.1 to 3.2.

4 Calculations
4.1 Calculate the degree of saturation as follows:

\[ S = \frac{w}{\rho_w} \frac{1}{\rho_d \rho_{st}} \]

where

- \( S \) = degree of saturation (%)
- \( w \) = insitu moisture content (%)
- \( \rho_w \) = water density (t/m³) (taken as 1.000 t/m³)
- \( \rho_d \) = compacted dry density (t/m³)
- \( \rho_{st} \) = apparent particle density (t/m³)

4.2 Where a number of tests have been performed on a lot, calculate the maximum characteristic degree of saturation as detailed in Test Method Q020.
5 Reporting

Report the following:

5.1 Degree of saturation to the nearest 1%.
5.2 Compacted dry density to the nearest 0.001 t/m³.
5.3 In situ moisture content to the nearest 0.1%.
5.4 Apparent particle density to the nearest 0.001 t/m³ and date determined.
5.5 If required, the maximum characteristic degree of saturation as detailed in Test Method Q020.

6 Notes on method

6.1 When the in situ dry density and the in situ moisture content of the compacted pavement material is determined as detailed in Test Method Q141A, a material wet density bias and a material moisture bias must always be determined and used to adjust the nuclear gauge wet density and moisture content respectively. Refer to Nuclear Gauge Testing Manual Test Method N01 for details.
Test Method Q147B: Compacted density of stabilised material - vacuum saturation

1 Source
This method applies the principles of ASTM C642: Standard test method for density, absorption and voids in hardened concrete to the determination of the compacted density of stabilised specimens.

2 Scope
This method describes a procedure for determining the compacted density of stabilised specimens. The specimens may be either laboratory or field compacted. The method is also applicable to cores removed from stabilised materials.

3 Apparatus
The following apparatus is required:

3.1 Balance, of suitable capacity, with a resolution of at least 0.1 g and with a limit of performance within the range of ± 0.5 g. The balance shall also be capable of below balance weighing.

3.2 Balance bench, equipped with a hole for below balance weighing.

3.3 Thermometer, a partial or total immersion thermometer or other suitable temperature measuring device having a temperature range which includes the test temperature, and graduated to 1°C or less with an uncertainty of no more than 0.5°C.

3.4 Attachment, a non-absorbent device to suspend the specimen (for example, nylon or wire loop, wire support frame).

3.5 Water container, fitted with an overflow and of suitable dimensions to allow the specimen to be completely immersed without contacting any part of the container.

3.6 Water container, of sufficient volume to contain the specimen.

3.7 Oven, of suitable capacity, having a temperature of 105 – 110°C and complying with AS 1289.0.

3.8 A vacuum apparatus and chamber.

3.9 Container for soaking specimens.

3.10 Tray for drying specimens.

4 Materials
The following materials are required:

4.1 Potable water.

4.2 Cloths for removing excess water from vacuum soaked specimens.

5 Procedure
The procedure shall be as follows:

5.1 Sample preparation
5.1.1 Where the specimen is a core, prepare the core specimen as detailed in Q303A Subsection 4.2 without air-drying to obtain specimens about 63.5 mm in height for testing.
5.1.2 Determine the mass of the specimen ($m_1$).

5.1.3 Place the specimen in a container and cover with potable water at $23 \pm 3.0^\circ C$. Place in the vacuum chamber and apply a partial vacuum of 13 kPa or less absolute pressure for 10 minutes (Note 8.1).

5.1.4 After the vacuum soaking remove the specimens from the water and carefully remove excess water using a cloth.

5.1.5 Determine the mass of the saturated-surface-dry specimen ($m_2$).

5.2 Density measurement

5.2.1 Place the container directly below the hole in the balance bench, fill it until water escapes from the overflow and allow the excess water to run to waste.

5.2.2 When water has ceased dripping from the overflow, fit the attachment to the balance, allow the remainder of the attachment to be immersed in the water container, and zero the balance.

5.2.3 Using the attachment, suspend the specimen from the balance and gently lower it into the water container until completely immersed, taking care to ensure that the suspended specimen hangs free of the sides and bottom of the container.

5.2.4 Add additional water if necessary until water escapes from the overflow, and allow the excess water to run to waste.

5.2.5 When water has ceased dripping from the overflow, determine the mass of the immersed specimen ($m_3$).

5.2.6 Record the temperature of the water in the container to the nearest 1°C.

5.3 Drying of specimen

5.3.1 Determine the mass of the drying tray ($m_4$).

5.3.2 Remove the specimen from the water and place in the drying tray. Place the specimen and drying tray in an oven and dry to constant mass (Note 8.2).

5.4 Determine the mass of the drying tray and dry specimen ($m_5$).

6 Calculations

Calculate as follows:

6.1 Calculate the compacted dry density of the specimen as follows:

$$\rho_d = \frac{m_5 - m_4}{m_2 - m_3} D_w$$

where

- $\rho_d$ = compacted dry density of specimen ($t/m^3$)
- $m_5$ = mass of dry specimen and tray (g)
- $m_4$ = mass of tray (g)
- $m_2$ = mass of saturated-surface-dry specimen (g)
- $m_3$ = mass of immersed specimen (g)
6.2 Calculate the moisture content as follows:

\[
\text{w} = \frac{m_1 - (m_5 - m_4)}{m_5 - m_4} \times 100
\]

where

- \(w\) = moisture content of specimen (%)
- \(m_1\) = mass of specimen (g)
- \(m_5\) = mass of dry specimen and tray (g)
- \(m_4\) = mass of tray (g)

7 Reporting

Report the following:

7.1 Compacted density of the sample to the nearest 0.001 t/m³.
7.2 Moisture content of specimen to the nearest 0.1%.

8 Notes on method

8.1 A partial vacuum of 13 kPa absolute pressure is approximately equivalent to a -88 kPa reading on a vacuum gauge at sea level.

8.2 The specimen is considered to have reached a constant mass when the difference between successive weighings, after a further 1 hour drying at 105-110°C, is not more than 1 percent of the total of the previous moisture losses.

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<thead>
<tr>
<th>Table 1 - Density of water</th>
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<td>Temperature (°C)</td>
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Test Method Q148: Manufacture of granular specimens for wheel tracker testing

1 Source

This method was developed in-house but applies the principles of Austroads Asphalt Test AST 05-1999: Sample Preparation - Compaction of Asphalt Slabs Suitable for Characterisation to granular materials.

2 Scope

This method describes the procedure for the laboratory manufacture of granular slab specimens using a segmental wheel compactor for wheel tracker testing.

3 Apparatus

The following apparatus is required:

3.1 Segmental wheel compactor, comprising the following (Note 9.1):

3.1.1 Compaction device, capable of applying a loading of 1000 to 30,000 N to within 500 N. The compaction device shall be in the form of a freely rotating wheel segment of diameter 1200 ± 200 mm. The foot of the compaction device shall have an arc length of 300 mm and a width of 300 mm. The compaction foot shall be able to be moved vertically and set to a specified height above the base of the compaction mould using a setting block. It shall have the option of vibratory compaction and shall be of sufficient rigidity that it will not deform under load over the operating range.

3.1.2 Compaction table, having an oscillating speed of 10 to 25 oscillations per minute adjustable to within 1 oscillation per minute, and a travel of 200 to 450 mm adjustable to within 5 mm. The table shall have provision to firmly attach the compaction mould.

3.1.3 Compaction moulds, three metal moulds of internal dimensions 300 mm length, 300 mm width and 100 mm height. A 55 mm detachable collar is also fitted to the top of the mould to accommodate the slab specimen material prior to compaction. Each mould shall be fitted with two removable end plates of dimensions 300 mm length and 125 mm height attached to the top of two opposite sides of the mould. The mould shall be equipped with a detachable base plate to facilitate locking of the mould into the slab compactor.

3.1.4 Lifting device, to move a compaction mould (with or without material) to and from the compaction table.

3.2 Sieves, 19.0 mm and 9.50 mm complying with AS 1152.

3.3 Miscellaneous mixing apparatus, such as a tray, trowel or scoop and water spray suitable for mixing increments of water into the material.

3.4 Sealable containers, suitable for curing the material samples.

3.5 Balance, of suitable capacity, with a resolution of at least 1 g and with a limit of performance within the range of ± 5 g.

3.6 Compaction apparatus meeting the requirements of Test Method Q145A.
4 Sample preparation

The sample shall be prepared as follows:

4.1 Prepare the bulk sample as detailed in Section 5 of Test Method Q101 to produce a representative subsample of at least 100 kg.

4.2 Further prepare the material by screening the subsample on a 19.0 mm sieve as detailed in Test Method Q101, Steps 6.2.1 to 6.2.3. Ensure that any aggregations are broken up to pass a 9.50 mm sieve and any oversize material is retained.

4.2.1 Where oversize is retained on the 19.0 mm sieve, determine its mass (\(m_{ow}\)) and the mass of the passing 37.5 mm (undersize) material (\(m_{uw}\)). Calculate the percentage oversize on a wet mass basis as follows:

\[
p_{ow} = \frac{100m_{ow}}{m_{ow} + m_{uw}}
\]

where

\(p_{ow}\) = percentage by wet mass of oversize
\(m_{ow}\) = wet mass of oversize (g)
\(m_{uw}\) = wet mass of undersize (g)

4.3 Discard any material retained on the 19.0 mm sieve.

4.4 Prepare representative test portions as follows:
   a) two test portions of 15,000 g for slab compaction and determine the mass of each test portion (\(m_1\))
   b) test portion for hygroscopic moisture content
   c) test portion for apparent particle density
   d) suitable number of test portions to determine the optimum moisture content (OMC) and maximum dry density (MDD).

4.5 Determine the hygroscopic moisture content (\(w_1\)) of the test portion prepared in Step 4.5 b) as detailed in Test Method Q102A.

4.6 Determine the apparent particle density (\(\rho_a\)) of the test portion prepared in Step 4.5 c) as detailed in Test Method Q109.

4.7 Determine the optimum moisture content (OMC) and maximum dry density (MDD) of the test portion prepared in Step 4.5 d) as detailed in the relevant test method from Test Methods Q142A or Q142B as appropriate using a Type A mould.

5 Preparation of test specimens

5.1 For each test portion calculate the dry mass of material as follows:

\[
m_2 = \frac{100m_1}{100+w_1}
\]

where

\(m_2\) = mass of dry material in test portion (g)
m_i = mass of wet material in test portion (g)

w_i = hygroscopic moisture content (%)

5.2 Using the procedure detailed in Test Method Q145A, calculate the target compaction moisture content (w_2) to achieve the nominated relative compaction and nominated relative moisture content or nominated degree of saturation.

5.3 For each test portion calculate the mass of mixing water to be added as follows:

\[ m_3 = \frac{m_2 w_2}{100} \times (m_i - m_2) \]

where

m_3 = mass of mixing water to be added (g)

m_2 = mass of dry material in test portion (g)

w_2 = target compaction moisture content (%)

m_i = mass of wet material in test portion (g)

5.4 Measure out the required mass of mixing water to be added (m_3).

5.5 Spread out each test portion on the mixing tray and add the mixing water to the material in small increments and combine thoroughly to form a uniform mixture (Note 9.2).

5.6 After mixing place each test portion into a curing container to cure for an adequate period of time for the material (Note 9.3).

6 Slab specimen compaction

The slab specimen shall be compacted as follows:

6.1 Using the procedure detailed in Test Method Q145A, calculate the mass of material per layer.

6.2 Assemble the mould and detachable base plate.

6.3 Determine the mass (m_1) of the mould and base plate. Attach the collar and fix the collar to the mould.

6.4 At the end of the required curing/conditioning period, spread the test portion on the mixing tray and thoroughly remix. Take a subsample and determine the achieved compaction moisture content (w_a) as detailed in Test Method Q102A.

6.5 Insert the 50 mm height setting block into the slab compactor to set the thickness of the slab specimen and locate the compaction foot at a height corresponding to just below the top of the mould end plate.

6.6 Transfer the cured test portion to the mould, screed it flat without segregation using a trowel and level the material.

6.7 With the compaction table at the end of its forward cycle, transfer the mould and sample to the compaction table using the lifting device.

6.8 Fix the mould to the compaction table.
6.9 Move the compaction table until the compaction foot is aligned with the inside edge of the mould collar.

6.10 Lower the compaction foot to rest on the material in the mould.

6.11 Compact the sample in the mould using the manufacturer's instructions to provide the following compaction sequence:
   a) 5 oscillations at a pressure of 25 kPa
   b) 5 oscillations at a pressure of 50 kPa
   c) 10 oscillations at a pressure of 100 kPa
   d) 10 oscillations at each additional increment of 100 kPa until the target slab thickness is attained across the whole of the slab specimen (Note 9.4).

6.12 Raise the compaction foot, remove the mould and scarify the top of the compacted material to promote bonding with the overlaying layer.

6.13 Transfer the second cured test portion to the mould, screed it flat without segregation using a trowel and level the material.

6.14 Remove the 50 mm height setting block and replace with the 100 mm height setting block and repeat Steps 6.8 to 6.11.

6.15 Raise the compaction foot, move the compaction table to the end of its forward cycle and remove the mould.

6.16 Remove the collar and mark the slab specimen with the direction of rolling and an identification number.

6.17 Determine the mass \( m_2 \) of the mould and base plate.

6.18 Remove the detachable base plate and transfer the mould from the segmental wheel compactor using the lifting device.

7 Calculations

7.1 For each specimen calculate the achieved compacted dry density, compaction moisture content, relative compaction percentage of OMC and degree of saturation as detailed in Test Method Q145A.

8 Reporting

Report the following values and general information:

8.1 The percentage of oversize material retained on 19.0 mm sieve.

8.2 For each specimen, the achieved dry density, achieved moisture content, target relative compaction, achieved relative compaction, nominated relative moisture content as a percentage of OMC, achieved percentage of OMC, nominated degree of saturation and achieved degree of saturation as detailed in Test Method Q145A.

9 Notes on method

9.1 The BP Slab Compactor satisfies the requirements of the segmental wheel compactor.

9.2 It is important that water is thoroughly mixed into the material and the test portion cured for sufficient time to allow the water to become evenly distributed throughout the material.
9.3 For a material prepared in a moist condition close to optimum moisture content, periods up to 2 hours may be adequate. However, if the material contains dry clay, periods of up to 7 days may be required. Thus, more cohesive materials will need longer curing times.

9.4 Vibratory compaction may be used where it becomes apparent that compaction without vibration will not achieve the target slab thickness.
Test Method Q149: Deformation of granular material - wheel tracker

1 Source
This method was developed in-house but applies the principles of Austroads Asphalt Test AST 01-1999 Deformation Resistance of Asphalt Mixtures by the Wheel Tracking Test to granular materials.

2 Scope
This method describes the procedure for determining the susceptibility of granular materials to deformation under load. It involves monitoring the deformation that occurs in a granular sample undergoing to and fro motion when a loaded wheel is brought to bear on its surface. The method is applicable to granular materials compacted in the laboratory.

3 Apparatus
The following apparatus is required:

3.1 Wheel tracker apparatus comprising the following:
3.1.1 Loaded wheel mechanism, consisting of a steel wheel of diameter 200 to 205 mm and width 50 ± 1 mm fitted with a smooth solid rubber tread of thickness 10 to 13 mm and hardness 90 ± 10 IRHD units. The mechanism shall include a means of loading the wheel so that a force of 700 ± 20 N is applied centrally and normal to the top surface of the test specimen. Vertical play in the loaded wheel mechanism shall be less than 0.25 mm.

3.1.2 Wheel tracker table, capable of moving in simple harmonic motion at a frequency of 21 ± 0.2 cycles per minute over a travel distance of 250 ± 20 mm (Note 7.1). It shall be fitted with a means for fixing a test specimen of dimensions up to 305 mm length, 305 mm width and 100 mm thickness to the table.

3.1.3 Rut depth measurement device, an electronic displacement measuring device having a minimum travel of 20 mm and a limit of performance within the range of ± 0.1 mm.

3.1.4 A means for continuously recording rut depth measurements at progressive numbers of wheel tracker cycles.

3.1.5 A means for controlling the test specimen temperature to within ± 1°C of the test temperature throughout the test.

3.2 Wheel tracker mould, a steel mould comprising detachable sides and baseplate and having dimensions of 300 mm length and 300 mm width and a depth of 100 mm.

4 Procedure
The procedure shall be as follows:

4.1 Prepare the test specimen as detailed in Test Method Q148.

4.2 Fix the test specimen to the wheel tracker table ensuring that the indicated rolling direction is aligned with the direction of travel of the loaded wheel.

4.3 Lower the loaded wheel to the surface of the test specimen and commence wheel tracking in accordance with the operating instructions for the wheel tracker apparatus.

4.4 Obtain a continuous record of the rut depth corresponding to different numbers of wheel tracker cycles.
4.5 Continue wheel tracking for a minimum of 5000 cycles or until the rut depth is in excess of 15 mm (Note 7.2).

4.6 Remove the specimen from the mould and determine the achieved compaction moisture content \( w_a \) of the whole specimen as detailed in Test Method Q102A.

5 Calculations

5.1 For each specimen calculate the tracking rate over the range of cycles specified for the test as follows:

\[
T_R = \frac{R_H - R_L}{N_H - N_L} \times 1000
\]

where

- \( T_R \) = tracking rate (mm/kCycle)
- \( R_H \) = rut depth at higher number of specified cycles (mm)
- \( R_L \) = rut depth at lower number of specified cycles (mm)
- \( N_H \) = higher number of specified cycles
- \( N_L \) = lower number of specified cycles

6 Reporting

Report the following values and general information:

6.1 Description of the sample.
6.2 The type and source of the material.
6.3 Tracking rate of the materials to the nearest 0.01 mm/kCycle.
6.4 Range of wheel tracker cycles over which the tracking rate was calculated.
6.5 Rut depth of the material at the completion of the test to the nearest 0.01 mm.
6.6 Layer thickness of the material to the nearest 1 mm.
6.7 Number of loading cycles.
6.8 Test temperature to the nearest 1°C.

7 Notes on method

7.1 One cycle represents the outward and return passes of the loaded wheel, that is, two passes.

7.2 Where no range of cycles is specified for the test, a range of 2000 to 5000 cycles may be used.
Test Method Q160: Water repellency of soil

1 Source
This method applies the principles of the water drop penetration time (WDPT) test developed by Bessel D. van’t Woudty, 1959 and classifies the soils wettability using a classification developed by Louis W. Decker, 1988.

2 Scope
This method sets out the procedure for determining water repellency (hydrophobicity) by using the water drop penetration time (WDPT1) test.

A measured amount of water in droplets is applied to a dried, smoothed, levelled and uncompacted soil surface and the time that lapses before the droplets are absorbed is determined.

3 Apparatus
The following apparatus is required:

3.1 Oven of suitable capacity, capable of heating a sample of soil to 40 ± 2°C.
3.2 Tray, suitable size for drying soil.
3.3 Standard medicine dropper.
3.4 Stopwatch.

4 Materials
The following materials are required:

4.1 Deionised or distilled water.

5 Procedure
The procedure shall be as follows:

5.1 Obtain a test portion of soil with a minimum volume of 300 mL.
5.2 Place the test portion on a tray and level to a smooth but uncompacted surface.
5.3 Place the test portion and tray in the oven and dry to a constant mass (Note 7.1).
5.4 Remove the test portion and tray from the oven and allow to cool to room temperature.
5.5 Using the standard medicine dropper, apply three water droplets to the surface of the from the test portion.
5.6 Determine the time it takes for the water to infiltrate (disappear) into the test portion and record as the water drop penetration time to the nearest second.

6 Reporting
Report the following:

6.1 Water drop penetration time to the nearest 1 second.
6.2 Water repellence class value (Table 1).
6.3 Water repellence rating description (if required).
7 Notes on method

7.1 Constant mass is achieved when, after the initial drying period, successive drying over 1 h periods gives rise to a weight loss of not more than 1% of the initial weight loss.

Table 1 - Soil water repellency class

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<thead>
<tr>
<th>Class</th>
<th>WDPT (seconds)</th>
<th>Water repellence rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>&lt; 5</td>
<td>wettable; non-water repellent</td>
</tr>
<tr>
<td>1</td>
<td>5 – 60</td>
<td>slightly water repellent</td>
</tr>
<tr>
<td>2</td>
<td>&gt; 60</td>
<td>strongly water repellent</td>
</tr>
</tbody>
</table>
Test Method Q161: Field dispersion indicator test of soil - slaking

1 Source

This method is based on the procedure described in the SOILpak – southern irrigators - Readers’ Note – Part C. Diagnosis of Soil, Chapter C7. Slaking and Dispersion; NSW Department of Primary Industry, 1999.

2 Scope

This method sets out the method for determining slaking of a soil. Slaking is the breakdown of soil aggregates into smaller fragments when placed in water.

Slaking indicates a soils resistance to erosion and how well it maintains its structure when wetted. Slaking is the breakdown of air-dry soil aggregates (> 2 – 5 mm) into smaller micro-aggregates (< 0.25 mm) when immersed in water. Slaking occurs when soil aggregates are not strong enough to withstand internal stresses caused by rapid water uptake as a result of swelling clay particles; trapped and escaping air in soil pores. Slaking results in detached soil particles that fill soil pores and cause surface sealing - reducing infiltration and plant available water; and increasing runoff and erosion (Note 8.1).

3 Apparatus

The following apparatus is required:

3.1 Clear petri dish or similar.

4 Materials

The following materials are required:

4.1 Deionised or distilled water.

5 Procedure

The procedure shall be as follows:

5.1 From the sample select three soil aggregates of 5-10 mm diameter.

5.2 If moist, air dry the aggregates.

5.3 Fill a petri dish with 5 mm of deionised or distilled water or at least enough water to cover the soil aggregates.

5.4 Carefully place the three soil aggregates into the water.

5.5 Do not knock, disturb or place the petri dish in a windy position.

5.6 Determine the class of slaking at 5 and 120 minutes for each aggregate using Table 1.

6 Calculations

Calculate the following:

6.1 The highest class value from the three aggregates at 120 minutes and record as the slaking class.

7 Reporting

Report the Slaking class.
8 Notes on method

8.1 The slaking classes have been adapted from Soil Quality indicators; USDA Natural Resources Conservation Services, 2008.

Table 1 - Slaking class

<table>
<thead>
<tr>
<th>Class</th>
<th>Aggregate description at 5 min.</th>
<th>Aggregate description at 120 min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>no change</td>
<td>no change</td>
</tr>
<tr>
<td>1</td>
<td>slight edge breakdown</td>
<td>slight edge breakdown</td>
</tr>
<tr>
<td>2</td>
<td>collapses in pieces</td>
<td>collapses in pieces</td>
</tr>
<tr>
<td>3</td>
<td>collapses into finer &lt; 2 mm pieces</td>
<td>collapses into finer &lt; 2 mm pieces</td>
</tr>
<tr>
<td>4</td>
<td>complete breakdown</td>
<td>complete breakdown</td>
</tr>
</tbody>
</table>
Test Method Q162 – Field dispersion indicator test of soil - clouding

1 Source

This method is based on the procedure described in the SOILpak – southern irrigators - Readers’ Note – Part C. Diagnosis of Soil, Chapter C7. Slaking and Dispersion; NSW Department of Primary Industry, 1999.

2 Scope

This method describes the procedure for determining clouding (dispersion) of soil. Clouding is the separation of individual clay particles when placed in water.

When a sodic (dispersive) soil comes into contact with non-saline water, water is drawn between the clay layers causing the clay to swell so that individual clay layers separate from the soil aggregate, this process is known as dispersion.

Dispersion describes the behaviour of clay particles separating from one another in a moist soil. Dispersion causes soil aggregates to breakdown resulting in the clogging of soil pores by the dispersed clay particles. This results in the swelling of clay platelets and the collapse of clay aggregates.

Dispersion is often seen as ‘muddy’ or ‘milky’ water in dams and surface and runoff water (Note 8.1).

3 Apparatus

The following apparatus is required:

3.1 Clear petri dish or similar.

4 Materials

The following materials are required:

4.1 Deionised or distilled water.

5 Procedure

The procedure shall be as follows:

5.1 From the sample select three soil aggregates of 5-10 mm diameter.

5.2 If moist, air dry the aggregates.

5.3 Fill a petri dish with 5 mm of deionised or distilled water or at least enough water to cover the soil aggregates.

5.4 Carefully place the three soil aggregates into the water.

5.5 Do not knock, disturb or place the petri dish in a windy position.

5.6 Determine the class of clouding at 5 and 120 minutes for each aggregate using Table 1.

5.7 Record the presence of a milky ring around the aggregates, even if the soil collapses or bubbles.
6 Calculations

Calculate the following:

6.1 The highest class value from the three aggregates at 120 minutes and record as the clouding class.

7 Reporting

Report the Clouding class.

8 Notes on method

8.1 Dispersion only occurs in non-saline water or rainwater; hence the use of deionised or distilled water for testing for clouding.

Table 1 - Clouding class

<table>
<thead>
<tr>
<th>Class</th>
<th>Aggregate description at 5 min.</th>
<th>Aggregate description at 120 min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>no clouding</td>
<td>no clouding</td>
</tr>
<tr>
<td>1</td>
<td>slight milky ring</td>
<td>slight milky ring</td>
</tr>
<tr>
<td>2</td>
<td>moderate milky ring</td>
<td>moderate milky ring</td>
</tr>
<tr>
<td>3</td>
<td>strong milky ring</td>
<td>strong milky ring</td>
</tr>
<tr>
<td>4</td>
<td>complete dispersion very strong milky ring</td>
<td>complete dispersion very strong milky ring</td>
</tr>
</tbody>
</table>
Test Method Q171: Moisture content and dry density of a soil sample

1 Source
This method applies the principles of AS 1289.6.4.1: Determination of compressive strength of a soil – Compressive strength of a specimen tested in undrained triaxial compression without measurement of pore water pressure, to the determination of the moisture content and dry density of a soil specimen.

2 Scope
This method describes the procedure for the determination of the moisture content and dry density of a sample of undisturbed soil or a remoulded soil sample. This method is primarily used for fine grained soils.

3 Apparatus
The following apparatus is required:

3.1 Split mitre mould (two piece) or steel cutting ring with an inside diameter equal to the inside diameter of a thin walled sampling tube (nominal sizes are 50, 75 and 100 mm diameter), for obtaining a specimen from an undisturbed sample. The length of the mould should be 1 to 2 times the nominal diameter of the sampling tube. The length for cutting rings should be no less than 20 mm.

3.2 Wire saw, sharp knife and spatula.

3.3 Calliper, with a resolution not greater than 0.1 mm complying with AS 1984 or JIS-B1904.

3.4 Balance of suitable capacity, having a resolution of at least 0.1 g and with a limit of performance within the range of ± 0.5 g.

3.5 Drying oven of suitable capacity, having a temperature 105-110°C and complying with AS 1289.0.

3.6 Containers with lids for moisture content determination.

4 Procedure
The procedure shall be as follows:

4.1 Extrude the soil sample from the sampling tube, taking care to avoid any disturbance to the soil shape or structure.

4.2 Cut a specimen from the required section of extruded sample. Ensure that the length of the untrimmed specimen is greater than the length of the split mould or cutting ring selected for trimming.

4.3 Place the specimen in the split mitre mould or cutting ring and trim the ends of the specimen square to the end of the mould (Note 7.1).

4.4 Remove the specimen from the mould or cutting ring.

4.5 Determine the length of the specimen (L) at three points evenly spaced around the specimen (Note 7.2).

4.6 Determine the diameter of the specimen (D) at three points evenly spaced along the specimen and evenly distributed around the circumference of the specimen (Note 7.2).

4.7 Determine the mass of the container and lid (m1).
4.8 Place undisturbed specimens or remoulded specimens with a diameter equal to or less than 50 mm into the container whole (Note 7.3).

4.9 Carefully split remoulded specimens with a diameter greater than 50 mm longitudinally and lay open in the container for drying (Note 7.4).

4.10 Determine the mass of the container, lid and wet specimen (\(m_2\)).

4.11 Remove the lid from the container and dry the test portion in the oven at 105-110°C (Notes 7.5 and 7.6).

4.12 Remove the container from the oven, replace the lid and allow the container to cool until it is warm to touch.

4.13 Determine the mass of the container, lid and specimen (\(m_3\)).

4.14 Remove the lid from the container and place the container and specimen in the oven. Dry the specimen for at least another hour after the temperature recovers to 105-110°C.

4.15 Repeat Steps 4.12 to 4.13.

4.16 Repeat Steps 4.14 to 4.15 until such time that the difference between successive weighings, after a further 1 hour drying, is not more than 1 per cent of the total of the previous moisture losses (Note 7.7).

5 Calculations

Calculate as follows:

5.1 Calculate the moisture content of the specimen as follows:

\[
w = \frac{m_2 - m_1}{m_3 - m_1} 
\]

where

- \(w\) = moisture content of the specimen (\%)
- \(m_2\) = mass of container, lid and wet specimen (g)
- \(m_3\) = mass of container, lid and dry specimen (g)
- \(m_1\) = mass of container and lid (g)

5.2 Calculate the average length of the specimen as follows:

\[
L_{av} = \frac{\sum L}{3}
\]

where

- \(L_{av}\) = average specimen length (mm)
- \(L\) = individual specimen length measurement (mm)

5.3 Calculate the average diameter of the specimen as follows:

\[
D_{av} = \frac{\sum D}{3}
\]

where

- \(D_{av}\) = average specimen diameter (mm)
D = individual specimen diameter measurement (mm)

5.4 Calculate the volume of the specimen as follows:

\[ V = \frac{\pi D_{av}^2 L_{av}}{4} \]

where

\[ V \] = volume of specimen (mm³)
\[ D_{av} \] = average specimen diameter (mm)
\[ L_{av} \] = average specimen length (mm)

5.5 Calculate the wet density of the sample as follows:

\[ \rho_w = \frac{(m_2 - m_1)1000}{V} \]

where

\[ \rho_w \] = wet density of specimen (t/m³)
\[ m_2 \] = mass of container and wet specimen (g)
\[ m_1 \] = mass of container (g)
\[ V \] = volume of specimen (mm³)

5.6 Calculate the dry density of the sample as follows:

\[ \rho_d = \frac{(m_3 - m_1)1000}{V} \]

where

\[ \rho_d \] = dry density of specimen (t/m³)
\[ m_3 \] = mass of container and dry specimen (g)
\[ m_1 \] = mass of container (g)
\[ V \] = volume of specimen (mm³)

6 Reporting

Report the following values and general information:

6.1 Moisture content to the nearest 0.1%.

6.2 Wet density and dry density to the nearest 0.01 t/m³.

6.3 The presence of any inclusions within the specimen which may influence the calculated moisture content and dry density values.

6.4 Drying temperature (if required) to the nearest 1°C.

7 Notes on method

7.1 Because of the size tolerance of a thin walled sampling tube, the extruded sample diameter may be slightly less than the diameter of the split mitre mould. It is suggested to wrap the
specimen with a soft packing material before placing it in the mould to prevent the sample from slipping during trimming. Where a split mitre mould is used to trim an oversized low strength soil sample, care must be taken not to press the mould too tightly together as distortion of the sample may occur.

7.2 Where the specimen is prepared using a cutting ring, measurements of the length and diameter of the ring may be used as the dimensions of the specimen.

7.3 The undisturbed specimens should not be broken up for drying as this will destroy evidence of lensing which becomes apparent during drying as a result of different shrinkage patterns for different materials.

7.4 Remoulded specimens shall be carefully broken up in a manner such that all the broken material is retained in the container for drying.

7.5 A drying time of 16 to 24 hours is usually sufficient for most soils, but certain soil types and large or very wet samples may require longer. The drying time will also depend on the total amount of material in the oven.

7.6 Gypsum loses water of crystallization on heating, and drying at 105-110°C will result in an approximate 0.2 per cent increase in moisture content for each 1 per cent gypsum. Soils containing gypsum should be dried at a temperature of not more than 80°C and the drying temperature reported.

7.7 The soil is considered to be dry when this requirement is first achieved. The confirmed mass \( m_3 \), that is, the penultimate weighing, shall be used in the calculation of moisture content.
Test Method Q172: Unconfined compressive strength of soil - triaxial

1 Source

This method is based on AS 1289.6.4.1: Compressive strength of a specimen tested in undrained triaxial compression without measurement of pore water pressure. It differs from this Australian Standard in that the compressive strength test is unconfined.

2 Scope

This test method describes the determination of the unconfined compressive strength of a soil using the triaxial compression machine. The test is normally made on cylindrical specimens 38 to 100 mm diameter (Note 8.1) and is suitable for saturated non-fissured cohesive soil.

3 Apparatus

The following apparatus is required:

3.1 Split mould or mitre box and wire saw or knife for obtaining plane ends normal to the axis of cylindrical specimens.

3.2 Metal or perspex upper-end cap, of size to suit the specimen and having a central seating to receive the loading ram.

3.3 Perspex bottom disk of size to suit the specimen.

3.4 Triaxial cell, of dimensions appropriate to the size of the specimen. The cell may have been converted by removal of the perspex shell to facilitate the placing and removing of the specimen. The cell shall be provided with a loading ram through which axial compressive load is applied to the specimen.

3.5 Compression machine, capable of applying axial compression to the specimen at convenient speeds. A speed of application in the range 0.5 mm to 2 mm per minute is normally satisfactory. The machine should be capable of applying an axial deformation of approximately one third the height of the specimen.

3.6 Force measuring device, such as a load ring or load cell for measuring the axial load applied to the specimen by the compression machine. The device should have a range(s) of 0.02 kN to 10 kN and at least be Class B as defined in AS 2193 for that part of its operating range which corresponds to the maximum load applied to any test specimen (Note 8.2).

3.7 Displacement device, such as a dial gauge or displacement transducer, capable of recording deformations up to one third the height of the specimen and with a resolution of 0.1 mm.

4 Specimen preparation

Prepare the specimen as follows:

4.1 Prepare the specimen as detailed in Test Method Q173A to produce a trimmed specimen with a length to diameter ratio of 2 to 1.

4.2 Determine the initial specimen length ($L_{in}$), diameter ($D_{in}$) and wet density as detailed in Test Method Q171.
5 Procedure

The procedure shall be as follows:

5.1 Set the cell pedestal on the compression machine and place the specimen on a perspex disk on the cell pedestal. Place the upper-end cap on the specimen.

5.2 Assemble the cell and secure it to the compression machine.

5.3 Mount the selected force measuring device on the compression machine.

5.4 Adjust the compression machine manually to bring the loading ram just into contact with the seat on the top of the specimen and set the load measuring device to zero. Select a load application rate to provide an axial strain of 1-2 per cent/minute.

5.5 Start the compression machine and take sufficient readings of load and displacement to define a stress/strain curve.

5.6 Continue the test until either the maximum load has passed or the axial strain exceeds 20%.

5.7 Unload the specimen and remove the cell. Record the mode of failure of the specimen as a sketch, showing the location and orientation of shear planes, or barrelling. If the failure is of the barrel type then determine the largest diameter.

5.8 Determine the moisture content, dry density and wet density of the specimen as detailed in Test Method Q171.

6 Calculations

The calculations shall be as follows:

6.1 Plot the axial deformation against the corresponding load values and draw a smooth curve through the points. Determine the maximum load at failure ($P$) and the axial deformation at failure ($d$) from the curve.

6.2 Calculate the initial area of the specimen as follows:

$$A = \frac{\pi D_{av}^2}{4}$$

where $A$ = initial area of specimen (mm$^2$)  
$D_{av}$ = average specimen diameter (mm)

6.3 Calculate the strain corresponding to the maximum load at failure as follows:

$$\varepsilon = \frac{100d}{L_{av}}$$

where $\varepsilon$ = strain corresponding to the maximum load at failure (%)  
$d$ = axial deformation at failure (mm)  
$L_{av}$ = average initial specimen length (mm)

6.4 Calculate the unconfined compressive strength as follows:

$$UCS = \frac{1000P(100-\varepsilon)}{100A}$$

Superseded
where \( \text{UCS} \) = unconfined compressive strength (kPa)
\( P \) = maximum load at failure (N)
\( \varepsilon \) = strain corresponding to the maximum load at failure (%)
\( A \) = initial area of specimen (mm\(^2\))

### 7 Reporting

Report the following values and general information:

7.1 Unconfined Compressive Strength (UCS) to the nearest 1 kPa.

7.2 Moisture content, wet density (initial and final) and dry density as detailed in Test Method Q171.

7.3 Axial deformation-load graph.

### 8 Notes on method

8.1 The length of the specimen shall be as near as possible to two times the specimen diameter as the nature of the soil and end preparation will permit. The length may be up to 8 per cent smaller than the nominal length provided the actual initial length is used when calculating strain.

8.2 A number of devices may be required to provide the range of forces and accuracy required to test soils from very soft to hard.
Test Method Q181A: Shear strength of soil - Direct shear of cohesionless materials

This test shall be performed in accordance with AS 1289.6.2.2: Determination of the shear strength of a soil – Direct shear test using a shear box by the procedure for dry sands.
Test Method Q181C: Effective angle of internal friction at constant volume conditions for granular materials - coarse grained

1 Source

This method is based on ASTM D3080: Standard Test Method for Direct Shear Test of Soils under Consolidated Drained Conditions. It differs from this standard in the procedures for sample compaction, determination of failure criteria and the calculation and reporting of the test parameters. It also includes other minor procedural variations.

2 Scope

This method describes the procedure for the determination of the effective angle of internal friction at constant volume conditions ($\phi'_{cv}$) of a disturbed sample of backfill material used in reinforced soil structures when compacted into a shearbox in accordance with the specification. This method is applicable only to granular (coarse grained) materials, such as those used in reinforced soil structures, as these best exhibit constant volume conditions during shearing.

The effective angle of friction is derived by linear regression and expressed as a line of best fit through the origin with a minimum of three individual tests at different values of normal stress.

As the effective angle of friction is dependent on material composition, determination of the particle size distribution of the material has been included as part of this test method.

3 Apparatus

The following apparatus is required:

3.1 Direct shear machine consisting of:

3.1.1 A base frame, motorised gear box unit, loading screw and 'frictionless' tracks.

3.1.2 A shearbox assembly, with a minimum shearbox size of 300 mm square (Figure 1).

3.1.3 A force measuring device, capable of measuring the expected range of force applied to the specimen during shear. The device shall have a resolution of 1 N and shall conform to the requirements of a Class B device in AS 2193.

3.1.4 Two displacement measuring devices, capable of measuring the expected ranges of travel of:

a) the change in height of the specimen

b) the horizontal displacement during shear.

The measuring devices shall have a resolution of 0.01 mm and conform to the calibration requirements of Table 1.

3.1.5 A vertical loading system, consisting of either a load hanger and masses or a hydraulic loading system capable of applying the required loads to an accuracy of $\pm$ 1% of the required normal load.

3.2 Compaction rammer, with approximately 50 mm square end to enable compaction of material into the corners of the shearbox.

3.3 Sieves, 19.0 and 9.50 mm complying with AS 1152.

3.4 Timer, capable of measuring 15 second intervals with a resolution not exceeding 1 second.

3.5 Calliper, suitable for measuring the dimensions of the shearbox with a resolution not exceeding 0.1 mm and complying with AS 1984 or JIS B 7507.
4 Specimen preparation

Prepare the specimen as follows:

4.1 Prepare the bulk sample as detailed in Section 5 of Test Method Q101 to produce a representative sample of appropriate size.

4.2 Further prepare the material by screening the sample on a 19.0 mm sieve as detailed in Test Method Q101, Steps 6.2.1 to 6.2.3 to provide a minimum of 120 kg of material. Ensure that any aggregations are broken up to pass a 9.50 mm sieve and any retained 19.0 mm (oversize) material is discarded.

4.3 Prepare test portions of the sample by splitting as detailed in Test Method Q101B for the purpose of determining the particle size distribution as detailed in Test Method Q103A.

4.4 Determine the maximum particle size of the sample and ensure the following complies:
   a) The minimum width for square specimens shall be 300 mm or not less than 10 times the maximum particle size, whichever is the larger, and shall conform to the width to thickness ratio specified in Step 4.4 c).
   b) The specimen thickness after consolidation shall be not less than 120 mm or 6 times the maximum particle size, whichever is the larger.
   c) After consolidation, the minimum specimen width to thickness ratio shall be 2:1.

4.5 Prepare representative subsamples and determine the placement dry density ($\rho_{pi}$) and placement moisture content ($\omega_{pi}$) of the shear test specimens in accordance with Table 2.

4.6 Once the placement density and moisture have been established, obtain a minimum of three shear test subsamples by the method of preparation indicated in Table 2. Ensure the subsamples are of sufficient mass to firstly, determine the moisture content and adjust if necessary and secondly, fill the shearbox when compacted to the required placement density (Note 8.1).

4.7 Store the subsamples in airtight containers to prevent moisture variation prior to compaction. Determine the moisture content of the shear test subsamples in accordance with Test Method Q102A. If necessary, adjust the moisture contents of the subsamples to achieve the required placement moisture, as detailed in Table 2. After any moisture adjustment, return the material to airtight containers and allow it to stand for the required curing time prior to again determining the moisture content.

5 Procedure

The procedure shall be as follows:

5.1 Selection and calibration of shearbox

The shearbox required for the test shall be of sufficient size to accommodate the test specimen as determined in Step 4.4. Measure the length and width of the shearbox to the nearest 0.1 mm and determine the net calibrated volume ($V_c$) of the shearbox as detailed in Step 6.1.3.

5.2 Normal stresses

Select three separate normal stresses for the test, evenly spaced over the range 100 to 300 kPa. Calculate the required normal loads as detailed in Step 6.2.
5.3 **Set-up of test specimen**

5.3.1 Lightly grease the contact surfaces between the upper and lower sections of the shearbox and then secure the sections using the two locking screws. Place the assembly in the carriage. Insert the two parting screws into the designated holes in the top half of the shearbox until contact is made with the bottom half.

5.3.2 Place the perforated, metal, gridded baseplate in the bottom of the shearbox assembly and seat it firmly. The teeth of the gridded plate must be aligned perpendicular to the direction of travel.

5.3.3 Form each test specimen in the shearbox in three layers as follows:

a) Determine the wet mass of the specimen and the wet mass required for each layer as detailed in Steps 6.3.1 and 6.3.2 respectively.

b) Measure the required wet mass for the first layer and place the wet soil evenly in the shearbox, taking care to avoid segregation of the larger gravel particles.

c) Tamp the layer to the required thickness using the square ended compaction rammer, ensuring uniform density throughout.

d) Scarify the top of the layer and repeat this process for the subsequent two layers, ensuring the compacted layer boundaries are positioned so they are not coincident with the shear plane defined by the shearbox halves (Note 8.2). Compaction of the final layer should also allow for the embedment of the upper gridded plate, the top of which should finish flush with the top of the shearbox.

5.3.4 Place the loading cap and ball on top of the upper gridded plate.

5.4 **Consolidation of the test specimen**

5.4.1 Assemble the normal loading system such that it makes contact with the loading ball and cap without transferring any load to the test specimen. When positioning the yoke hanger to contact the loading ball and cap, ensure it is level and that load is not transferred to the specimen prior to commencing consolidation.

5.4.2 Position a vertical displacement measurement device on top of the yoke hanger and align it with the vertical axis of the specimen. Adjust the measurement device so that it is near the upper end of its range of travel. At this point, set the device to a convenient value and record the measurement as the initial (zero) vertical displacement reading \( r_i \) (Note 8.3).

5.4.3 Fill the carriage with demineralised water.

5.4.4 Transfer the normal load directly to the specimen. Monitor the vertical deformation of the specimen by reading the vertical displacement device at the following time intervals: 0.25, 0.5, 1, 2, 4, 9, 16, 36, 64, 100 and 121 minutes from commencement of loading. Take readings for a minimum of 2 hours or until primary consolidation is substantially complete.

5.4.5 Plot vertical displacement against the square root of time and determine \( t_{100} \) by:

a) Approximating the initial part of the curve by a straight line and extrapolating this line back to \( t = 0 \). The corresponding displacement represents 0 per cent primary consolidation.

b) A second straight line is then drawn through this point so that the abscissa of the line is 1.15 times the abscissa of the straight line approximation of the initial part of the curve. The intersection of the new line with the displacement/square root of time curve
corresponds to 90 per cent primary consolidation. The displacement at 100 per cent primary consolidation is one-ninth more than the difference in displacements between 0 and 90 per cent consolidation (Figure 2) (Note 8.4).

5.4.6 Calculate the time to failure (in minutes) as detailed in Step 6.5.1.

5.4.7 Calculate the rate of horizontal displacement in mm/minute as detailed in Step 6.5.3. The rate of displacement to be used during shearing is to be the lesser of this calculated value or 1 mm/minute.

5.5 Shearing of the test specimen

5.5.1 Advance the drive on the direct shear machine so that the upper half of the shearbox assembly contacts the load measuring device and apply a slight seating load. Set the load measuring device to zero.

5.5.2 Set the horizontal displacement device to the zero displacement position and record the initial horizontal displacement reading ($\ell_0$).

5.5.3 Record the reading on the vertical displacement device as the initial (zero) reading immediately prior to shear ($r_0$).

5.5.4 Select a rate of travel on the direct shear machine to produce the calculated rate of horizontal displacement.

5.5.5 Remove any locking screws from the shearbox prior to shear and slightly separate the two box halves to ensure there is no contact between them during shearing (Note 8.5).

5.5.6 Commence shearing. As a minimum, record readings of shear load, vertical and horizontal displacement for every 0.2% of horizontal strain, that is, every 0.5 mm for the 300 mm box. Plot both shear load ($P$) and vertical displacement readings ($r$) against horizontal displacement ($\ell$). Continue to take readings until the vertical displacement and shear load become constant or a minimum horizontal displacement of 15% of the length of the shearbox is attained.

5.5.7 After completion of the test, remove the specimen from the shearbox and determine its moisture content ($\omega_f$) in accordance with Test Method Q102A.

5.5.8 Repeat Steps 5.3 to 5.5.7 for two other values of normal stress as selected in Step 5.2.

6 Calculations

Calculate as follows:

6.1 Shearbox dimensions
6.1.1 Calculate the mean thickness of each gridded plate as follows:

\[ h_p = b + \frac{npq}{L} \]

where

- \( h_p \) = mean plate thickness (mm)
- \( b \) = thickness of base (mm)
- \( n \) = number of ribs
- \( p \) = height of rib (mm)
- \( q \) = width of rib (mm)
- \( L \) = length of shearbox (mm)

6.1.2 Calculate the net calibrated height of the shearbox as follows:

\[ h_c = \left( H - \left( \bar{h}_{p1} + \bar{h}_{p2} \right) \right) \]

where

- \( h_c \) = net calibrated height of shearbox (mm)
- \( H \) = total height of shearbox (mm)
- \( \bar{h}_{p1} \) = mean thickness of bottom gridded plate (mm)
- \( \bar{h}_{p2} \) = mean thickness of top gridded plate (mm)

6.1.3 Calculate the net calibrated volume and cross-sectional area of the shearbox as follows:

\[ V_c = h_c A \]

where

- \( V_c \) = net calibrated volume of shearbox (mm³)
- \( h_c \) = net calibrated height of shearbox (mm)
- \( A \) = cross-sectional area of the shearbox (mm²)

\[ A = LW \]

where

- \( A \) = cross-sectional area of the shearbox (mm²)
- \( L \) = length of shearbox (mm)
- \( W \) = width of shearbox (mm)

6.2 Applied normal load

Calculate the normal load to be applied for each normal stress as follows:

\[ F_n = \frac{\sigma_n A}{10^6} \]

where

- \( F_n \) = normal load (kN)
- \( \sigma_n \) = required normal stress (kPa)
- \( A \) = cross-sectional area of the shearbox (mm²)
6.3 Mass of test specimen

6.3.1 Determine the wet mass of each test specimen as follows:

\[ m_w = \frac{\rho_{di} V_c \left(100 + \omega_p \right)}{100,000} \]

where

- \( m_w \) = wet mass of specimen (g)
- \( \rho_{di} \) = required placement dry density (t/m³)
- \( V_c \) = net calibrated volume of shearbox (mm³)
- \( \omega_p \) = required placement moisture content (%)  

6.3.2 Calculate the wet mass of soil for a layer as follows:

\[ m_{wi} = \frac{m_w h_i}{h_c} \]

where

- \( m_{wi} \) = wet mass of layer (g)
- \( m_w \) = wet mass of specimen (g)
- \( h_i \) = thickness of compacted layer (mm)
- \( h_c \) = net calibrated height of shearbox (mm)

6.4 Density

6.4.1 Determine the volume of each specimen prior to shear as follows:

\[ V_s = V_c - \left( A \left( r_i - r_f \right) \right) \]

where

- \( V_s \) = volume of specimen prior to shear (mm³)
- \( V_c \) = net calibrated volume of shearbox (mm³)
- \( A \) = area of shearbox (mm²)
- \( r_f \) = vertical displacement immediately prior to commencing shearing (mm)
- \( r_i \) = initial vertical displacement reading at set-up (mm)

6.4.2 Calculate the dry density for each specimen prior to shear as follows:

\[ \rho_{ds} = \frac{\rho_{di} V_c}{V_s} \]

where

- \( \rho_{ds} \) = dry density prior to shear (t/m³)
- \( \rho_{di} \) = required placement dry density (t/m³)
- \( V_c \) = net calibrated volume of shearbox (mm³)
- \( V_s \) = volume of specimen prior to shear (mm³)
6.5 Rate of horizontal displacement

6.5.1 Calculate the time to failure of each specimen as follows:

\[ t_f = 12.7 t_{100} \]

where

- \( t_f \) = time to failure (minutes)
- \( t_{100} \) = time required for 100% primary consolidation to occur (minutes)

6.5.2 Estimate the horizontal displacement required to reach constant volume conditions (Note 8.6).

6.5.3 Calculate the rate of horizontal displacement as follows:

\[ \text{rate} = \frac{d_{cv}}{t_f} \]

where

- \( d_{cv} \) = estimated horizontal displacement (mm)
- \( t_f \) = calculated time to failure (minutes)

6.6 Effective angle of internal friction

6.6.1 From plots of vertical displacement against horizontal displacement and shear load against horizontal displacement, determine the horizontal displacement and the shear load at which the vertical displacement becomes constant for each.

6.6.2 Calculate the shear stress at constant vertical displacement for each specimen as follows:

\[ \tau_{cv} = \frac{P_{cv}}{A} \times 10^6 \]

where

- \( \tau_{cv} \) = shear stress at constant vertical displacement (kPa)
- \( P_{cv} \) = shear load at constant vertical displacement (kN)
- \( A \) = cross-sectional area of shear box (mm²)

6.6.3 Plot each calculated shear stress at constant vertical displacement, \( \tau_{cv} \), on the y axis against the corresponding normal stress at constant vertical displacement, \( \sigma_{cv} \), on the x axis using the same linear scale for both the y and x axes.

6.6.4 Determine an imposed line of regression through the origin in the form \( y = a \times x \) using the plotted points

where

\[ a = \frac{\sum xy}{\sum x^2} \]

6.6.5 Determine the effective angle of internal friction at constant volume conditions as follows:

\[ \phi'_{cv} = \tan^{-1}a \]

where \( \phi'_{cv} \) = effective angle of internal friction at constant volume conditions.
6.7 Stress/strain

6.7.1 Calculate the shear strains for each specimen as follows:

\[ \gamma = \frac{100 (\ell - \ell_i - d)}{h_c - (r_f - r_i)} \]

where
- \( \gamma \) = shear strain (%)
- \( \ell \) = horizontal displacement gauge reading during shearing (mm)
- \( \ell_i \) = initial horizontal displacement gauge reading (mm)
- \( d \) = horizontal proving ring compression during shear (mm) (Note 8.7)
- \( h_c \) = net calibrated height of shearbox (mm)
- \( r_f \) = vertical displacement reading immediately prior to commencing shearing (mm)
- \( r_i \) = initial vertical displacement reading at set-up (mm)

6.7.2 Calculate the volumetric strains for each specimen as follows:

\[ \varepsilon_v = \frac{100 (r - r_f)}{h_c - (r_f - r_i)} \]

where
- \( \varepsilon_v \) = volumetric strain (%)
- \( r \) = vertical displacement reading during shearing (mm)
- \( r_f \) = vertical displacement reading immediately prior to commencing shearing (mm)
- \( h_c \) = net calibrated height of shearbox (mm)
- \( r_i \) = initial vertical displacement reading at set-up (mm)

6.7.3 Calculate the shear stresses, during shearing, for each specimen as follows:

\[ \tau = \frac{P}{A} \times 10^6 \]

where
- \( \tau \) = shear stress during shearing (kPa)
- \( P \) = shear load during shearing (kN)
- \( A \) = cross-sectional area (mm²)

7 Reporting

Report the following values and general information:

7.1 The placement dry density for each specimen to the nearest 0.01 t/m³.
7.2 The placement moisture content for each specimen to the nearest 0.1%.
7.3 Plot of vertical displacement against root time showing consolidation curves for each of the applied normal loads.
7.4 The dry density prior to shear for each specimen to the nearest 0.01 t/m³.
7.5 Horizontal displacement at constant volume for each specimen to the nearest 0.01 mm.
7.6 Normal stress and shear stress at constant volume conditions for each specimen to the nearest 1 kPa.
7.7 Plot of shear stress (kPa) against normal stress (kPa) using the same linear scale for both horizontal and vertical axes. The imposed line of regression through the origin shall also be shown.
7.8 The effective angle of internal friction at constant volume conditions for the sample to the nearest 0.5°.
7.9 Plot of shear stress and volumetric strain against shear strain (Figure 3).
7.10 The moisture content for each specimen after shearing to the nearest 0.1%.
7.11 The test conditions and test type.
7.12 Specimen preparation details, including the method of placement and drainage conditions.
7.13 The rate of shearing (mm/minute).

8 Notes on method
8.1 A subsample mass of about 30 kg should be sufficient for this purpose.
8.2 Layer thickness may vary for different shearboxes. However, layers should be thick enough to completely envelop the largest particles, but not so thick that a uniform compacted density is not achievable for their full depth.
8.3 Settlement is denoted as a positive value with decreasing specimen height resulting in an increase in the vertical displacement reading.
8.4 At times it may be difficult to draw a tangent to the early portion of the consolidation curve as this portion up to about 50% consolidation is not linear. The following technique is useful in providing a reasonable estimation of $\sqrt{t_{100}}$.

8.4.1 Locate the earliest point at which consolidation is substantially complete, that is, the point beyond which the vertical displacement vs root time curve virtually flattens out.
8.4.2 Bisect the horizontal distance between this point and the vertical axis. Read off the value on the horizontal axis corresponding to the halfway point. This value is the $\sqrt{t_{100}}$.
8.5 Separating the two halves of the shearbox is normally done by using parting screws. A gap of approximately 1 to 2 mm is normally sufficient.
8.6 For compacted soils, the horizontal displacement is estimated to be 15 to 25 mm for the 300 mm box.
8.7 Correction of horizontal displacement for compression in the shear load proving ring is only necessary if the horizontal displacement gauge is mounted independently of the carriage. No correction is necessary if using a load cell to capture shear load data.
Table 1 – Limits of error for displacement measuring devices

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Limits of error (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calibration requirement over an interval of one revolution of a dial gauge or 1 mm displacement of an LVDT-type gauge</td>
<td>± 0.01</td>
</tr>
<tr>
<td>Calibration requirement over an interval of two revolutions of a dial gauge or 2 mm displacement of an LVDT-type gauge</td>
<td>± 0.015</td>
</tr>
<tr>
<td>Calibration requirement over an interval of more than two revolutions of a dial gauge or more than 2 mm displacement of an LVDT-type gauge</td>
<td>± 0.035</td>
</tr>
<tr>
<td>Repeatability</td>
<td>± 0.005</td>
</tr>
</tbody>
</table>

Table 2 – Conditions for specimen preparation

<table>
<thead>
<tr>
<th>Maximum particle size</th>
<th>≤ 4.75 mm</th>
<th>&gt; 4.75 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method of preparation</td>
<td>Q101B</td>
<td>Q101C</td>
</tr>
<tr>
<td>% passing 0.075 mm*</td>
<td>&lt; 5</td>
<td>≥ 5</td>
</tr>
<tr>
<td>Method to determine placement criteria</td>
<td>Q142E: Minimum and maximum dry density of a cohesionless material</td>
<td>Q142A: Dry Density/Moisture Relationship (Standard Compaction)</td>
</tr>
<tr>
<td>Placement dry density (ρd)</td>
<td>70% Density Index</td>
<td>97% of Standard Maximum Dry Density</td>
</tr>
<tr>
<td>Placement moisture (ρω)</td>
<td>Sufficient to aid compaction</td>
<td>95-105% of Standard Optimum Moisture Content</td>
</tr>
<tr>
<td>Minimum curing time</td>
<td>No requirement</td>
<td>3 hours</td>
</tr>
</tbody>
</table>

* Material < 0.075 mm as a percentage of the passing 19.0 mm component of the sample
Figure 1 - Shearbox Assembly (Schematic)

1. Carriage
2. Shearbox - Lower Half
3. Shearbox - Upper Half
4. Parting Screw
5. Locking Screw
6. Loading Cap
7. Test Specimen
8. Perforated Gridded Plates
9. Loading Ball
10. Loading Yoke
11. Vertical Displacement Measuring Device
12. Horizontal Displacement Measuring Device
**Figure 2 – Consolidation point**

If $t_{100} = 4.42$, $t_{100} = (4.42)^2 = 19.5\text{min}$

$\therefore t_f = 12.7 \times 19.5 = 248 \text{min}$

If estimated displacement to failure = 25 mm

$\therefore$ rate of displacement $= \frac{25}{248} = 0.102 \text{ mm/ min}$
Figure 3 – Typical plot of test data
Test Method Q185: Brazilian compressive strength of rock

1 Source

This method is based on ISRM Part 2: Suggested method for determining indirect tensile strength by the Brazil test. It differs from this ISRM method in that the Brazilian compressive strength is determined.

2 Scope

This method describes the procedure for the determination of Brazilian compressive strength of a rock sample cut into at least two specimens.

3 Apparatus

The following apparatus is required:

3.1 Compression machine, complying with the requirements for Class B of AS 2193 for that part of its operating range which corresponds to the maximum force applied to any test specimen. It shall be equipped with an indicator of a resolution not exceeding 25 N and able to apply the required load at a uniform rate of application specified Section 5.

3.2 Brazil jig, consisting of upper and lower jaws each having an accurately machined inside face. The jaws should contact the disc-shaped rock specimen at diametrically-opposed surfaces over an arc of approximately 10° at failure. The lower segment shall be mounted on a base having two perpendicular guide pins extending upwards. Guide bushes on the upper segment shall be located to direct the segments together without binding or loose motion on the guide pins. The dimensions of the jaws shall be a radius of 1.5 times the specimen radius and a thickness of 1.1 times the specimen thickness. A guide pin clearance of 0.10 mm for a 25 mm pin has been found to be sufficient (Table 1 and Figure 1).

3.3 Masonry saw.

3.4 Calliper, with a resolution not exceeding 0.1 mm and complying with AS 1984 or JIS B 7507.

3.5 Marker.

3.6 Double thickness (0.2 – 0.4 mm) adhesive paper strip (masking tape) with a width equal to or slightly greater than the specimen thickness.

4 Specimen preparation

Prepare the specimen as follows:

4.1 Mark each sample to produce a suitable number of test specimens each with a thickness approximately equal to the specimen radius. Ten specimens are recommended, with two the minimum.

4.2 Using the saw, cut the required number of specimens.

4.3 Mark each specimen with a suitable identification.

4.4 Check each specimen and reject those that have:

4.4.1 End faces not flat to within 0.25 mm.

4.4.2 Cylindrical surfaces having tools marks and other irregularities greater than 0.025 mm.

4.4.3 End faces not square and parallel to within 0.25°.
4.5 Measure the thickness of each test specimen at four points evenly spaced around the specimen and calculate the average thickness to 0.1 mm (t).

4.6 Measure the two diameters at right angles to each other and calculate the average diameter to 0.1 mm (d).

4.7 Wrap the test specimen around its periphery with one or two layers of masking tape.

5 Procedure
The procedure shall be as follows:

5.1 Clean the inside surfaces of the breaking head and lightly grease the guide pins.

5.2 Place the specimen in the jig such that the curved platens load the specimen diametrically and the defects of the test specimen are in the desired orientation, (for example, defects are usually oriented parallel or perpendicular to the direction of loading).

5.3 Select the load application rate such that the failure in the weakest rock occurs within 15-30 seconds. A loading rate of 200 N/sec. is recommended.

5.4 Apply the load continuously at a constant rate and record the maximum load at failure (P) along with the sketch, showing the location and orientation of failure plane.

5.5 Determine the moisture content of the specimen as detailed in Australian Standard Test Method AS 4133.1.1.1.

6 Calculations
6.1 Calculate the Brazilian compressive strength as follows:

\[ \text{BCS} = \frac{P}{dt} \]

where
- \( \text{BCS} \) = Brazilian compressive strength (MPa)
- \( P \) = maximum load at failure (N)
- \( d \) = average diameter of the specimen (mm)
- \( t \) = average thickness of the specimen (mm)

7 Reporting
Report the following values and general information:

7.1 Brazilian compressive strength for each specimen in the sample, expressed to nearest to 0.01 MPa, together with the average result for the sample to nearest to 0.01 MPa.

7.2 Number of the specimens tested for the sample.

7.3 Orientation of the axis of loading with respect to specimen anisotropy, for example, bedding plane, foliation and so on.

7.4 Storage history and environment.

7.5 Mode of failure, test duration and stress rate.

7.6 Average specimen diameter and thickness to nearest 0.1 mm.

7.7 Moisture content to the nearest 0.1% (Note 8.1).
8 Notes on method

8.1 It is recognised that in some cases for some materials (for example, shale), it may be desired to test specimens in other moisture conditions, for example saturated or oven-dry at 110°C. Such conditions shall be noted in the test report.

Table 1 – Typical apparatus dimensions

<table>
<thead>
<tr>
<th>Drill core diameter (mm)</th>
<th>Jaw radius (mm)</th>
<th>Jaw thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>52</td>
<td>39</td>
<td>29</td>
</tr>
<tr>
<td>63</td>
<td>47</td>
<td>35</td>
</tr>
<tr>
<td>75</td>
<td>56</td>
<td>42</td>
</tr>
</tbody>
</table>

Figure 1 – Apparatus for Brazil test
Test Method Q188: Quartz content of sand - petrological assessment

1  Source
This method applies the principles derived from ASTM C295: Standard Guide for Petrographic Examination of Aggregates for Concrete. It differs from this American Standard by providing more detailed instructions for the selection and evaluation of sand clasts within a thin section.

2  Scope
This method describes the procedure for the determination of quartz within fine aggregate for use in base course concrete. The method is based upon petrographic examination and point counting on a representative thin section of the sand. No attempt is made to describe in detail the techniques of thin section preparation, mineral identification and petrographic description since it is assumed that the test method will be used by operators with adequate qualifications and experience to undertake the work.

3  Definition
For the purposes of this method, 'quartz' is defined to comprise the total of the following components:

- quartz which is present as free mineral grains
- quartz which is locked with other minerals in sand-sized lithic clasts
- chert (arbitrarily defined as polycrystalline quartz with a grain size finer than 0.03 mm).

All three components share the same chemical composition, hardness, strength and durability.

4  Apparatus
The following apparatus is required:

4.1 Facilities, adequate for the preparation of thin sections of epoxy stabilised blocks of sand.
4.2 Microscope, a petrographical (polarising) microscope equipped with low, medium and high power objectives, an ocular lens containing crosshairs and a mechanical stage suitable for incremental traversing.
4.3 A point counter, suitable for recording the number of points observed in the course of incremental traversing.

5  Procedure
5.1 Sample preparation
5.1.1 Obtain two representative subsamples of the sand, each between 10 and 20 g, using a riffle splitter or by coning and quartering (Note 8.1).
5.1.2 Using one entire subsample, mould and prepare a thin section using recognised techniques.

5.2 Petrographic examination
5.2.1 In general, perform a petrographic examination of the thin section using transmitted polarised light microscopy, supplemented by binocular microscopic examination of the other complementary subsample of unsectioned sand. Record sufficient petrographic observations on the grain size, grain shape and composition of the sand to characterise the sand for comparative purposes and to attract attention to any perceived deleterious characteristics.
5.2.2 In particular, perform a point count on the thin section in a fashion which records, not only the volume percent of fragment types (also known as clast types), but also the volume percent of...
'quartz' components as defined in Section 3. The point count should involve no less than 100 observation points established by incremental traversing evenly across the whole area of the thin section accessible to the mechanical stage. The incremental locations established during traversing are only counted as observation points if they occur within a sectioned sand clast (that is, they are ignored if the location occurs within the epoxy between sand clasts).

5.2.3 In the case of observation points falling within clasts of chert (and related jasper), or within other lithic clasts containing quartz, it is necessary to record subdivisions in the point count for that type of clast (for example, record the observation point as falling on quartz within a granitic clast or on other minerals within the granitic clast). This procedure permits the resultant single point count to be used to report either in terms of volume percent of clast types (in which case, for example, the quartz recorded within granite fragments would be added to the other minerals recorded within granite fragments to report the overall percentage of granite fragments) or in terms of total quartz content (in which case the percentage of free grains of quartz is added to the percentage of quartz locked within lithic clasts and to the percentage of chert within finely siliceous lithic clasts).

6 Calculations

If a total of exactly 100 observation points has been counted, then the number of points per fragment type and the number of points corresponding with 'quartz' as defined in this standard translate directly into volume percent. If a total of more than 100 points has been counted, then the counts per fragment type and counts for 'quartz' are converted to a percentage of the total number of points counted.

7 Reporting

Report the following:

7.1 A basic petrographic description of the tested sand, incorporating observations on grain size, grain shape and fragment types.

7.2 The volume percent of fragments (or clasts) of various compositions.

7.3 The total volume percent of 'quartz' as defined in this test method, along with more specific details on the volume percentages of free grains of quartz, of quartz locked within lithic clasts and of chert.

7.4 Any pertinent comments which may bear on the perceived suitability of the sand for its proposed use in concrete pavements.

8 Notes on method

8.1 In order to minimise segregation during handling, any dry sand sample must first be wetted with water so that it is damp, yet in a free flowing condition.
Test Method Q190: Vertical compression of strip filter drains

This test shall be performed in accordance with ASTM D6244: Vertical Compression of Geocomposite Pavement Panel Drains.
Test Method Q191: Inspection of installed pavement drains - bore scope

1 Source

This test method applies the principles of the Virginia Department of Transport Test Method 108 and the supporting specification Virginia Department of Transport Road and Bridge Specification Section 501 Underdrains.

2 Scope

This test method outlines the procedure for inspection of a pipe or strip filter drain (pavement drain) by bore scope to determine its condition.

3 Apparatus

The following apparatus is required:

3.1 Bore scope, an optical device consisting of a rigid or flexible tube with an eyepiece at one end and an objective lens at the other, linked together by a relay optical system. The optical system is usually surrounded by optical fibres contained within a rigid or flexible protective outer sheath to illuminate a remote object. An internal image of the remote object is formed by the objective lens and relayed to the eyepiece which magnifies the internal image and presents it to the viewer's eye. The bore scope shall:

3.1.1 Have a maximum diameter of 10 mm
3.1.2 Have a length of camera cable of at least 20 m
3.1.3 Be capable of capturing clear video images with a minimum resolution of 10,000 pixels.

3.2 A device to electronically record the images from the bore scope onto suitable recording media.

3.3 Drain locator, to establish the distance from the outlet of any pavement drain deficiencies.

4 Procedure

The procedure shall be as follows:

4.1 Feed the bore scope through the pavement drain at a rate not exceeding 5 metres per minute (Note 7.1).

4.2 Progressively record the condition of the pavement drain in terms of the following deficiencies, if any:

4.2.1 Penetration by guardrail posts, signposts, delineator posts and so on.
4.2.2 Sag in the longitudinal profile of the pavement drain as evidenced by ponding of water for continuous lengths of 3.0 m or greater.
4.2.3 Any blocked or crushed pavement drain that will not allow the passage of the bore scope.
4.2.4 Any partially blocked or partially crushed/split/cracked pavement drain for any length greater than 300 mm.

4.3 Using the drain locator, determine and record the location of any deficient condition detected in accordance with Step 4.2.

4.4 Electronically record on suitable media the inspection condition of the pavement drain as shown by the bore scope.
4.5 Record the total length of the pavement drain inspected.

5 Calculations

Calculate the following:

5.1 The total length of deficient condition recorded for the pavement drain.

5.2 The total length of deficient condition as a percentage of the total length of pavement drain inspected.

6 Reporting

Report the following:

6.1 Inspection date.

6.2 Project identification.

6.3 Pavement drain location, for example, chainage/offset.

6.4 Pavement drain manufacturer and product name.

6.5 Pavement drain inspection length.

6.6 Location from the outlet and nature of any deficient condition in accordance with Step 4.2.

6.7 Length of deficient condition as a percentage of the total length inspected.

7 Notes on method

7.1 Where an outlet location is inaccessible with the bore scope, visual inspection will be permitted.
Materials Testing Manual

Part 6: Aggregates
Test Method Q201: Flakiness index of aggregate

1 Source
This method applies the principles of AS 1141.15: Flakiness index. It differs from this standard by:

a) not permitting the use of slotted sieves
b) including the use of a 16.0 mm sieve when required (for example, for larger sized cover aggregate)
c) including 19.0-16.0 mm, 16.0-13.2 mm and 6.70-4.75 mm slots in the thickness gauge when required, and
d) allowing a test fraction to be reduced to produce a test portion.

2 Scope
This method describes a procedure for determining the flakiness index of a general aggregate or cover aggregate. The method applies to aggregates having a nominal size not greater than 63.0 mm.

3 Definitions
3.1 Mean dimension - the mean of the smallest sieve aperture through which the particle passes and the largest sieve aperture on which the particle is retained.
3.2 Flaky particle - a particle with a least dimension (thickness) less than 0.6 of its mean dimension.
3.3 Flakiness index - the percentage by mass of flaky particles.

4 Apparatus
The following apparatus is required:

4.1 Balance of suitable capacity, having a resolution of at least 1 g and with a limit of performance not exceeding ± 5 g.
4.2 Drying oven of suitable capacity, having a temperature of 105-110ºC and complying with AS 1141.2.
4.3 Thickness (flakiness) gauge with apertures conforming to the dimensions shown in Table 1.
4.4 Sieves, 37.5 mm, 26.5 mm, 19.0 mm, 16.0 mm, 13.2 mm, 9.50 mm, 6.70 mm and 4.75 mm as required, complying with AS 1152.
4.5 Sample dividers.
4.6 Sieve brushes.
4.7 Container of suitable size, for drying the test portion.
4.8 Dishes and trays.

5 Procedure
The procedure shall be as follows:
5.1 **Particle size distribution**

5.1.1 Prepare the bulk sample as detailed in Section 5 of Test Method Q101 to obtain a test portion which, when dry, will comply with the minimum mass requirement of Test Method Q103B Table 1.

5.1.2 Place the test portion in the container and dry in the oven to a constant mass (Note 8.1).

5.1.3 In order to determine the sieves required, it is necessary to consult any applicable specification for the material under test.

5.1.4 Determine the particle size distribution of the sample as detailed in Test Method Q103A, Q103B or AS 1141.11.1 (Note 8.2) using the sieves required in Step 5.1.3.

5.2 **Test fractions from Q103A**

5.2.1 Combine the size fractions retained on the sieves as necessary, into the fractions shown in Table 1.

5.2.2 Include all fractions which constitute five or more percent of the sample mass and are larger than 4.75 mm.

5.2.3 Obtain the mass of each test fraction as follows:

   a) For fractions larger than 19.0 mm (that is, obtained from Test Method Q103A Subsection 6.2), determine the mass of each test fraction \( m_1 \) between 19.0 and 63.0 mm.

   b) Where the sample has not been coarse sieved or the passing 19.0 mm material has not been subsampled (that is, obtained from Test Method Q103A Step 7.2.3), determine the mass of each test fraction \( m_1 \) between 4.75 and 19.0 mm.

   c) Otherwise:

      i. Determine the subsampled mass of each test fraction \( m_2 \).

      ii. Calculate the mass of each test fraction \( m_1 \) between 19.0 and 4.75 mm as follows:

\[
m_1 = m_2 \frac{M_T - M_c}{m_4 - m_3}
\]

   where

   - \( m_1 \) = mass of each test fraction (g)
   - \( m_2 \) = subsampled mass of each test fraction (g)
   - \( M_T \) = mass of sample from particle size distribution (g)
   - \( M_c \) = cumulative mass retained on the 19.0 mm sieve (g), obtained from Q103A.
   - \( m_3 \) = mass of container (g), obtained from Q103A.
   - \( m_4 \) = mass of container and test portion subsample (g), obtained from Q103A.

5.3 **Test fractions from Q103B or AS 1141.11.1**

5.3.1 Combine the size fractions retained on the sieves as necessary, into the fractions shown in Table 1.
5.3.2 Include all fractions which constitute five or more percent of the sample mass and are larger than 4.75 mm.

5.3.3 Determine the mass of each test fraction \( m_i \).

5.4 Flakiness index

5.4.1 Using either a sample divider or by cone and quartering, obtain a test portion from each fraction to be tested:
   a) of at least 200 pieces of the predominant fraction, and
   b) of at least 100 pieces or the complete fraction for each of the remaining fractions, whichever provides the fewer pieces for testing.

5.4.2 Determine the mass of each test portion \( m_5 \).

5.4.3 Test each portion by attempting to pass each piece of aggregate through the appropriate gauge slot using the size of the slot shown in Table 1.

5.4.4 Retain the aggregate passing through the slot and determine the mass of the aggregate passing the appropriate gauge slot \( m_6 \).

6 Calculations

6.1 Calculate the total mass of sample from the particle size distribution as follows:

\[
M_T = \sum m_i
\]

where

\( M_T \) = mass of sample from particle size distribution (g)

\( m_i \) = mass of each test fraction (g)

6.2 For each test fraction calculate the percentage of aggregate passing each slot as follows:

\[
P = \frac{m_6}{m_5} \times 100
\]

where

\( P \) = percentage of aggregate passing each slot

\( m_6 \) = mass of aggregate passing selected gauge slot (g)

\( m_5 \) = mass of test portion (g)

6.3 For each test fraction calculate the weighted percentage of aggregate passing each slot as follows:

\[
P_w = \frac{P m_i}{M_T}
\]

where

\( P_w \) = weighted percentage of aggregate passing each slot

\( P \) = percentage of aggregate passing each slot

\( m_i \) = mass of each test fraction (g)

\( M_T \) = mass of sample from particle size distribution (g)
6.4 Calculate the flakiness index as follows:

\[ FI = \sum P_w \]

where

- \( FI \) = flakiness index (%)
- \( P_w \) = weighted percentage of aggregate passing each slot

7 Reporting

Report the flakiness index to the nearest 1%.

8 Notes on method

8.1 The material is considered to have reached a constant mass when the difference between successive weighings, after a further 1 hour drying at 105-110°C, is not more than 1 percent of the total of the previous moisture losses.

8.2 For ease in determining the flakiness index, it is advisable to keep the fractions retained on each sieve separated during the performance of Test Method Q103A, Q103B or AS 1141.11.1.

Table 1 - Thickness gauge

<table>
<thead>
<tr>
<th>Size fractions (mm)</th>
<th>Dimensions of rectangular slots</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Passing</td>
</tr>
<tr>
<td>63.0</td>
<td>53.0</td>
</tr>
<tr>
<td>53.0</td>
<td>37.5</td>
</tr>
<tr>
<td>37.5</td>
<td>26.5</td>
</tr>
<tr>
<td>26.5</td>
<td>19.0</td>
</tr>
<tr>
<td>19.0#</td>
<td>16.0</td>
</tr>
<tr>
<td>16.0#</td>
<td>13.2</td>
</tr>
<tr>
<td>19.0</td>
<td>13.2</td>
</tr>
<tr>
<td>13.2</td>
<td>9.50</td>
</tr>
<tr>
<td>9.50</td>
<td>6.70</td>
</tr>
<tr>
<td>6.70</td>
<td>4.75</td>
</tr>
</tbody>
</table>

* These widths are 0.6 times the mean of the limiting sieve sizes used to define the size fraction.

# Fractions required for sprayed surfacing aggregates to replace 19.0 to 13.2 mm fraction.
Test Method Q202: Average least dimension of cover aggregate

1 Source
This method applies the principles of AS 1141.20.3: Average least dimension - Calculation (nomograph). It differs from this standard by directly calculating the average least dimension rather than utilising the nomograph. This method uses the term 'average least dimension' that is first attributed to F.M. Hanson, in the paper *Bituminous Surface Treatment of Rural Highways* published by the New Zealand Society of Civil Engineers.

2 Scope
This method describes the procedure for calculating the median size and average least dimension (ALD) of a sprayed sealing cover aggregate using the calculation method. The method is applicable to aggregates for bituminous surfacing having a nominal size 7 mm and greater.

3 Definitions
3.1 Average least dimension - the average of the thickness of all individual particles weighted in proportion to the surface areas covered when the particles lie with their least dimension upwards.

3.2 Median Size - the theoretical sieve size through which 50 percent of the aggregate will pass.

4 Procedure
The procedure shall be as follows:

4.1 Determine the particle size distribution of the aggregate as detailed in Test Method Q103B.

4.2 Determine the flakiness index of the aggregate as detailed in Test Method Q201.

5 Calculations
5.1 Calculate the median size from the particle size distribution as follows:

\[ MS = 10^{\left(\frac{\log D_2 + (50 - P_2) \log D_1 - \log D_2}{\log D_2 - \log D_1}\right)} \]

where

- **MS** = median size of the aggregate (mm)
- **log** = logarithm to base 10
- **D_2** = largest sieve size with less than 50% passing (mm)
- **P_2** = proportion passing **D_2** (%)
- **D_1** = smallest sieve with more than 50% passing (mm)
- **P_1** = proportion passing **D_1** (%)

5.2 Calculate the average least dimension (ALD) as follows:

\[ ALD = \frac{MS}{1.09 + (0.0118 \text{ FI})} \]

where

- **ALD** = average least dimension of the aggregate (mm)
Test Method Q202: Average least dimension of cover aggregate

\[ MS = \text{median size of the aggregate (mm)} \]
\[ FI = \text{flakiness index as determined in Test Method Q201} \]

6 Reporting

Report the average least dimension (ALD) to the nearest 0.1 mm.
Test Method Q203: Polished aggregate friction value

1 Source

This method is based on AS 1141.40: Polished aggregate friction value - Vertical road wheel machine, and AS 1141.42: Pendulum friction test.

This method differs from AS 1141.40 in the specification of the polishing materials, the procedure used to select aggregate particles for the test and the aperture size of the slotted sieve.

This method differs from AS 1141.42 in the conditions for using rubber sliders where the requirements are based on EN1097 - Tests for mechanical and physical properties of aggregates – Part 8: Determination of polished stone value. The method also allows the use of the UK reference aggregate with assigned friction values as detailed in Austroads, “Establishing a reference aggregate for aggregate polishing tests”, AP-T212-12, August 2012.

2 Scope

This method describes the procedure for determining the polished aggregate friction value (PAFV) of a naturally occurring or artificially produced aggregate which is intended for use as a pavement surfacing material. It involves friction testing of prepared specimens of the aggregate following laboratory polishing.

3 Apparatus

Where appropriate, the working tolerances of particular apparatus are contained in Tables 1 and 2. Examples of the apparatus are shown in AS 1141.40 Figure 1 and AS 1141.42 Figure 2.

The following apparatus is required:

3.1 Accelerated polishing machine, vertical road wheel type rigidly mounted on a firm level base and comprised and constructed as follows:

3.1.1 Road wheel accommodating 14 specimens clamped on its periphery to form a surface of exposed aggregate particles of 45 mm in width and 406 mm in diameter. It is rotated at 320 revolutions/min.

3.1.2 Solid rubber-tyred wheel having, in the unused condition, a diameter of 225 mm, a width of 35 mm and a Shore A hardness of 60. It is brought to bear on the surface of the aggregate specimens mounted on the road wheel with a total force of 390 N. The force of 390 N is normally achieved by a weight having a mass of approximately 11.0 kg attached to the end of the arm.

Two rubber tyres are required, one for coarse polishing with silicon carbide grit and the other for fine polishing with optical emery. When in use, the rubber tyre shall sit flat on the specimens and shall have minimum sideways movement and eccentricity. The tyre shall be discarded when it shows signs of irregular wear or its Shore A hardness falls outside the specified range or its diameter falls below 210 mm.

3.1.3 Both the road wheel and the solid rubber-tyred wheel must be mounted vertically, aligned accurately to each other and be free to rotate without play in the bearings. The following limits apply:

a) The axes of rotation of the two wheels in both the horizontal and vertical planes shall not be more than 20 minutes of arc out of parallel (1 mm in 200 mm).
b) The planes of rotation through the centres of the two wheels (tracking planes) shall be not more than 0.8 mm apart, measured at the two axes of rotation.

c) Abrasive grit feeder and water feed control shall be capable of delivering abrasive and water between the road wheel and the rubber-tyred wheel at the prescribed feed rates.

3.2 Pendulum friction tester, comprising a tester and auxiliary scale constructed in accordance with details available from the Australian Road Research Board, Melbourne. All bearings and working parts of the instrument shall be enclosed as far as possible and all materials used shall be suitably treated to prevent corrosion under wet conditions. The pendulum friction tester shall be used and stored in a dust-free environment and one which is not subject to a large temperature variation. The tester shall be calibrated to ensure compliance with the following requirements at intervals not exceeding two years or when results obtained from the friction tester control specimens vary from the established values by more than three units.

The tester shall incorporate the following:

3.2.1 Spring-loaded rubber slider mounted on the end of a pendulum so that the sliding edge is 515 mm from the axis of suspension. The sliding edge shall be square, clean cut and free from contamination. The rubber slider shall be 24 mm long, 32 mm wide and 6 mm thick. The slider shall be rigidly backed and, together with the rigid backing plate shall have a total mass of 20 g.

Handling of the surface of a rubber slider shall be avoided and, when not in use, sliders shall be stored in the dark at a temperature between 10°C and 25°C. A slider shall be discarded when:

a) more than 12 months old from the date stamped on the slider, or

b) it does not comply with the requirements of Table 2, or

c) it does not comply with Step 5.6.8.

The mass of the pendulum including the slider shall be 1.50 kg with the centre of gravity lying on the axis of the pendulum at a distance of 410 mm from the centre of suspension. The slider shall be mounted on an axis set at an angle of 25 degrees to the horizontal when the pendulum is at the lowest point of its swing, so that only the rear edge of the slider contacts the test surface. The slider can turn about its axis without obstruction to follow unevenness of the surface. It shall be spring loaded against the test surface and the nominal static force on the slider is set by the calibration procedure.

3.2.2 Means for levelling the instrument.

3.2.3 Means for raising and lowering the axis of suspension of the pendulum so that the slider can:

a) swing clear of the surface of the specimen

b) be set to slide over a fixed length of the surface.

3.2.4 Means for holding and releasing the pendulum so that it falls freely from a horizontal position.

3.2.5 Pointer balanced about the axis of suspension, indicating the position of the pendulum throughout its forward swing and moving over the circular scale attached to the instrument. The mass of the pointer, excluding felt friction washers, shall be not more than 85 g. The friction in the pointer mechanism shall be adjustable so that, with the pendulum swinging freely from a horizontal position, the outward tip of the pointer may be brought to rest on the forward swing of the pendulum at a point 10 mm below the horizontal, the point corresponding to the zero position on the attached circular scale.
3.2.6 Specimen holder for rigidly locating the specimens so that:
   a) the specimen is bisected by a vertical plane perpendicular to the frame of the instrument and passing through the axis of suspension of the pendulum
   b) the slider and pendulum will pass over the specimen in the direction of polishing
   c) the full width of the slider will contact only the polished area of the specimen over the full contact length as described in Step 5.8.6.

3.3 Drying ovens:
3.3.1 Oven of suitable capacity, having a temperature of 45-50°C and complying with AS 1141.2.
3.3.2 Oven of suitable capacity, having a temperature of 105-110°C and complying with AS 1141.2.

3.4 Thermometer, a liquid-in-glass thermometer or other suitable temperature-measuring device with a temperature range including 0°C to 50°C. It shall be graduated in subdivisions of 1°C or less and have an uncertainty of no more than 0.5°C.

3.5 Moulds, accurately machined metal moulds for preparing longitudinally curved specimens of the following dimensions:
   a) Radius of curvature of the outer face of 203 mm.
   b) Radius of curvature of the inner face equal to the periphery of the road wheel.
   c) Outer face curved length of 90 mm.
   d) Width of 45 mm.
   e) Thickness of not less than 12 mm.

3.6 Sieve, a 9.50 mm sieve complying with AS 1152.
3.7 Slotted sieve, having apertures of about 40 mm in length and 7.2 ± 0.1 mm in width.
3.8 Clock or timing device, preferably fitted with an alarm.
3.9 Water spray bottle, containing clean potable water.
3.10 Apparatus for specimen preparation for either of the following:
3.10.1 Specimens prepared using sand-cement mortar:
   a) Three lengths of wire for each specimen, of about 1 mm in diameter and 75 mm in length.
   b) Straight-edge steel screeding block, of about 200 mm in length.
   c) Assorted equipment, such as spatula, stiff bristle brush, fine-haired brush, tray, rubber bands, thin plastic sheeting.

3.10.2 Specimens prepared using resin:
   a) Disposable cups.
   b) Metal plate accurately formed to the inner radius of the metal mould, a little larger than the mould and with holes drilled in it.
   c) Weight of 2 kg minimum mass or clamp.
   d) Two fine-haired brushes, of about 3 mm size.
   e) Metal blade.
4 Materials

The following materials are required:

4.1 Reference aggregate, aggregate from a specified source for which the polished aggregate friction value is known to be within the range 48 to 54 or 43 to 49 (Note 8.1).

4.2 Black silicon carbide F320, oven dried at a minimum temperature of 105°C to a free flowing condition and complying with AS 4518.2 (Note 8.2).

4.3 Optical emery F600, oven dried at a minimum temperature of 105°C to a free flowing condition and complying with AS 4518.2 (Note 8.2).

4.4 Fine sand passing a 0.300 mm sieve.

4.5 Light oil (Note 8.2).

4.6 Materials for specimen preparation for either of the following:

4.6.1 Specimens prepared using sand-cement mortar:
   a) Fresh high alumina cement (Note 8.2).

4.6.2 Specimens prepared using resin:
   a) Polyester or epoxy resin and hardener (Note 8.2).
   b) Solvent, such as a mixture of 90 per cent acetone and 10 per cent kerosene (by volume) to clean apparatus (Note 8.2).

5 Procedure

The procedure shall be as follows:

5.1 Test material preparation

5.1.1 Obtain a representative sample of the test material containing about 5 kg of material passing the 9.50 mm sieve.

5.1.2 Sieve the sample over the 9.50 mm sieve and discard the particles retained.

5.1.3 Sieve the material passing the 9.50 mm sieve over the slotted sieve and discard the material passing.

5.1.4 Wash the particles retained on the slotted sieve to remove surface dust and dry the particles at a temperature not exceeding 50°C.

5.2 Specimen preparation

5.2.1 Select the aggregate particles to be used in specimen preparation carefully so that the surface texture of the particles which are to be exposed to the polishing action of the tyre is typical of the average surface texture of the material under test. This shall be achieved as follows:

   a) Sort sufficient of the aggregate particles prepared in Steps 5.1.1 to 5.1.4 to remove all particles having:
      i. a very rough or very smooth surface texture, that is, texture exhibited by less than 5 per cent of the aggregate particles.
      ii. a length greater than 20 mm.
      iii. an inability to rest securely on their flattest face, that is, particles which rock when touched.
b) Remove additional aggregate particles if necessary to ensure that, within the total number of particles rejected, there are equal numbers of roughly and smoothly textured particles.

c) Where the aggregate particles are derived from a non-homogeneous material, remove further particles if necessary to ensure that the proportional representation of the different materials in the selected and rejected particles is the same.

5.2.2 Place selected particles in the bottom of the mould with their flattest face downwards. Place the particles close together (almost touching) to form a stone mosaic but avoid regularity of pattern. About 35 to 50 particles will usually be required. For non-homogeneous materials, the proportional representation of the different materials within the specimen shall be the same as that determined in Step 5.2.1c).

5.2.3 Fill all interstices between the particles to roughly half of their depth with fine sand.

5.2.4 Complete specimen preparation using either sand-cement mortar or resin as follows:

a) Sand-cement mortar:
   i. Spray the assembly with a fine spray of water until the sand is thoroughly wet.
   ii. Lightly oil the internal surfaces of the mould to the level of the sand.
   iii. Using equal portions by mass of fine sand and high alumina cement, prepare a sand-cement mortar, mixed with sufficient water to provide a free-flowing consistency so that the mortar is able to penetrate easily between the particles.
   iv. Partially fill the mould with mortar, lay three pieces of wire longitudinally and evenly spaced in the mould as reinforcement and fill the mould to overflowing.
   v. After the mortar has set sufficiently to be worked without tearing but firm enough to retain its shape when not under pressure (between 3 hours and 6 hours), use the steel block to screed the mortar so that the surface becomes smooth and level with the curved sides of the mould.
   vi. Cover the surface of the mortar in the mould with a water saturated cloth and allow it to cure for at least 24 hours.
   vii. Mark the sample number on the specimen and remove the specimen from the mould. Use a stiff bristle brush and running water to remove sand from the interstices between the particles. If mortar has penetrated through to the surface of the specimen, the mortar shall be completely removed or the specimen shall be discarded.
   viii. Cure the specimen under water for about 4 days with the particle surface downwards.

b) Resin:
   i. Level the sand in the mould with a fine-haired brush.
   ii. Lightly oil the metal plate and top edges and all exposed internal surfaces of the mould.
   iii. Mix the hardener and resin in a disposable cup in the proportions recommended by the manufacturer. The consistency of the mixture shall permit it to flow freely around the particles and, if necessary, the mixture may be thinned with the solvent.
iv. Fill the mould to overflowing with the mixed resin. Immediately press the metal plate against the mould, squeezing the surplus resin out through the holes in the plate. Remove surplus resin using the metal blade.

v. To prevent distortion of the resin during setting, press the metal plate against the mould using the weight or clamp. Allow the resin to set and cool (about 30 minutes after mixing).

vi. Mark the sample number on the specimen and remove the specimen from the mould. Use a stiff bristle brush and running water to remove sand from the interstices between the particles. If resin has penetrated through to the surface of the specimen, the resin shall be completely removed or the specimen shall be discarded.

vii. Cure the specimen in air for at least 30 minutes.

5.2.5 Repeat Steps 5.2.2 to 5.2.4 to prepare four specimens for each sample and at least two reference specimens.

5.2.6 Clean the specimens thoroughly, soak them under water for 30 minutes and then test each specimen as follows:

a) Install a conditioned rubber slider on the friction tester, ensuring the correct positioning of the two washers and spring.

b) Raise the axis of the suspension of the pendulum so that it swings freely. Adjust the friction rings in the pointer mechanism so that, when the pendulum and pointer are released from the right hand horizontal position, the pointer will zero repeatedly.

c) Position the specimen in the specimen holder.

d) Check that the trailing edge of the slider is parallel to the minor axis of the polished area of the specimen when the pendulum hangs freely at the bottom of its swing.

e) Adjust the height of the axis of suspension of the pendulum so that the entire trailing edge of the slider is in contact with the polished area of the specimen while traversing the specimen surface. The trailing edge of the slider shall be in contact with the specimen over an arc length of 75 ± 1 mm while traversing the curved surface.

f) Return the pendulum to its horizontal position and move the pointer against its stop.

g) Wet the surface of the specimen using the water spray bottle.

h) Release the pendulum from its horizontal position and allow the pendulum and pointer to swing over the specimen. To avoid damage to the slider, catch the pendulum on its return swing, lift the slider and return the pendulum to the horizontal position.

i) Multiply the reading on the auxiliary scale by 100 and record the value. Move the pointer against its stop.

j) Repeat Steps 5.2.6 g) to 5.2.6 i) to obtain values from five successive swings. Successive swings of the pendulum should always show the same or a lower friction value. If the second, third, fourth or fifth swing shows a higher value than any of the preceding values, a fault is indicated and must be rectified before proceeding. Usually, the fault is an increased contact length between slider and specimen. Check the contact length and reset if necessary.

k) Calculate the average of the last three values recorded for each specimen and record this average as the specimen mean value.
5.2.7 Accept the specimens provided that:
   a) the range of the four specimen mean values does not exceed 5 units.
   b) if the specimens are reference specimens, the specimen mean value falls within the range 65 to 80 (Panmure) or 60 to 68 (UK) inclusive.

Otherwise, reject one or more specimens as necessary and prepare additional specimens in accordance with Step 5.2 until a set of specimens is prepared which complies with these requirements.

5.3 Conditioning new rubber tyres

Condition new rubber tyres as follows:

5.3.1 Make up a road wheel of 14 used reference specimens. Avoid looseness of fit and ensure that the outer surface of the specimens is essentially continuous (see Step 5.4.2).

5.3.2 Assemble the accelerated polishing machine using the tyre required for coarse polishing. Polish the specimens as follows:
   a) Lower the rubber-tyred wheel to bear on the surface of the specimens and start the machine. It is preferable that polishing be carried out at an air temperature in the vicinity of 23°C.
   b) Adjust the grit feeder to feed silicon carbide onto the surface of the specimens at a rate of about 2.0 ± 0.5 g/min. Feed water onto the surface of the specimens at a rate of about four times the grit feed rate so that the abrasive and water are uniformly spread over the surface of the specimens (Note 8.3).
   c) Check the feed rate every 30 minutes by collecting a sample of the dry abrasive from the grit feeder for a 30 second period and weighing. Allow the polishing and water feed to continue during the sampling period. Adjust the feed rate as required.
   d) Interrupt the polishing after two hours and remove the used silicon carbide from the base of the machine and above the rubber tyre to prevent build-up and possible fouling. Continue the polishing as described in Steps 5.3.2 b) and 5.3.2 c) until the total polishing time is 3 h ± 1 min (Note 8.4).
   e) Remove the machine guards, grit feeder, rubber-tyred wheel and road wheel and thoroughly clean these components and the machine. Remove the specimens from the road wheel and use a stiff bristle brush and running water to remove all traces of abrasive.
   f) Mark the direction of rotation of the tyre.

5.3.3 Assemble the accelerated polishing machine as described in Step 5.3.1 using the tyre required for fine polishing. Polish the specimens as described in Step 5.3.2 except that optical emery is used as the abrasive, feed rate checks are performed at 15 minute intervals and polishing is terminated after 2 h ± 1 min.

5.4 Polishing of specimens

5.4.1 Obtain and number the 14 specimens for the road wheel as follows:
   a) The two reference specimens shall be numbered 13 and 14.
   b) If specimens from three samples are being polished, they shall be numbered consecutively 1 to 4, 5 to 8 and 9 to 12.
c) If specimens from two samples are being polished, they shall be numbered consecutively 1 to 4 and 5 to 8.

d) If specimens from one sample are being polished, they shall be numbered consecutively 1 to 4.

e) If fewer than three samples are to be polished, an appropriate number of dummy specimens shall be used to make up the number (Note 8.5). When these are used, number them 9 to 12 or 5 to 12 depending on whether four or eight dummy specimens are required.

f) Mark each specimen on the underside surface with an arrow in the longitudinal direction of rotation of the tyre.

5.4.2 Clamp the 14 specimens around the periphery of the road wheel in the following order and with the arrows pointing in the direction of road wheel rotation:

13, 4, 5, 8, 7, 1, 10, 14, 3, 11, 12, 2, 6, 9.

If there is any looseness of fit, insert strips of thin plastic sheeting or similar material between adjacent specimens and between the underside of the specimens and the periphery of the road wheel as required. The outer surface of the specimens must form an essentially continuous strip of particles with a periphery of 406 mm diameter, upon which the rubber-tyred wheel shall ride freely without any bumping or slipping.

5.4.3 Assemble the accelerated polishing machine with the tyre conditioned with coarse abrasive, ensuring that the tyre rotates in the direction marked on its side during conditioning.

5.4.4 Lower the rubber-tyred wheel to bear on the surface of the specimens and start the machine. It is preferable that polishing be carried out at an air temperature in the vicinity of 23°C.

5.4.5 Adjust the grit feeder to feed silicon carbide onto the surface of the specimens at a rate of about 2.0 ± 0.5 g/min. Feed water onto the surface of the specimens at a rate of about four times the grit feed rate so that the abrasive and water are uniformly spread over the surface of the specimens (Note 8.3).

5.4.6 Check the feed rate every 30 minutes by collecting a sample of the dry abrasive from the grit feeder for a 30 second period and weighing. Allow the polishing and water feed to continue during the sampling period. Adjust the feed rate as required.

5.4.7 Interrupt the polishing after two hours and remove the used silicon carbide from the base of the machine and above the rubber tyre to prevent build-up and possible fouling. Continue the polishing as described in Steps 5.4.5 and 5.4.6 until the total polishing time is 3 h ± 1 min (Note 8.4).

5.4.8 Remove the machine guards, grit feeder, rubber-tyred wheel and road wheel and thoroughly clean these components and the machine. Remove the specimens from the road wheel and use a stiff bristle brush and running water to remove all traces of abrasive.

5.4.9 Repeat Steps 5.4.2 to 5.4.8 except that optical emery is used as the abrasive, feed rate checks are performed at 15 minute intervals and polishing is terminated after 2 h ± 1 min (Note 8.6).

5.4.10 Soak all specimens face downwards under water at a temperature of 23 ± 2°C for at least 30 minutes. At no time prior to friction testing shall test specimens or reference specimens be allowed to dry out.
5.5 **Adjusting the friction tester equipment**

5.5.1 Bring the pendulum apparatus, the contents of the water spray bottle and the temperature of the room in which friction testing is to be carried out to $23 \pm 2^\circ\text{C}$ at least two hours before friction testing and maintain at this temperature until testing is completed. Record the room temperature at the time of testing. It is desirable that this temperature requirement is met. If for any reason this cannot be achieved, the results may be corrected in accordance with Step 6.2.3.

5.5.2 Mount the friction tester on its base and adjust the levelling screws so that the levelling bubble is centred and the tester is appropriately aligned with the specimen.

5.6 **Conditioning rubber sliders**

Sliders are dry conditioned before their first use and may be reused provided they are wet conditioned and checked as detailed in Steps 5.6.6 to 5.6.8 (Note 8.7 and 8.8). Dry condition two new rubber sliders on the day of the test as follows:

5.6.1 Select a conditioning specimen (Note 8.9).

5.6.2 Install the first rubber slider on the friction tester, ensuring the correct positioning of the two washers and spring.

5.6.3 Perform dry conditioning of the first rubber slider as follows:

a) Raise the axis of the suspension of the pendulum so that it swings freely. Adjust the friction rings in the pointer mechanism so that, when the pendulum and pointer are released from the right hand horizontal position, the pointer will zero repeatedly.

b) Position the specimen in the specimen holder so that the slider traverses the specimen against the direction of the arrow.

c) Check that the trailing edge of the slider is parallel to the minor axis of the polished area of the specimen when the pendulum hangs freely at the bottom of its swing.

d) Adjust the height of the axis of suspension of the pendulum so that the entire trailing edge of the slider is in contact with the polished area of the specimen while traversing the specimen surface. The trailing edge of the slider shall be in contact with the specimen over an arc length of $75 \pm 1$ mm while traversing the curved surface.

e) Return the pendulum to its horizontal position and move the pointer against its stop.

f) Release the pendulum from its horizontal position and allow the pendulum and pointer to swing over the specimen. To avoid damage to the slider, catch the pendulum on its return swing, lift the slider and return the pendulum to the horizontal position.

g) Perform Step 5.6.3 f) a further four times.

5.6.4 Repeat Steps 5.6.2 to 5.6.3 using the second rubber slider.

5.6.5 Install the first rubber slider on the friction tester, ensuring the correct positioning of the two washers and spring.

5.6.6 Perform wet conditioning of the first rubber slider as follows:

a) Raise the axis of the suspension of the pendulum so that it swings freely. Adjust the friction rings in the pointer mechanism so that, when the pendulum and pointer are released from the right hand horizontal position, the pointer will zero repeatedly.
b) Position the specimen in the specimen holder so that the slider traverses the specimen against the direction of the arrow.

c) Check that the trailing edge of the slider is parallel to the minor axis of the polished area of the specimen when the pendulum hangs freely at the bottom of its swing.

d) Adjust the height of the axis of suspension of the pendulum so that the entire trailing edge of the slider is in contact with the polished area of the specimen while traversing the specimen surface. The trailing edge of the slider shall be in contact with the specimen over an arc length of 75 ± 1 mm while traversing the curved surface.

e) Return the pendulum to its horizontal position and move the pointer against its stop.

f) Wet the surface of the specimen using the water spray bottle.

g) Release the pendulum from its horizontal position and allow the pendulum and pointer to swing over the specimen. To avoid damage to the slider, catch the pendulum on its return swing, lift the slider and return the pendulum to the horizontal position.

h) Repeat Step 5.6.6 g) until the slider has moved 20 times across the wet conditioning specimen.

i) Note the readings from the last five swings, multiply each reading by 100 and record these values. Calculate the average of the last three values and record this average as the slider mean value.

5.6.7 Repeat Steps 5.6.5 to 5.6.6 for the second rubber slider.

5.6.8 Compare the slider mean values with the minimum acceptable value of 48 (Panmure) or 43 (UK) and proceed as follows:

a) If the slider mean values for both sliders are not less than 48 (Panmure) or 43 (UK) and the two slider values differ by no more than two units, these sliders may be used in friction testing. If the slider values differ by more that two units, additional sliders shall be conditioned until a pair of sliders complying with these requirements is available.

b) If the slider mean value for one of the sliders is less than 48 (Panmure) or 43 (UK), the fault is assumed to be in the slider. Reject this slider and condition a replacement slider.

c) If the slider mean values for both sliders are less than 48 (Panmure) or 43 (UK), the fault may lie with either the conditioning specimen or the friction tester. Reject the conditioning specimen and substitute a recently prepared conditioning specimen. Condition either the other edge of the sliders or new sliders if the other edge has previously been used, paying particular attention to the setting of the contact length of the slider with the specimen.

d) If after a second conditioning run, both sliders have mean values less than 48 (Panmure) or 43 (UK), the fault is assumed to be in the friction tester or polishing procedures. Both slider edges shall not be used and testing shall not proceed until the fault is identified and remedied.

5.7 Friction tester checking

5.7.1 Soak the set of friction tester control specimens in water at a temperature of 23 ± 2°C for a period of at least 30 minutes (Note 8.10).
5.7.2 Perform the checking of the friction tester using the first of the conditioned rubber sliders as follows:

a) Install a conditioned rubber slider on the friction tester, ensuring the correct positioning of the two washers and spring.

b) Raise the axis of the suspension of the pendulum so that it swings freely. Adjust the friction rings in the pointer mechanism so that, when the pendulum and pointer are released from the right hand horizontal position, the pointer will zero repeatedly.

c) Select a control specimen.

d) Position the specimen in the specimen holder so that the slider traverses the specimen against the direction of the arrow.

e) Check that the trailing edge of the slider is parallel to the minor axis of the polished area of the specimen when the pendulum hangs freely at the bottom of its swing.

f) Adjust the height of the axis of suspension of the pendulum so that the entire trailing edge of the slider is in contact with the polished area of the specimen while traversing the specimen surface. The trailing edge of the slider shall be in contact with the specimen over an arc length of $75 \pm 1$ mm while traversing the curved surface.

g) Return the pendulum to its horizontal position and move the pointer against its stop.

h) Wet the surface of the specimen using the water spray bottle.

i) Release the pendulum from its horizontal position and allow the pendulum and pointer to swing over the specimen. To avoid damage to the slider, catch the pendulum on its return swing, lift the slider and return the pendulum to the horizontal position.

j) Multiply the reading on the auxiliary scale by 100 and record the value. Move the pointer against its stop.

5.7.3 Repeat Steps 5.7.2 h) to 5.7.2 j) to obtain values from five successive swings. Successive swings of the pendulum should always show the same or a lower friction value. If the second, third, fourth or fifth swing shows a higher value than any of the preceding values, a fault is indicated and must be rectified before proceeding. Usually, the fault is an increased contact length between slider and specimen. Check the contact length and reset if necessary.

5.7.4 Repeat Step 5.7.2 c) to 5.7.3 for the remaining control specimens.

5.7.5 Repeat Steps 5.7.2 to 5.7.4 for the second of the newly conditioned rubber sliders.

5.7.6 Record the air temperature to the nearest 1ºC ($T_a$).

5.7.7 Calculate and correct the specimen mean value as detailed in Step 6.1 for each control specimen.

5.7.8 If any one of the friction tester control specimens has a corrected specimen mean value which is more than two units lower or one unit higher that its known value, discontinue testing until the cause of the discrepancy has been traced.

5.8 Friction testing

Perform friction testing of each specimen at a temperature of $23 \pm 2$ºC as follows:

5.8.1 Install a conditioned rubber slider on the friction tester, ensuring the correct positioning of the two washers and spring.
5.8.2 Raise the axis of the suspension of the pendulum so that it swings freely. Adjust the friction rings in the pointer mechanism so that, when the pendulum and pointer are released from the right hand horizontal position, the pointer will zero repeatedly.

5.8.3 Select a specimen. Specimens shall be tested with the first conditioned slider in the following order except that dummy specimens are not tested:

13, 1, 3, 5, 7, 9, 11.

5.8.4 Position the specimen in the specimen holder so that the slider traverses the specimen against the direction of the arrow.

5.8.5 Check that the trailing edge of the slider is parallel to the minor axis of the polished area of the specimen when the pendulum hangs freely at the bottom of its swing.

5.8.6 Adjust the height of the axis of suspension of the pendulum so that the entire trailing edge of the slider is in contact with the polished area of the specimen while traversing the specimen surface. The trailing edge of the slider shall be in contact with the specimen over an arc length of 75 ± 1 mm while traversing the curved surface.

5.8.7 Return the pendulum to its horizontal position and move the pointer against its stop.

5.8.8 Wet the surface of the specimen using the water spray bottle.

5.8.9 Release the pendulum from its horizontal position and allow the pendulum and pointer to swing over the specimen. To avoid damage to the slider, catch the pendulum on its return swing, lift the slider and return the pendulum to the horizontal position.

5.8.10 Multiply the reading on the auxiliary scale by 100 and record the value. Move the pointer against its stop.

5.8.11 Repeat Steps 5.8.8 to 5.8.10 to obtain values from five successive swings. Successive swings of the pendulum should always show the same or a lower friction value. If the second, third, fourth or fifth swing shows a higher value than any of the preceding values, a fault is indicated and must be rectified before proceeding. Usually, the fault is an increased contact length between slider and specimen. Check the contact length and reset if necessary.

5.8.12 Repeat Steps 5.8.3 to 5.8.11 for the remaining specimens to be tested using the first conditioned slider.

5.8.13 Replace the slider with the second conditioned slider and repeat Steps 5.8.3 to 5.8.11 except that specimens shall be tested in the following order:

12, 10, 8, 6, 4, 2, 14.

5.8.14 Record the air temperature to the nearest 1°C ($T_a$).

6 Calculations

Calculate as follows:

6.1 Control specimens

6.1.1 Calculate the average of the last three values recorded for each control specimen and record this average as the control specimen mean value.
6.1.2 Correct each control specimen mean value to 23°C:

\[ CSM_c = CSM_T \left( \frac{T_1 + 100}{123} \right) \]

where

- \( CSM_c \) = control specimen mean value corrected to 23°C
- \( CSM_T \) = control specimen mean value at the test temperature
- \( T_1 \) = recorded air temperature (°C)

6.2 Friction testing

6.2.1 Calculate the average of the last three values recorded for each specimen and record this average as the specimen mean value.

6.2.2 Calculate the average of the specimen mean values for each sample and record this value as the sample mean value to the nearest whole number. Reject any sample mean value for which the range of the specimen mean values exceeds five.

6.2.3 Correct each sample mean value to 23°C:

\[ SMV_c = SMV_T \left( \frac{T_2 + 100}{123} \right) \]

where

- \( SMV_c \) = sample mean value corrected to 23°C
- \( SMV_T \) = sample mean value at the test temperature
- \( T_2 \) = recorded air temperature (°C)

6.2.4 Reject all sample mean values from the test if the value of \( SMV_c \) for the reference aggregate falls outside the range of 48 to 54 (Panmure) or 43 to 49 (UK). New specimens shall then be prepared, polished and tested (Note 8.11).

6.2.5 Calculate the PAFV for each sample as follows:

\[ PAFV = SMV_c + PFV_R - SMV_R \]

where

- \( PAFV \) = polished aggregate friction value
- \( PFV_R \) = polished friction value of reference aggregate, Panmure = 51 and UK = 46
- \( SMV_c \) = sample mean value of the test aggregate corrected to 23°C
- \( SMV_R \) = sample mean value of the reference aggregate corrected to 23°C

7 Reporting

Report the following values and general information:

7.1 The PAFV for the test sample to the nearest whole unit, for example PAFV=39.

7.2 The sample mean value corrected to a temperature of 23°C for the test sample prior to polishing.

7.3 Source of reference aggregate (Panmure or UK).
7.4 The PAFV and the initial sample mean value for the reference aggregate (Panmure or UK).

7.5 The air temperature at the time when the friction test was performed.

8 **Notes on method**

8.1 Reference specimens incorporating reference aggregate are used in the conditioning of a new tyre and as reference specimens in each test. It is convenient to prepare a number of reference specimens at the one time, storing those not immediately required. The reference aggregate may be either:

8.1.1 Australian Standard Reference Aggregate, known as Panmure basalt, which is available from either Australian Road Research Board, Melbourne or the Department of Transport and Main Roads, Herston, Queensland.

8.1.2 UK Reference Aggregate which is available from Wessex Engineering, United Kingdom.

8.2 Before handling silicon carbide, optical emery, oil, high alumina cement, polyester resin, epoxy resin, acetone or kerosene, the operator must consult the relevant Safety Data Sheet (SDS). Specimen moulds should only be prepared in a well ventilated room.

8.3 Silicon carbide or optical emery as appropriate is fed into a chute via a suitable feed mechanism and water is fed by gravity flow at an adjustable rate into the same chute. The feed rates and the positioning of the chute shall be such that there shall be no clogging of the chute and the mixture of abrasive and water is continuously fed directly onto the road wheel near, and ahead of, the point of contact with the rubber -tyred wheel in such a way that the abrasive and water are uniformly spread over the surface of the specimens when contact is made with the tyre.

8.4 If it is not possible for all the procedures involving polishing, soaking and testing to be carried out in a single working day, the preferred point to interrupt the procedure is after polishing with silicon carbide. Place the specimens under water overnight and commence the following day by polishing with optical emery and continue with soaking and testing without further interruptions.

8.5 Dummy specimens are specimens which have been polished and tested and would otherwise be discarded. They are used to make up the number of specimens to fourteen when fewer than twelve test specimens are to be polished.

8.6 Thorough cleaning of the specimens is often more difficult after polishing with optical emery than after polishing with silicon carbide, but it is even more important because the slightest trace of optical emery on or between the particles will cause a lowering of the polished aggregate friction value.

8.7 Two sliders are used in a test run to even out the effects of wear on a slider during a run and to facilitate differentiation between a faulty slider and a defective instrument. Each slider is reversible and has two edges which can be conditioned for use. Both edges may be used but not for the same test run and each edge is used on only one test run.

8.8 To commission new sliders, it is desirable to have access to reference specimens already tested and validated. In the absence of these, on the very first run, one of the specimens incorporating reference aggregate will be required to act as a conditioning specimen and this must not be soaked after polishing. Also in this case, if the specimen mean value of the conditioning specimen is below 48 (Panmure) or 43 (UK) or the sample mean value for the reference specimens is not within the range 48 to 54 (Panmure) or 43 to 49 (UK), it is necessary to discard the two sliders and all specimens from the run.
8.9 Conditioning specimens are specimens incorporating the reference aggregate which are prepared and polished in the same manner but not necessarily at the same time as test specimens. They are used to condition new rubber sliders for use in the friction tester. Reference specimens from a previous test run may be used provided that their PAFV is not less than 48 (Panmure) or 43 (UK).

8.10 Friction tester control specimens are a set of at least three previously used specimens of known values within the range of PAFV from 40 to 70.

8.11 In the event that the sample mean value of the reference specimens consistently falls outside the range of 48 to 54 (Panmure) or 43 to 49 (UK), attention should be paid to the air temperature at which the polishing is carried out (preferably 23°C) in the vicinity of the polishing machine.

**Table 1 – Dimensions and tolerances for PAFV apparatus**

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Dimension</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Road wheel</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed (revolutions / min)</td>
<td>320</td>
<td>± 5</td>
</tr>
<tr>
<td><strong>Solid rubber-tyred wheel</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter (mm)</td>
<td>225</td>
<td>± 2</td>
</tr>
<tr>
<td>Width (mm)</td>
<td>35</td>
<td>+2, -0</td>
</tr>
<tr>
<td>Hardness (Shore A)</td>
<td>60</td>
<td>± 5</td>
</tr>
<tr>
<td>Bearing force (N)</td>
<td>390</td>
<td>± 5</td>
</tr>
<tr>
<td><strong>Pendulum friction tester</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance of sliding edge from axis of suspension (mm)</td>
<td>515</td>
<td>± 2</td>
</tr>
<tr>
<td>Length of rubber slider (mm)</td>
<td>24</td>
<td>± 1</td>
</tr>
<tr>
<td>Width of rubber slider (mm)</td>
<td>32</td>
<td>± 1</td>
</tr>
<tr>
<td>Thickness of rubber slider (mm)</td>
<td>6</td>
<td>± 1</td>
</tr>
<tr>
<td>Mass of rubber slider and backing plate (g)</td>
<td>20</td>
<td>± 5</td>
</tr>
<tr>
<td>Mass of slider and pendulum (kg)</td>
<td>1.50</td>
<td>± 0.03</td>
</tr>
<tr>
<td>Distance from centre of gravity of pendulum to the centre of suspension (mm)</td>
<td>410</td>
<td>± 5</td>
</tr>
<tr>
<td>Angle of slider to horizontal at lowest point of swing (°)</td>
<td>25</td>
<td>± 1</td>
</tr>
<tr>
<td>Mass of pointer (g)</td>
<td>85</td>
<td>maximum</td>
</tr>
<tr>
<td><strong>Moulds</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thickness of specimen produced (mm)</td>
<td>12</td>
<td>minimum</td>
</tr>
<tr>
<td><strong>Slotted sieve</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Width of apertures (mm)</td>
<td>7.2</td>
<td>± 0.1</td>
</tr>
</tbody>
</table>
Table 2 – Properties of rubber slider

<table>
<thead>
<tr>
<th>Property</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Resilience (%)*</td>
<td>44 to 49</td>
</tr>
<tr>
<td>Hardness (IRHD)+</td>
<td>55 ± 5</td>
</tr>
</tbody>
</table>

* Lupke rebound test in accordance with BS903: Part A8.
+ International rubber hardness degrees in accordance with BS903: Part A26.
Test Method Q205A: Ten per cent fines value of aggregate - dry

1 Source

This method is based on AS 1141.22: Wet/dry strength variation. There are some minor procedural differences and the option for duplicate testing has been removed.

2 Scope

This method describes the procedure for the determination of the crushing force which, when applied to a known mass of dry coarse aggregate, will produce fines amounting to 10 per cent of the original mass.

The test is normally performed on aggregate passing a 13.20 mm sieve and retained on a 9.50 mm sieve but may be carried out on other size fractions. However, it is not intended that the test be performed on material retained on a 26.5 mm sieve.

3 Apparatus

Where appropriate, the working tolerances of particular apparatus are contained in Table 1 and AS 1141.22 Figure 1.

The following apparatus is required:

3.1 For aggregate of test size fraction requiring a 150 mm diameter test cylinder (Table 2):

3.1.1 Test cylinder, open-ended steel cylinder, 150 mm diameter, internal depth of 135 mm and wall thickness of 15 mm.

3.1.2 Plunger, steel plunger with a tapered piston having a bottom diameter of 148 mm, top diameter of 146 mm and depth of 30 mm. The piston is mounted on a stem 130 mm diameter with a combined length of the piston and stem of 115 mm. The stem should include a 20 mm diameter hole for lifting of the plunger from within the cylinder.

3.1.3 Baseplate, steel baseplate, 220 mm diameter and thickness of 7.5 mm.

3.1.4 Measuring cylinder, steel cylindrical measure of internal diameter of 115 mm and internal depth of 180 mm.

3.2 For aggregate of test size fraction requiring a 75 mm diameter test cylinder (Table 2):

3.2.1 Test cylinder, open-ended steel cylinder, 75 mm diameter, internal depth of 77.5 mm and wall thickness of 8 mm.

3.2.2 Plunger, steel plunger with a tapered piston having a bottom diameter of 74 mm, top diameter of 72 mm and depth of 20 mm. The piston is mounted on a stem 55 mm diameter with a combined length of the piston and stem of 72.5 mm. The stem should include a 10 mm diameter hole for lifting of the plunger from within the cylinder.

3.2.3 Baseplate, steel baseplate, 115 mm diameter and thickness of 7.5 mm.

3.2.4 Measuring cylinder, steel measure, internal diameter of 60 mm and internal depth of 90 mm.

3.3 Drying oven of suitable capacity, having a temperature of 105-110ºC and complying with AS 1289.0.

3.4 Sieves:

3.4.1 Perforated plate, 26.5 mm, 19.0 mm, 13.20 mm, 9.50 mm, 6.70 mm and 4.75 mm complying with AS 1152.
3.4.2 Woven wire, 3.35 mm, 2.36 mm, 1.70 mm, 1.18 mm, 0.850 mm and 0.600 mm, as required, complying with AS 1152.

3.5 Mallet - rubber mallet with face about 75 mm diameter, mass 1100 g and handle length about 300 mm.

3.6 Compression machine, a Class A compression machine of at least 500 kN capacity and able to apply the required load at a uniform rate of application.

3.7 Balance of suitable capacity, with a resolution of at least 0.1 g and with a limit of performance within the range of ± 0.5 g.

3.8 Steel straightedge, about 300 mm long.

4 Procedure

The procedure shall be as follows:

4.1 Preparation

4.1.1 Prepare the bulk sample as detailed in Section 5 of Test Method Q101 to produce a representative sample of appropriate size.

4.1.2 Further prepare the sample to produce sufficient washed materials of the size and quantity specified in Table 2 as detailed in Test Method Q101, Subsection 6.5 for specified fraction subsamples.

4.1.3 Place the washed sample in the drying oven, dry to a constant mass (Note 7.1) and allow to cool to room temperature.

4.2 Mass of test portion

4.2.1 Select the appropriate measuring cylinder (measure) for the test size fraction from Table 2.

4.2.2 Obtain one representative test portion from the specified fraction subsample.

4.2.3 Slowly fill the measure to about one-third of its capacity by pouring the aggregate from approximately 100 mm above the measure.

4.2.4 Compact the aggregate in the measure by tapping the measure with 25 blows of the rubber mallet evenly distributed around the circumference at the level of the aggregate.

4.2.5 Repeat Steps 4.2.3 and 4.2.4 for two further layers of aggregate.

4.2.6 Top up the measure if necessary and level the surface with a straightedge.

4.2.7 Determine the mass of aggregate in the measure ($m_1$).

4.2.8 Obtain at least three representative test portions of mass $m_1$ from the specified fraction subsample (Note 7.2).

4.3 Testing

4.3.1 Position the test cylinder on the baseplate and place one of the test portions in the cylinder using the method detailed in Steps 4.2.3 to 4.2.5.

4.3.2 Level the surface of the aggregate and insert the plunger so that it rests horizontally on the surface of the aggregate, taking care to ensure the plunger does not jam in the cylinder.

4.3.3 Place the assembled cylinder, test portion and plunger in position between the platens of the compression testing machine.
4.3.4 Estimate the approximate force to produce 10 per cent fines for the particular aggregate type from previous experience with the material type. Use Table 3 as a guide to strengths typically expected (Note 7.3). Where the test portion size fraction requires the use of the smaller 75 mm test mould, then the expected force should be divided by four.

4.3.5 Apply the force at a uniform rate such that the required force is applied in 10 minutes. Record the maximum force applied to the nearest kilonewton \((f_1, f_2)\). If the smaller 75 mm mould has been used for the test, then multiply the maximum force applied by four and record to the nearest kilonewton.

4.3.6 Release the force and remove the cylinder assembly from the compression machine.

4.3.7 Remove the plunger from the cylinder and the whole of the test portion, without deliberate breaking of the particles, and place in a suitable container avoiding loss of fines.

4.3.8 Separate the fines in the test portion using the appropriate separating sieve listed in Table 2 for the size fraction tested.

4.3.9 Determine the mass of the material retained by the separating sieve \((m_2)\).

4.3.10 Calculate the percentage of fines \((P_1, P_2)\) produced during the test as detailed in Step 5.1.

4.3.11 The percentage of fines should normally fall within the range 7.5 per cent to 12.5 per cent. If it does not, take a new test portion and perform a further test as detailed in Steps 4.3.2 to 4.3.10 adjusting the force applied in 10 minutes as required to bring the percentage of fines within the range of 7.5 per cent to 12.5 per cent (Notes 7.3, 7.4 and 7.5).

4.3.12 Repeat Steps 4.3.2 to 4.3.12 with another test portion at a different applied force to produce a percentage fines value \((P_1, P_2)\) within the range of 7.5 per cent to 12.5 per cent, but above 10 per cent if the result on the previous portion was less than 10 per cent or vice versa (Notes 7.3, 7.4 and 7.5).

5 Calculations

Calculate as follows:

5.1 The percentage of fines produced during the test as follows:

\[
P_i = \frac{m_i - m_2}{m_i} \times 100
\]

where

\(P_i\) = percentage of fines (%)

\(m_i\) = mass of test portion (g)

\(m_2\) = mass of material retained on separating sieve (g)

5.2 The dry ten per cent fines value as follows:

\[
D = f_1 + \frac{(10-P_1)(f_2-f_1)}{P_2-P_1}
\]

where

\(D\) = dry ten per cent fines value (%)

\(f_1\) = applied force to produce a percentage of fines within the range of 7.5 to 10.0 per cent (kN)
Test Method Q205A: Ten per cent fines value of aggregate - dry

\[ P_1 = \text{percentage of fines produced by applied force} \ f_1 \]
\[ f_2 = \text{applied force to produce a percentage of fines within the range of } 10.0 \text{ to } 12.5 \text{ per cent (kN)} \]
\[ P_2 = \text{percentage of fines produced by applied force} \ f_2 \]

6 Report

Report the following values and general information:

6.1 The nature of the bulk sample (crushed rock, spalls, drill core) tested.
6.2 The nominal size of the bulk sample (mm).
6.3 The size fraction tested (mm).
6.4 The dry ten per cent fines value to the nearest 1 kN.

7 Notes on method

7.1 The fraction is considered to have reached a constant mass when the difference between successive weighings, after a further 1 hour drying at 105-110°C, is not more than 1 percent of the total of the previous moisture losses.

7.2 The aggregate used in Subsection 4.2 to determine the mass of test portion may be used as a test portion if no significant breakdown has occurred during tapping. If the material is suspect the amount of breakdown can be checked by separating the aggregate on the nominated separating sieve (Table 2). If more than 0.2 per cent passes the sieve then the material from the measuring cylinder should be discarded.

7.3 An indication of the force required to produce ten per cent fines can be estimated from:

\[ F = \frac{14x}{P + 4} \]

where \( F \) = force required to produce 10 per cent fines
\( x \) = maximum force of test (kN)
\( P \) = percentage fines produced from a force of \( x \) kN

7.4 If a result of 10.0 per cent is obtained, take a new test portion and perform a further test as detailed in Steps 4.3.2 to 4.3.10 adjusting the force applied in 10 minutes as required to bring the percentage of fines within the range of 7.5 per cent to less than 10.0 per cent or within the range of 12.5 to greater than 10.0 per cent as appropriate.

7.5 When calculating the ten per cent fines value in accordance with the procedures described, the value of \( f_1 \) should be less than the value of \( f_2 \). If not, then the test be repeated using fresh test portions and the procedure checked to ensure all requirements have been complied with, such as the plunger moves freely in the cylinder.

Table 1 – Dimensions and tolerances for apparatus

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Dimension</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measuring cylinder (150 mm)</td>
<td>115</td>
<td>± 5</td>
</tr>
</tbody>
</table>
### Apparatus Dimension Tolerance

<table>
<thead>
<tr>
<th>Internal depth (mm)</th>
<th>180</th>
<th>± 5</th>
</tr>
</thead>
</table>

#### Measuring cylinder (75 mm)

<table>
<thead>
<tr>
<th>Internal diameter (mm)</th>
<th>60</th>
<th>± 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal depth (mm)</td>
<td>90</td>
<td>± 3</td>
</tr>
</tbody>
</table>

#### Mallet

| Mass (g)               | 1100| ± 100 |

### Table 2 – Test conditions for various aggregate sizes

<table>
<thead>
<tr>
<th>Test size fraction (mm)</th>
<th>Diameter of test cylinder (mm)</th>
<th>Diameter of measuring cylinder (mm)</th>
<th>Approximate quantity of material to provide three test portions and fill measure</th>
<th>Depth of test portion in test cylinder after tamping (mm)</th>
<th>Aperture of sieve for separating fines (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>26.5</td>
<td>19.0</td>
<td>150</td>
<td>15</td>
<td>9</td>
<td>100</td>
</tr>
<tr>
<td>19.0</td>
<td>13.20</td>
<td>150</td>
<td>15</td>
<td>9</td>
<td>100</td>
</tr>
<tr>
<td>13.20</td>
<td>9.50</td>
<td>150</td>
<td>15</td>
<td>9</td>
<td>100</td>
</tr>
<tr>
<td>9.50</td>
<td>6.70</td>
<td>150</td>
<td>15</td>
<td>9</td>
<td>100</td>
</tr>
<tr>
<td>6.70</td>
<td>4.75</td>
<td>75</td>
<td>1.8</td>
<td>1.5</td>
<td>50</td>
</tr>
<tr>
<td>4.75</td>
<td>3.35</td>
<td>75</td>
<td>1.8</td>
<td>1.5</td>
<td>50</td>
</tr>
<tr>
<td>3.35</td>
<td>2.36</td>
<td>75</td>
<td>1.8</td>
<td>1.5</td>
<td>50</td>
</tr>
</tbody>
</table>

### Table 3 – Typical dry strength values (150 mm) for various rock types

<table>
<thead>
<tr>
<th>Rock type</th>
<th>Typical dry strength (kN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adamellite</td>
<td>150</td>
</tr>
<tr>
<td>Andesite</td>
<td>190</td>
</tr>
<tr>
<td>Basalt</td>
<td>290</td>
</tr>
<tr>
<td>Diorite</td>
<td>260</td>
</tr>
<tr>
<td>Dolerite</td>
<td>180</td>
</tr>
<tr>
<td>Gabbro</td>
<td>250</td>
</tr>
<tr>
<td>Granite</td>
<td>200</td>
</tr>
<tr>
<td>Granodiorite</td>
<td>300</td>
</tr>
<tr>
<td>Greenstone</td>
<td>330</td>
</tr>
<tr>
<td>Hornfels</td>
<td>290</td>
</tr>
<tr>
<td>Limestone</td>
<td>200</td>
</tr>
<tr>
<td>Meta-Greywacke</td>
<td>270</td>
</tr>
<tr>
<td>Rock type</td>
<td>Typical dry strength (kN)</td>
</tr>
<tr>
<td>-----------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>Mudstone</td>
<td>180</td>
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<tr>
<td>Quartzite</td>
<td>220</td>
</tr>
<tr>
<td>Rhyolite</td>
<td>230</td>
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<tr>
<td>Slate</td>
<td>190</td>
</tr>
<tr>
<td>Trachyte</td>
<td>220</td>
</tr>
<tr>
<td>Tuff</td>
<td>250</td>
</tr>
</tbody>
</table>
Test Method Q205B: Ten per cent fines value of aggregate - wet

1 Source

This method is based on AS 1141.22: Wet/dry strength variation. There are some minor procedural differences and the option for duplicate testing has been removed.

2 Scope

This method describes the procedure for the determination of the crushing force which, when applied to a known mass of saturated surface dry coarse aggregate, will produce fines amounting to 10 per cent of the original mass.

The test is normally performed on aggregate passing a 13.20 mm sieve and retained on a 9.50 mm sieve but may be carried out on other size fractions. However, it is not intended that the test be performed on material retained on a 26.5 mm sieve.

3 Apparatus

Where appropriate, the working tolerances of particular apparatus are contained in Table 1 and AS 1141.22 Figure 1.

The following apparatus is required:

3.1 For aggregate of test size fraction requiring a 150 mm diameter test cylinder (Table 2):

3.1.1 Test cylinder, open-ended steel cylinder, 150 mm diameter, internal depth of 135 mm and wall thickness of 15 mm.

3.1.2 Plunger, steel plunger with a tapered piston having a bottom diameter of 148 mm, top diameter of 146 mm and depth of 30 mm. The piston is mounted on a stem 130 mm diameter with a combined length of the piston and stem of 115 mm. The stem should include a 20 mm diameter hole for lifting of the plunger from within the cylinder.

3.1.3 Baseplate, steel baseplate, 220 mm diameter and thickness of 7.5 mm.

3.1.4 Measuring cylinder, steel cylindrical measure of internal diameter of 115 mm and internal depth of 180 mm.

3.2 For aggregate of test size fraction requiring a 75 mm diameter test cylinder (Table 2):

3.2.1 Test cylinder, open-ended steel cylinder, 75 mm diameter, internal depth of 77.5 mm and wall thickness of 8 mm.

3.2.2 Plunger, steel plunger with a tapered piston having a bottom diameter of 74 mm, top diameter of 72 mm and depth of 20 mm. The piston is mounted on a stem 55 mm diameter with a combined length of the piston and stem of 72.5 mm. The stem should include a 10 mm diameter hole for lifting of the plunger from within the cylinder.

3.2.3 Baseplate, steel baseplate, 115 mm diameter and thickness of 7.5 mm.

3.2.4 Measuring cylinder, steel measure, internal diameter of 60 mm and internal depth of 90 mm.

3.3 Drying oven of suitable capacity, having a temperature of 105-110ºC and complying with AS 1289.0.

3.4 Sieves:

3.4.1 Perforated plate, 26.5 mm, 19.0 mm, 13.20 mm, 9.50 mm, 6.70 mm and 4.75 mm complying with AS 1152.
3.4.2 Woven wire, 3.35 mm, 2.36 mm, 1.70 mm, 1.18 mm, 0.850 mm and 0.600 mm, as required, complying with AS 1152.

3.5 Mallet - rubber mallet with face about 75 mm diameter, mass 1100 g and handle length about 300 mm.

3.6 Compression machine, a Class A compression machine of at least 500 kN capacity and able to apply the required load at a uniform rate of application.

3.7 Balance of suitable capacity, with a resolution of at least 0.1 g and with a limit of performance within the range of ± 0.5 g.

3.8 Steel straightedge, about 300 mm long.

3.9 Absorbent cloth or towel.

4 Procedure

The procedure shall be as follows:

4.1 Preparation

4.1.1 Prepare the bulk sample as detailed in Section 5 of Test Method Q101 to produce a representative sample of appropriate size.

4.1.2 Further prepare the sample to produce sufficient washed materials of the size and quantity specified in Table 2 as detailed in Test Method Q101, Subsection 6.5 for specified fraction subsamples.

4.1.3 Place the washed sample in the drying oven, dry to a constant mass (Note 7.1) and allow to cool to room temperature.

4.2 Mass of test portion

4.2.1 Select the appropriate measuring cylinder (measure) for the test size fraction from Table 2.

4.2.2 Obtain one representative test portion from the specified fraction subsample.

4.2.3 Slowly fill the measure to about one-third of its capacity by pouring the aggregate from approximately 100 mm above the measure.

4.2.4 Compact the aggregate in the measure by tapping the measure with 25 blows of the rubber mallet evenly distributed around the circumference at the level of the aggregate.

4.2.5 Repeat Steps 4.2.3 and 4.2.4 for two further layers of aggregate.

4.2.6 Top up the measure if necessary and level the surface with a straightedge.

4.2.7 Determine the mass of aggregate in the measure ($m_1$).

4.2.8 Obtain at least three representative test portions of mass $m_1$ from the specified fraction subsample (Note 7.2).

4.3 Testing

4.3.1 Immerse the test portions in water overnight but for not longer than 24 hours.

4.3.2 After soaking, remove one portion from the water and allow it to drain.

4.3.3 After draining, place the aggregate one particle deep on a dry cloth and roll and wipe the particles until all visible films of water have been removed but the surfaces of the aggregate still appear damp.
4.3.4 Position the test cylinder on the baseplate and place the test portion in the cylinder using the method detailed in Steps 4.2.3 to 4.2.5.

4.3.5 Level the surface of the aggregate and insert the plunger so that it rests horizontally on the surface of the aggregate, taking care to ensure the plunger does not jam in the cylinder.

4.3.6 Place the assembled cylinder, test portion and plunger in position between the platens of the compression testing machine.

4.3.7 Estimate the approximate force to produce ten per cent fines for the particular aggregate type from previous experience with the material type. Use Table 3 as a guide to strengths typically expected (Note 7.3). Where the test portion size fraction requires the use of the smaller 75 mm test mould, then the expected force should be divided by four.

4.3.8 Apply the force at a uniform rate such that the required force is applied in 10 minutes. Record the maximum force applied to the nearest kilonewton ($f_1$, $f_2$). If the smaller 75 mm mould has been used for the test, then multiply the maximum force applied by four and record to the nearest kilonewton.

4.3.9 Release the force and remove the cylinder assembly from the compression machine.

4.3.10 Remove the plunger from the cylinder and the whole of the test portion, without deliberate breaking of the particles, and place in a suitable container avoiding loss of fines.

4.3.11 Place the crushed portion in an oven and dry to a constant mass (Note 7.1).

4.3.12 Separate the fines in the test portion using the appropriate separating sieve listed in Table 2 for the size fraction tested.

4.3.13 Determine the mass of the material retained by the separating sieve ($m_2$).

4.3.14 Calculate the percentage of fines ($P_1$, $P_2$) produced during the test as detailed in Step 5.1.

4.3.15 The percentage of fines should normally fall within the range 7.5 per cent to 12.5 per cent. If it does not, take a new test portion and perform a further test as detailed in Steps 4.3.2 to 4.3.14 adjusting the force applied in 10 minutes as required to bring the percentage of fines within the range of 7.5 per cent to 12.5 per cent (Notes 7.3, 7.4 and 7.5).

4.3.16 Repeat Steps 4.3.1 to 4.3.15 with another test portion at a different applied force to produce a percentage fines value ($P_1$, $P_2$) within the range of 7.5 per cent to 12.5 per cent, but above 10 per cent if the result on the previous portion was less than 10 per cent or vice versa (Notes 7.3, 7.4 and 7.5).

5 Calculations

Calculate as follows:

5.1 The percentage of fines produced during the test as follows:

$$P_i = \frac{m_2 - m_1}{m_1} \times 100$$

where $P_i$ = percentage of fines (%), $m_1$ = mass of test portion (g), $m_2$ = mass of material retained on separating sieve (g)
5.2 The wet ten per cent fines value as follows:

\[ W = f_1 + \frac{(10-P_2)(f_2-f_1)}{P_2-P_1} \]

where

- \( W \) = wet ten per cent fines value (%)
- \( f_1 \) = applied force to produce a percentage of fines within the range of 7.5 to 10.0 per cent (kN)
- \( P_1 \) = percentage of fines produced by applied force \( f_1 \)
- \( f_2 \) = applied force to produce a percentage of fines within the range of 10.0 to 12.5 per cent (kN)
- \( P_2 \) = percentage of fines produced by applied force \( f_2 \)

6 Report

Report the following values and general information:

6.1 The nature of the bulk sample (crushed rock, spalls, drill core) tested.
6.2 The nominal size of the bulk sample (mm).
6.3 The size fraction tested (mm).
6.4 The wet ten per cent fines value to the nearest 1 kN.

7 Notes on method

7.1 The fraction is considered to have reached a constant mass when the difference between successive weighings, after a further 1 hour drying at 105-110°C, is not more than 1 percent of the total of the previous moisture losses.

7.2 The aggregate used in Subsection 4.2 to determine the mass of test portion may be used as a test portion if no significant breakdown has occurred during tapping. If the material is suspect the amount of breakdown can be checked by separating the aggregate on the nominated separating sieve (Table 2). If more than 0.2 per cent passes the sieve then the material from the measuring cylinder should be discarded.

7.3 An indication of the force required to produce ten per cent fines can be estimated from:

\[ F = \frac{14x}{P+4} \]

where

- \( F \) = force required to produce 10 per cent fines
- \( x \) = maximum force of test (kN)
- \( P \) = percentage fines produced from a force of \( x \) kN

7.4 If a result of 10.0 per cent is obtained, take a new test portion and perform a further test as detailed in Steps 4.3.2 to 4.3.14 adjusting the force applied in 10 minutes as required to bring the percentage of fines within the range of 7.5 per cent to less than 10.0 per cent or within the range of 12.5 to greater than 10.0 per cent as appropriate.

7.5 When calculating the ten per cent fines value in accordance with the procedures described, the value of \( f_1 \) should be less than the value of \( f_2 \). If not, then the test be repeated using fresh
test portions and the procedure checked to ensure all requirements have been complied with, such as the plunger moves freely in the cylinder.

Table 1 – Dimensions and tolerances for apparatus

<table>
<thead>
<tr>
<th>Apparatus Dimension</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measuring cylinder (150 mm)</td>
<td></td>
</tr>
<tr>
<td>Internal diameter (mm)</td>
<td>115 ± 5</td>
</tr>
<tr>
<td>Internal depth (mm)</td>
<td>180 ± 5</td>
</tr>
<tr>
<td>Measuring cylinder (75 mm)</td>
<td></td>
</tr>
<tr>
<td>Internal diameter (mm)</td>
<td>60 ± 3</td>
</tr>
<tr>
<td>Internal depth (mm)</td>
<td>90 ± 3</td>
</tr>
<tr>
<td>Mallet Mass (g)</td>
<td>1100 ± 100</td>
</tr>
</tbody>
</table>

Table 2 – Test conditions for various aggregate sizes

<table>
<thead>
<tr>
<th>Test size fraction (mm)</th>
<th>Diameter of test cylinder (mm)</th>
<th>Diameter of measuring cylinder (mm)</th>
<th>Approximate quantity of material to provide three test portions and fill measure</th>
<th>Depth of test portion in test cylinder after tamping (mm)</th>
<th>Aperture of sieve for separating fines (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>26.5</td>
<td>19.0</td>
<td>150</td>
<td>115</td>
<td>15</td>
<td>9</td>
</tr>
<tr>
<td>19.0</td>
<td>13.20</td>
<td>150</td>
<td>115</td>
<td>15</td>
<td>9</td>
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<tr>
<td>13.20</td>
<td>9.50</td>
<td>150</td>
<td>115</td>
<td>15</td>
<td>9</td>
</tr>
<tr>
<td>9.50</td>
<td>6.70</td>
<td>150</td>
<td>115</td>
<td>15</td>
<td>9</td>
</tr>
<tr>
<td>6.70</td>
<td>4.75</td>
<td>75</td>
<td>60</td>
<td>1.8</td>
<td>1.5</td>
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<td>60</td>
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<td>1.5</td>
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<tr>
<td>3.35</td>
<td>2.36</td>
<td>75</td>
<td>60</td>
<td>1.8</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Table 3 – Typical dry strength values (150 mm) for various rock types

<table>
<thead>
<tr>
<th>Rock type</th>
<th>Typical dry strength (kN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adamellite</td>
<td>150</td>
</tr>
<tr>
<td>Andesite</td>
<td>190</td>
</tr>
<tr>
<td>Basalt</td>
<td>290</td>
</tr>
<tr>
<td>Diorite</td>
<td>260</td>
</tr>
<tr>
<td>Dolerite</td>
<td>180</td>
</tr>
<tr>
<td>Gabbro</td>
<td>250</td>
</tr>
<tr>
<td>Granite</td>
<td>200</td>
</tr>
<tr>
<td>Rock type</td>
<td>Typical dry strength (kN)</td>
</tr>
<tr>
<td>-----------------</td>
<td>---------------------------</td>
</tr>
<tr>
<td>Granodiorite</td>
<td>300</td>
</tr>
<tr>
<td>Greenstone</td>
<td>330</td>
</tr>
<tr>
<td>Hornfels</td>
<td>290</td>
</tr>
<tr>
<td>Limestone</td>
<td>200</td>
</tr>
<tr>
<td>Meta-Greywacke</td>
<td>270</td>
</tr>
<tr>
<td>Mudstone</td>
<td>180</td>
</tr>
<tr>
<td>Quartzite</td>
<td>220</td>
</tr>
<tr>
<td>Rhyolite</td>
<td>230</td>
</tr>
<tr>
<td>Slate</td>
<td>190</td>
</tr>
<tr>
<td>Trachyte</td>
<td>220</td>
</tr>
<tr>
<td>Tuff</td>
<td>250</td>
</tr>
</tbody>
</table>
Test Method Q205C: Wet/dry strength variation of aggregate

1 Source
This method is based on AS 1141.22: Wet/dry strength variation. There are some minor procedural differences and the option for duplicate testing has been removed.

2 Scope
This method describes the procedure for the determination of the strength variation of aggregate when tested in both the oven dry (dry) and saturated surface dry (wet) conditions.

The standard test is carried out on aggregate passing a 13.20 mm sieve and retained on a 9.50 mm sieve but can be performed on other size fractions. However the same size fraction must be used for both the wet and dry tests.

3 Procedure
The procedure shall be as follows:

3.1 Determine the dry ten per cent fines value \( D \) as detailed in Test Method Q205A.
3.2 Determine the wet ten per cent fines value \( W \) as detailed in Test Method Q205B.

4 Calculations
Calculate the wet/dry strength variation as follows:

\[
WDV = \frac{100(D - W)}{D}
\]

where

- \( WDV \) = wet/dry strength variation (%).
- \( D \) = dry ten per cent fines value, obtained from Test Method Q205A (kN)
- \( W \) = wet ten per cent fines value, obtained from Test Method Q205B (kN)

5 Reporting
Report the following values and general information:

5.1 The nature of the bulk sample (crushed rock, spalls, drill core) tested.
5.2 The nominal size of the bulk sample.
5.3 The size fraction tested (mm).
5.4 The wet ten per cent fines value and the dry ten per cent fines value to the nearest 1 kN.
5.5 The wet/dry strength variation to the nearest 1%.
Test Method Q208A: Degradation factor of source rock

1 Source
This method applies the principles of AS 1141.25.1: Degradation factor - Source rock. It differs from this Australian Standard by minor alterations to the defined test portion and stock solution ingredients, by modifying the washing technique during preparation and after abrasion, and by directly calculating the degradation factor.

2 Scope
This method describes the procedure for the determination of the degradation factor of source rock, for example, from rock spalls or drill cores. The degradation factor indicates the aggregate quality by categorising the fines produced by the self-abrasion of the aggregate particles in the presence of water.

3 Apparatus
Where appropriate, the working tolerances of particular apparatus are contained in Table 1.

The following apparatus is required:

3.1 Shaker, a motorised shaker as illustrated in Figure 1.
3.2 Canister, a plastic canister fitted with a close fitting lid.
3.3 Test cylinder, a cylinder consisting of a transparent measuring tube and base with a rubber or plastic stopper. The tube shall be graduated from the base to a height of 380 mm in increments of 5 mm.
3.4 Measuring cylinders:
   3.4.1 500 mL measuring cylinder graduated at 100 mL intervals with a rubber or plastic stopper.
   3.4.2 10 mL measuring cylinder graduated at 1 mL intervals.
3.5 Sieves:
   3.5.1 19.0 mm, 13.2 mm, 9.50 mm, 6.70 mm, 4.75 mm and 2.36 mm sieves complying with AS 1152.
   3.5.2 Reinforced 2.36 mm and 0.075 mm sieves of 300 mm diameter and complying with AS 1152.
3.6 Funnel, a funnel having an internal diameter of approximately 325 mm.
3.7 Timer, a timer capable of measuring at least 20 minutes and reading in minutes and seconds.
3.8 Water sprayer, such as a vegetable sprayer connected to a mains pressure water supply.
3.9 Wash bottle with a fine jet.
3.10 Wash bowls, four metal bowls, approximately 180 mm diameter and 100 mm deep.
3.11 Drying oven of suitable capacity, having a temperature of 105-110°C and complying with AS 1141.2.
3.12 Balances:
   3.12.1 Balance of suitable capacity, having a resolution of at least 0.1 g and with a limit of performance within the range of ± 0.5 g.
3.12.2 Balance of suitable capacity, having a resolution of at least 0.01 g and with a limit of performance within the range of ± 0.05 g (Note 10.1).

3.13 Crusher, a motorised crusher such as a jaw crusher suitable for reducing the sample of source rock to the required sizes.

3.14 Scalping screen, a scalping screen or other suitable equipment with an aperture size within the range of 12 mm to 19 mm.

3.15 Brush, a stiff wire brush.

4 Reagents

The following reagents are required:

4.1 Stock solution:

- Prepare by dissolving 21.9 ± 0.2 g of calcium chloride hexahydrate (AR grade) and 48.0 ± 0.5 g of glycerine (99% glycerol (LR grade)) in distilled water and making up to 100 mL (Notes 10.2, 10.3, 10.4 and 10.5).

5 Sample preparation

Prepare the sample as follows:

5.1 Thoroughly wash and dry the sample before using the wire brush to remove any adhering fines or soft weathered rock.

5.2 Crush the sample by gradually reducing the maximum particle size to 30-33 mm.

5.3 Sieve the crushed sample over an appropriately sized scalping screen to remove material that is not of a size corresponding to that of the quarried product.

5.4 If the material retained on the scalping screen is not homogenous, remove and discard any particles which are at variance with the bulk of the sample.

5.5 Further crush the retained material, gradually reducing its size until nearly all material passes the 19.0 mm sieve and a range of particle sizes in keeping with the requirements of Table 2 is produced.

5.6 Prepare a representative subsample to provide a test portion containing the required fractions as follows:

5.6.1 Screen the subsample through each of the sieves listed in Table 2, in turn. Discard the material retained on the largest sieve and the material passing the smallest sieve.

5.6.2 Place the fractions in separate wash bowls and wash each fraction using clean water until all coatings of fines have been removed from the surface of the particles. Use the procedure and observe the precautions detailed below.

a) Wash each fraction in turn as follows:

i. Hold the bowl at about a 45° angle in a sink and use the water sprayer to wash the particles, changing the orientation of the bowl to expose all particles to the water stream.

ii. Stop washing when the bowl is full and decant the wash water, ensuring only clay-sized particulates are run to waste.

iii. Repeat the washing and decanting until the surface of the particles first appear clean to the naked eye.
b) While the wash water is usually clean once all coatings of fines have been removed, some discrete rock particles will slowly break down when subjected to a stream of water. This is evidenced by discolouration of the wash water. In such cases, discontinue washing once the surface of the particles first appear clean to the naked eye (Note 10.6).

5.6.3 Place each washed fraction in the oven in its wash bowl and dry until a constant mass has been reached, recording the mass at each weighing (Note 10.7).

5.6.4 Reduce each dried fraction to the required mass as per Table 2, using appropriately sized sample splitters as detailed in Test Method Q101 Step 5.3. Ensure each resultant subsample is representative of the washed fraction and includes any rock fragments and fines. Combine the four fractions to produce the test portion.

6 Procedure

The procedure shall be as follows:

6.1 Rinse the canister lid, funnel, measuring cylinders, reinforced 2.36 mm and 0.075 mm sieves and the test cylinder with distilled water and allow the rinsed apparatus to drain.

6.2 Place the test portion in the canister, together with 200 mL of distilled water.

6.3 Place the lid on the canister and secure the assembly in the shaker.

6.4 Operate the shaker for 20 minutes.

6.5 After the 20 minutes shaking, empty the test portion into nested 2.36 mm and 0.075 mm sieves held in the funnel over the 500 mL measuring cylinder.

6.6 Wash out the canister with distilled water from the water sprayer and continue to wash the aggregate with the wash water from the canister and distilled water until the measuring cylinder is full to the 500 mL mark. In order that the maximum amount of fines is deposited into the measuring cylinder, use the procedure and observe the precautions detailed below.

6.6.1 Wash the canister and aggregate as follows:

a) Use a minimum amount of water to wash the canister, placing larger particles into the 2.36 mm sieve by hand. Direct the canister wash water over the material retained on the 2.36 mm sieve.

b) Separate and hold the 2.36 mm sieve just above the 0.075 mm sieve. Tilt the 2.36 mm sieve so that the wash water is directed over the retained 0.075 mm material. Remove fines by lightly tapping the 2.36 mm sieve and sparingly rinsing with water.

c) Clean the retained 0.075 mm material with water, tilting the sieve to allow drainage.

d) Tilt the 0.075 mm sieve and direct wash water over the back of the sieve. Remove fines by lightly tapping the back of the 0.075 mm sieve and sparingly rinsing with water.

6.6.2 Since some wash water will be held on and between the aggregate particles retained on the sieves and will drain slowly, the spray rate must be reduced as the level in the cylinder approaches 500 mL to prevent overfilling. The aggregate may drain 50-100 mL of wash water after the washing has ceased, thus allowance should be made for this extra wash water to drain.

6.6.3 With some soft discrete rock particles, the wash water will not be clear after washing.

6.7 Using the 10 mL measuring cylinder, transfer 7 mL of stock solution into the graduated test cylinder.
6.8 Stopper the 500 mL measuring cylinder and bring all solids in the wash water into suspension by inverting the cylinder end to end about ten times allowing the bubble to travel completely from one end to the other each time.

6.9 Immediately pour the suspension into the test cylinder to the 380 mm mark and insert the stopper.

6.10 Mix the contents of the test cylinder by inverting the cylinder end to end, allowing the bubble to travel completely from one end to the other. This alternating end to end mixing cycle shall be repeated 20 times in approximately 35 seconds.

6.11 At the conclusion of the mixing period, place the test cylinder on a bench free from vibration, remove the stopper and start the timer. Allow the test cylinder to stand undisturbed for a period of 20 minutes ± 10 seconds.

6.12 After the 20 minute period, estimate and record the height of the upper surface of the flocculate column (h) to the nearest 1 mm.

7 Calculations

7.1 Calculate the degradation factor (D) as follows:

\[
D = \frac{100(380-h)}{380+1.75h}
\]

where

\begin{align*}
D & \quad = \text{degradation factor} \\
h & \quad = \text{height of flocculate column (mm)}
\end{align*}

8 Reporting

Report the degradation factor to the nearest whole number.

9 Precision

The following criteria should be used to judge the acceptability of results (95% probability).

9.1 Repeatability

Duplicate tests by the same operator are acceptable if their results do not differ by more than four units.

9.2 Reproducibility

Independent test results obtained by different operators working in different laboratories on identical samples are acceptable if the results do not differ by more than 16 units.

10 Notes on method

10.1 The balance used to weigh the reagents must have a readability which displays to one significant figure more than the required mass being weighed and a limit of performance commensurate with the readability.

10.2 Before handling the reagents, the operator must consult the relevant Safety Data Sheet (SDS).

10.3 Due to the very hygroscopic nature of calcium chloride hexahydrate, it will begin to dissolve in the water which it attracts, even in its original container once that has been opened. However,
any undissolved crystals are able to be used by simply decanting any free solution from the calcium chloride hexahydrate container before use.

10.4 The stock solution may be prepared using anhydrous calcium chloride (11.1 ± 0.1 g) in place of calcium chloride hexahydrate. Due to the extremely hygroscopic nature of anhydrous calcium chloride, it must be kept in a desiccator or dried in an oven at 200°C before use.

10.5 Record the date of preparation of the stock solution on the reagent bottle. Stock solution may be used for 5 days from the date of preparation after which fresh stock solution must be prepared.

10.6 Insufficient washing may result in clay fines being retained as adherent coatings which are subsequently released during the test. On the other hand, aggressive and prolonged washing may prematurely remove hydrophilic clay minerals from the rock structure due to leaching and abrasion.

10.7 The material is considered to have reached a constant mass when the difference between successive weighings, after a further 1 hour drying at 105-110°C, is not more than 1 percent of the total of the previous moisture losses.

Table 1 – Specifications and working tolerances of apparatus

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Value</th>
<th>Working tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shaker</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
<td>cycles/min</td>
<td>300</td>
<td>± 5</td>
</tr>
<tr>
<td>Throw (total)</td>
<td>mm</td>
<td>44</td>
<td>± 0.5</td>
</tr>
<tr>
<td>Pivot to base length</td>
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</tr>
<tr>
<td>pPivot to cam shaft length</td>
<td>mm</td>
<td>585</td>
<td>± 5</td>
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<td>Canister</td>
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<td>Height</td>
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</tr>
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<td>± 5</td>
</tr>
<tr>
<td>Base thickness</td>
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<td>max</td>
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<tr>
<td>Test Cylinder</td>
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<td>Tube height</td>
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<td>approx.</td>
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<tr>
<td>Tube external diameter</td>
<td>mm</td>
<td>40</td>
<td>approx.</td>
</tr>
<tr>
<td>Tube internal diameter</td>
<td>mm</td>
<td>32</td>
<td>± 0.5</td>
</tr>
</tbody>
</table>

Table 2 – Mass of fractions required for test portion

<table>
<thead>
<tr>
<th>Particle size (mm)</th>
<th>Mass of fraction (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>13.2 to 9.50</td>
<td>250 ± 2.5</td>
</tr>
<tr>
<td>9.50 to 6.70</td>
<td>250 ± 2.5</td>
</tr>
<tr>
<td>6.70 to 4.75</td>
<td>250 ± 2.5</td>
</tr>
<tr>
<td>4.75 to 2.36</td>
<td>250 ± 2.5</td>
</tr>
</tbody>
</table>
Figure 1 – Motorised shaker
(All dimensions are in millimetres)
Test Method Q208B: Degradation factor of coarse aggregate

1 Source
This method applies the principles of AS 1141.25.2: Degradation factor – Coarse aggregate. It differs from this Australian Standard by minor alterations to the defined test portion and stock solution ingredients, by modifying the washing technique during preparation and after abrasion, and by directly calculating the degradation factor.

2 Scope
This method describes the procedure for the determination of the degradation factor of coarse aggregate (retained 2.36 mm sieve). The degradation factor indicates the aggregate quality by categorising the fines produced by the self-abrasion of the aggregate particles in the presence of water.

3 Apparatus
Where appropriate, the working tolerances of particular apparatus are contained in Table 1.

The following apparatus is required:

3.1 Shaker, a motorised shaker as illustrated in Figure 1.
3.2 Canister, a plastic canister fitted with a close fitting lid.
3.3 Test cylinder, a cylinder consisting of a transparent measuring tube and base with a rubber or plastic stopper. The tube shall be graduated from the base to a height of 380 mm in increments of 5 mm.
3.4 Measuring cylinders:
   3.4.1 500 mL measuring cylinder graduated at 100 mL intervals with a rubber or plastic stopper.
   3.4.2 10 mL measuring cylinder graduated at 1 mL intervals.
3.5 Sieves:
   3.5.1 19.0 mm, 13.2 mm, 9.50 mm, 6.70 mm, 4.75 mm and 2.36 mm sieves complying with AS 1152.
   3.5.2 Reinforced 2.36 mm and 0.075 mm sieves of 300 mm diameter and complying with AS 1152.
3.6 Funnel, a funnel having an internal diameter of approximately 325 mm.
3.7 Timer, a timer capable of measuring at least 20 minutes and reading in minutes and seconds.
3.8 Water sprayer, such as a vegetable sprayer connected to a mains pressure water supply.
3.9 Wash bottle with a fine jet.
3.10 Wash bowls, four metal bowls, approximately 180 mm diameter and 100 mm deep.
3.11 Drying oven of suitable capacity, having a temperature of 105-110°C and complying with AS 1141.2.
3.12 Balances:
   3.12.1 Balance of suitable capacity, having a resolution of at least 0.1 g and with a limit of performance within the range of ± 0.5 g.
3.12.2 Balance of suitable capacity, having a resolution of at least 0.01 g and with a limit of performance within the range of ± 0.05 g (Note 10.1).

4 Reagents
The following reagents are required:

4.1 Stock solution:
- Prepare by dissolving 21.9 ± 0.2 g of calcium chloride hexahydrate (AR grade) and 48.0 ± 0.5 g of glycerine (99% glycerol (LR grade)) in distilled water and making up to 100 mL (Notes 10.2, 10.3, 10.4 and 10.5).

5 Sample preparation
Prepare the sample as follows:

5.1 Prepare the bulk sample as detailed in Section 5 of Test Method Q101 to produce a representative subsample of appropriate size.

5.2 Prepare a representative subsample to provide a test portion containing the fractions in Table 2 as follows:

5.2.1 Screen the subsample through each of the sieves listed in Table 2 in turn, breaking up aggregations of fines either by hand or by using a rubber pestle and mortar such that discrete particles are not broken.

5.2.2 Where difficulty exists in ascertaining whether particles are discrete or, in fact, aggregations of fines, a small number of such particles should be placed in water and boiled. If disaggregation occurs, such particles shall be considered as aggregations of fines.

5.2.3 Discard the material retained on the largest sieve and the material passing the smallest sieve.

5.2.4 Place the fractions in separate wash bowls and wash each fraction using clean water until all coatings of fines have been removed from the surface of the particles. Use the procedure and observe the precautions detailed below.

a) Wash each fraction in turn as follows:
   i. Hold the bowl at about a 45º angle in a sink and use the water sprayer to wash the particles, changing the orientation of the bowl to expose all particles to the water stream.
   ii. Stop washing when the bowl is full and decant the wash water, ensuring only clay-sized particulates run to waste.
   iii. Repeat the washing and decanting until the surface of the particles first appear clean to the naked eye.

b) While the wash water is usually clean once all coatings of fines have been removed, some discrete rock particles will slowly break down when subjected to a stream of water. This is evidenced by discolouration of the wash water. In such cases, discontinue washing once the surface of the particles first appear clean to the naked eye (Note 10.6).

5.2.5 Place each washed fraction in the oven in its wash bowl and dry until a constant mass has been reached, recording the mass at each weighing (Note 10.7).

5.2.6 Reduce each dried fraction to the required mass as per Table 2, using appropriately sized sample splitters as detailed in Test Method Q101 Step 5.3. Ensure each resultant subsample
is representative of the washed fraction and includes any rock fragments and fines. Combine the four fractions to produce the test portion.

6 Procedure

The procedure shall be as follows:

6.1 Rinse the canister, lid, funnel, measuring cylinders, the reinforced 2.36 and 0.075 mm sieves and the test cylinder with distilled water and allow the rinsed apparatus to drain.

6.2 Place the test portion in the canister, together with 200 mL of distilled water.

6.3 Place the lid on the canister and secure the assembly in the shaker.

6.4 Operate the shaker for 20 minutes.

6.5 After the 20 minutes shaking, empty the test portion into nested 2.36 mm and 0.075 mm sieves held in the funnel over the 500 mL measuring cylinder.

6.6 Wash out the canister with distilled water from the water sprayer and continue to wash the aggregate with the wash water from the canister and distilled water until the measuring cylinder is full to the 500 mL mark. In order that the maximum amount of fines is deposited into the measuring cylinder, use the procedure and observe the precautions detailed below.

6.6.1 Wash the canister and aggregate as follows:

a) Use a minimum amount of water to wash the canister, placing larger particles into the 2.36 mm sieve by hand. Direct the canister wash water over the material retained on the 2.36 mm sieve.

b) Separate and hold the 2.36 mm sieve just above the 0.075 mm sieve. Tilt the 2.36 mm sieve so that the wash water is directed over the retained 0.075 mm material. Remove fines by lightly tapping the 2.36 mm sieve and sparingly rinsing with water.

c) Clean the retained 0.075 mm material with water, tilting the sieve to allow drainage.

d) Tilt the 0.075 mm sieve and direct wash water over the back of the sieve. Remove fines by lightly tapping the back of the 0.075 mm sieve and sparingly rinsing with water.

6.6.2 Since some wash water will be held on and between the aggregate particles retained on the sieves and will drain slowly, the spray rate must be reduced as the level in the cylinder approaches 500 mL to prevent overfilling. The aggregate may drain 50-100 mL of wash water after the washing has ceased, thus allowance should be made for this extra wash water to drain.

6.6.3 With some soft discrete rock particles, the wash water will not be clear after washing.

6.7 Using the 10 mL measuring cylinder, transfer 7 mL of stock solution into the graduated test cylinder.

6.8 Stopper the 500 mL measuring cylinder and bring all solids in the wash water into suspension by inverting the cylinder end to end about ten times allowing the bubble to travel completely from one end to the other each time.

6.9 Immediately pour the suspension into the test cylinder to the 380 mm mark and insert the stopper.

6.10 Mix the contents of the test cylinder by inverting the cylinder end to end, allowing the bubble to travel completely from one end to the other. This alternating end to end mixing cycle shall be repeated 20 times in approximately 35 seconds.
6.11 At the conclusion of the mixing period, place the test cylinder on a bench free from vibration, remove the stopper and start the timer. Allow the test cylinder to stand undisturbed for a period of 20 minutes ± 10 seconds.

6.12 After the 20 minute period, estimate and record the height of the upper surface of the flocculate column (h) to the nearest 1 mm.

7 Calculations

Calculate the degradation factor (D) as follows:

\[
D = \frac{100(380-h)}{380+1.75h}
\]

where

- \(D\) = degradation factor
- \(h\) = height of flocculate column (mm)

8 Reporting

Report the degradation factor to the nearest whole number.

9 Precision

The following criteria should be used to judge the acceptability of results (95% probability).

9.1 Repeatability

Duplicate tests by the same operator are acceptable if their results do not differ by more than four units.

9.2 Reproducibility

Independent test results obtained by different operators working in different laboratories on identical samples are acceptable if the results do not differ by more than 16 units.

10 Notes on method

10.1 The balance used to weigh the reagents must have a readability which displays to one significant figure more than the required mass being weighed and a limit of performance commensurate with the readability.

10.2 Before handling the reagents, the operator must consult the relevant Safety Data Sheet (SDS).

10.3 Due to the very hygroscopic nature of calcium chloride hexahydrate, it will begin to dissolve in the water which it attracts, even in its original container once that has been opened. However, any undissolved crystals are able to be used by simply decanting any free solution from the calcium chloride hexahydrate container before use.

10.4 The stock solution may be prepared using anhydrous calcium chloride (11.1 ± 0.1 g) in place of calcium chloride hexahydrate. Due to the extremely hygroscopic nature of anhydrous calcium chloride, it must be kept in a desiccator or dried in an oven at 200ºC before use.

10.5 Record the date of preparation of the stock solution on the reagent bottle. Stock solution may be used for 5 days from the date of preparation after which fresh stock solution must be prepared.

Superseded
10.6 Insufficient washing may result in clay fines being retained as adherent coatings which are subsequently released during the test. On the other hand, aggressive and prolonged washing may prematurely remove hydrophilic clay minerals from the rock structure due to leaching and abrasion.

10.7 The material is considered to have reached a constant mass when the difference between successive weighings, after a further 1 hour drying at 105-110°C, is not more than 1 percent of the total of the previous moisture losses.

Table 1 – Specifications and working tolerances of apparatus

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Value</th>
<th>Working tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Shaker</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
<td>cycles/min</td>
<td>300</td>
<td>± 5</td>
</tr>
<tr>
<td>Throw (total)</td>
<td>mm</td>
<td>44</td>
<td>± 0.5</td>
</tr>
<tr>
<td>Pivot to base length</td>
<td>mm</td>
<td>520</td>
<td>± 5</td>
</tr>
<tr>
<td>Pivot to cam shaft length</td>
<td>mm</td>
<td>585</td>
<td>± 5</td>
</tr>
<tr>
<td><strong>Canister</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height</td>
<td>mm</td>
<td>150</td>
<td>approx.</td>
</tr>
<tr>
<td>Internal diameter</td>
<td>mm</td>
<td>190</td>
<td>± 5</td>
</tr>
<tr>
<td>Base thickness</td>
<td>mm</td>
<td>5</td>
<td>max.</td>
</tr>
<tr>
<td><strong>Test cylinder</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tube height</td>
<td>mm</td>
<td>430</td>
<td>approx.</td>
</tr>
<tr>
<td>Tube external diameter</td>
<td>mm</td>
<td>40</td>
<td>approx.</td>
</tr>
<tr>
<td>Tube internal diameter</td>
<td>mm</td>
<td>32</td>
<td>± 0.5</td>
</tr>
</tbody>
</table>

Table 2 – Mass of fractions required for test portions

<table>
<thead>
<tr>
<th>Particle size (mm)</th>
<th>Mass of fraction (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>13.2 to 9.50</td>
<td>250 ± 2.5</td>
</tr>
<tr>
<td>9.50 to 6.70</td>
<td>250 ± 2.5</td>
</tr>
<tr>
<td>6.70 to 4.75</td>
<td>250 ± 2.5</td>
</tr>
<tr>
<td>4.75 to 2.36</td>
<td>250 ± 2.5</td>
</tr>
</tbody>
</table>
Figure 1 – Motorised shaker
Test Method Q211: Binder absorption by aggregate

1 Source

This method was developed in-house using techniques evolved through internal departmental research investigations. It applies the principles of Test Method Q214B: Particle density and water absorption of aggregate - coarse fraction.

2 Scope

This method describes the procedure for determining the quantity of binder absorbed by an aggregate. Two determinations of aggregate volume are made, one being the volume related to the aggregate particle density on a dry basis, and the other being the volume of the binder free aggregate following immersion of the aggregate in hot binder. Binder absorption is then measured by volume difference and expressed as a percentage by mass. The method is applicable to aggregates used in asphalt mix.

3 Apparatus

The following apparatus is required:

3.1 Test oven, an oven of suitable capacity to hold two sample containers and capable of maintaining a temperature of 150 ± 5°C for bitumen binders and 180 ± 5°C for polymer modified binders.

3.2 Drying oven, of suitable capacity, having a temperature of 105-110°C and complying with AS 1141.2.

3.3 Balance, a top pan balance of suitable capacity, with a resolution of at least 0.1 g and with a limit of performance within the range of ± 0.5 g, and capable of below balance weighing.

3.4 Balance bench, equipped with a hole for below balance weighing.

3.5 Basket, a wire basket of suitable mesh and capacity to contain the aggregate sample.

3.6 Attachment, a non-absorbent device to suspend the wire basket under the balance and inside the water container.

3.7 Water container, a container fitted with an overflow and filled with clean water to the overflow. The container shall be of suitable dimensions to allow the basket and sample container to be completely immersed without contacting any part of the container.

3.8 Sample containers, two containers of at least 4 L capacity fitted with wire handles.

3.9 Localised heating device, such as a heat and strip gun.

3.10 Thermometer, a partial or total immersion thermometer or other suitable temperature measuring device with a temperature range of at least 0-40°C and graduated to 1°C or less with an uncertainty of no more than 0.5°C.

3.11 Stirrers, two suitable metal stirring rods or spatulas.

3.12 Sieve, 4.75 mm sieve complying with AS 1152.

4 Materials

The following materials are required:

4.1 Cloth, suitable absorbent lintless cloth.
5 Sample preparation

5.1 Prepare the bulk sample as detailed in Section 5 of Test Method Q101 to produce a representative sample of appropriate size.

5.2 Further prepare the sample to produce four representative subsamples of about 1500 g retained on the 4.75 mm sieve as detailed in Test Method Q101, Subsection 6.3 for coarse fraction subsamples.

6 Bulk particle density

Perform the following procedure on two aggregate subsamples.

6.1 Immerse the aggregate subsample in water for at least 24 hours.

6.2 Remove the aggregate from soaking and place the aggregate one particle deep on a dry cloth.

6.3 Roll and wipe the particles until all visible films of water have been removed but the surfaces of the aggregate still appear damp (Note 10.1).

6.4 Determine the mass of the saturated surface-dry test portion (m₂).

6.5 Place the container directly below the hole in the balance bench and fill it until water escapes from the overflow.

6.6 Attach the basket to the balance so that it is completely immersed in water and determine the mass of the immersed basket (m₃).

6.7 Transfer the test portion to the basket and agitate the aggregate particles to remove any entrapped air.

6.8 Determine the mass of the immersed aggregate and basket (m₄).

6.9 Measure the temperature of the water in the container to the nearest 1°C.

6.10 Remove the aggregate from the basket and dry to a constant mass in the drying oven (Note 10.2).

6.11 Determine the dry mass of the aggregate (m₅).

7 Binder absorption

Perform the following procedure on two aggregate subsamples.

7.1 Place the aggregate subsample in the drying oven and dry to a constant mass (Note 10.2).

7.2 Heat the binder in the test oven until it is sufficiently fluid to pour, and pour approximately 1500 g binder into a sample container.

7.3 Place a stirring rod in the sample container and stir the binder to remove entrapped air. Remove any bubbles remaining on the surface of the binder using the localised heating device.

7.4 Allow the sample container to cool to room temperature in a dust free environment. Determine the mass of the sample container, binder and stirring rod (m₆).

7.5 Suspend the sample container from the balance and completely immerse it in the water container. Determine the mass of the immersed sample container, binder and stirring rod (m₇) (Note 10.3).
7.6 Measure the temperature of the water in the container to the nearest 1°C.

7.7 Dry the sample container using the lintless cloth and then place it in the test oven for four hours together with the aggregate subsample prepared in Step 7.1.

7.8 Remove the sample container and aggregate subsample from the oven. Carefully add the aggregate to the binder in the sample container with constant stirring, avoiding any loss of binder or aggregate.

7.9 Stir the mix for about 30 seconds using a circular stirring motion. Apply a localised heating device to the surface of the binder to remove any air bubbles.

7.10 Stir the mix progressively around the circumference of the sample container using a digging stirring motion. This involves moving the end of the stirring rod from a point of contact between the top surface of the binder and container wall, down the inside wall of the container, and along the base of the container towards its centre. The stirring rod is then pulled back through the binder, retracing the same path but without being fully removed from the sample (Note 10.4).

7.11 Apply a localised heating device to the surface of the binder to remove any air bubbles.

7.12 Repeat Steps 7.10 and 7.11 until no more than three air bubbles appear within 10 seconds of the completion of the stirring cycle.

7.13 Allow the sample container to cool to room temperature in a dust free environment. Determine the mass of the sample container, binder, stirring rod and aggregate (\(m_7\)).

7.14 Suspend the sample container from the balance and completely immerse it in the water container. Determine the mass of the immersed sample container, binder, stirring rod and aggregate (\(m_8\)) (Note 10.3).

7.15 Measure the temperature of the water in the container to the nearest 1°C.

8 Calculations

8.1 Particle density

8.1.1 Calculate the particle density on a dry basis for each of the two subsamples as follows:

\[
\rho_{Di} = \frac{m_1 \rho_w}{m_2 - (m_4 - m_3)}
\]

where

- \(\rho_{Di}\) = subsample particle density on a dry basis (t/m³)
- \(m_1\) = mass of dry aggregate (g)
- \(\rho_w\) = density of the water at test temperature (t/m³) (Table 1)
- \(m_2\) = mass of saturated surface-dry aggregate (g)
- \(m_4\) = mass of immersed basket and aggregate (g)
- \(m_3\) = mass of immersed basket (g)

8.2 Provided that the results from the two subsamples do not differ by more than 0.030 t/m³, calculate the average result as the sample particle density (\(\rho_D\)) to the nearest 0.001 t/m³.
8.3 Binder absorption

8.3.1 Calculate the binder absorption for each of the two subsamples as follows:

\[
b = 100 \rho_B \left( \frac{1}{\rho_D} + \frac{(m_5 - m_6)}{(m_7 - m_5) \rho_1} - \frac{(m_7 - m_8)}{(m_7 - m_5) \rho_2} \right)
\]

where

- \( b \) = binder absorption (%)
- \( \rho_B \) = density of binder (t/m³) (Note)
- \( \rho_D \) = sample particle density on a dry basis (t/m³)
- \( m_5 \) = mass of container, binder and stirring rod (g)
- \( m_6 \) = mass of immersed container, binder and stirring rod (g)
- \( m_7 \) = mass of container, binder, stirring rod and aggregate (g)
- \( \rho_1 \) = density of the water at test temperature for \( m_6 \) (t/m³) (Table 1)
- \( m_8 \) = mass of immersed container, binder, stirring rod and aggregate (g)
- \( \rho_2 \) = density of the water at test temperature for \( m_8 \) (t/m³) (Table 1)

8.4 Provided that the results from the two subsamples do not differ by more than 0.15 %, calculate the average result as the sample binder absorption to the nearest 0.01 percentage units.

9 Reporting

Report the binder absorption of the sample to the nearest 0.05 %.

10 Notes on method

10.1 A gentle current of air may be used to accelerate drying but care must be taken to avoid over-drying.

10.2 The aggregate subsample is considered to have reached a constant mass when the difference between successive weighings, after a further 1 hour drying at 105-110°C, is not more than 1 percent of the total of the previous moisture losses.

10.3 Prior to weighing, check the water container to ensure that it is filled to the overflow.

10.4 As the binder cools, the viscosity of the mix will increase. To avoid entrapment of air, stirring of the mix will need to be slowed.

10.5 If unknown, the binder density may be determined using Test Method Q331.

**Table 1 – Water density**

<table>
<thead>
<tr>
<th>Test temperature (ºC)</th>
<th>Water density (t/m³)</th>
<th>Test temperature (ºC)</th>
<th>Water density (t/m³)</th>
</tr>
</thead>
<tbody>
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<td>1</td>
<td>1.000</td>
<td>21</td>
<td>0.998</td>
</tr>
<tr>
<td>2</td>
<td>1.000</td>
<td>22</td>
<td>0.998</td>
</tr>
<tr>
<td>3</td>
<td>1.000</td>
<td>23</td>
<td>0.998</td>
</tr>
<tr>
<td>4</td>
<td>1.000</td>
<td>24</td>
<td>0.997</td>
</tr>
<tr>
<td>Test temperature (°C)</td>
<td>Water density (t/m³)</td>
<td>Test temperature (°C)</td>
<td>Water density (t/m³)</td>
</tr>
<tr>
<td>-----------------------</td>
<td>----------------------</td>
<td>-----------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>5</td>
<td>1.000</td>
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<tr>
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<td>26</td>
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<td>0.993</td>
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<td>0.999</td>
<td>38</td>
<td>0.993</td>
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<td>19</td>
<td>0.998</td>
<td>39</td>
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</tr>
<tr>
<td>20</td>
<td>0.998</td>
<td>40</td>
<td>0.992</td>
</tr>
</tbody>
</table>
Test Method Q212A: Bitumen stripping value - standard plate

This test shall be performed in accordance with AS 1141.50: Resistance to stripping of cover aggregates from binders.
Test Method Q212B: Binder stripping value - modified plate

1 Source
This method was developed in-house and applies the principles of AS 1141.50 -1998: Resistance to stripping of cover aggregates from binders.

2 Scope
This method determines the resistance to stripping of a bituminous binder from aggregate using a modified plate stripping test. It provides a more rapid estimate of binder stripping potential than that achieved using AS 1141.50. Exclusive use of either Test Method Q212B or AS 1141.50 should be made for any series of tests.

The test procedure may be varied to allow for testing with binder containing anti-stripping agents or precoated aggregates.

3 Apparatus
The following apparatus is required:

3.1 Test plates, metal plates of 150 mm diameter with raised edges (for example, press-on lids from 4 litre containers).

3.2 Balance of suitable capacity, having a resolution of at least 0.01 g and a limit of performance within the range of ± 0.05 g.

3.3 Drying oven of suitable capacity, having a temperature of 105-110°C and complying with AS 1289.0.

3.4 Oven of suitable capacity, capable of heating a sample of binder to a temperature of 135-140°C.

3.5 Oven of suitable capacity, thermostatically controlled at a temperature of 60°C.

3.6 Water bath, thermostatically controlled at a temperature of 50°C.

3.7 Fan, an electric fan to assist in air drying aggregate samples.

3.8 Pliers, suitable for extracting aggregate pieces from a bituminous binder.

4 Materials
The following materials are required (Note 9.1):

4.1 Bituminous binder (Note 9.2).

4.2 Cloth, suitable for cleaning test plates.

4.3 Mineral turpentine.

4.4 Acetone.

5 Preparation of test materials

5.1 Aggregates
Aggregate may be tested as received and or air dried in either the precoated or uncoated condition.
5.1.1 For aggregate to be tested in the as received condition, obtain a representative subsample which includes approximately 1 kg of the dominant particle size and seal it in an airtight container.

5.1.2 For aggregate to be tested in the air dried condition obtain a representative subsample which includes approximately 1 kg of the dominant particle size. Spread the aggregate subsample in a single layer in an oven tray and air dry overnight (alternatively the tray can be placed in front of a fan to expedite the drying process).

5.2 Binder
Heat about 200 g of the binder in the 135-140°C oven until it reaches pouring consistency.

5.3 Test plates
Remove any oil film or residue from the test plates, by cleaning each plate thoroughly with a cloth saturated in mineral turpentine, then rinse with acetone and allow to dry in a dust free environment.

6 Procedure
Perform the following procedure:

6.1 Pour 23.5-27.5 g portions of the binder onto each of two test plates, ensuring an even distribution of binder (Note 9.3).

6.2 Allow the prepared test plates to cool to room temperature in a dust free area.

6.3 Select 50 representative pieces of the dominant size fraction of the aggregate.

6.4 Firmly press 25 aggregate pieces into the binder layer in each of the two test plates.

6.5 Place the test plates in the 60°C oven for 1 hour, and then transfer to the water bath for 4 hours.

6.6 Remove the test plates from the water bath and immerse in water at room temperature for 30 minutes.

6.7 Remove one of the test plates from the water.

6.8 Extract an aggregate piece from the binder by hand or using the pliers as follows (Note 9.5):

6.8.1 Extract the aggregate piece evenly with a direct upward pull and without any twisting or shoving motion.

6.8.2 Where only collar or edge adhesion has taken place, ensure that the binder retained at the edge of the aggregate piece does not contact or overlay its underside before assessment of stripping is made.

6.9 Examine the underside of the aggregate piece and note the amount of binder adhering to it. Record it in one of the following categories:
   a) Completely stripped: <10 percent binder adhering.
   b) Partly stripped: 10-90 percent binder adhering.
   c) No stripping: >90 percent binder adhering.

6.10 Repeat Steps 6.8 and 6.9 for the remaining aggregate pieces.

6.11 Repeat Steps 6.7 to 6.9 for the second test plate.
7 Calculations

7.1 For each test plate, count the number of aggregate pieces in each category.

7.2 Calculate the stripping value for each test plate as follows:

\[ S_p = 4N_c + 2N_p \]

where

\[ S_p \] = Plate stripping value (%)

\[ N_c \] = Number of aggregate pieces completely stripped

\[ N_p \] = Number of aggregate pieces partly stripped

7.3 Provided that the difference between the two plate stripping values is no greater than 10, average the two values and record this average as the binder stripping value to the nearest 1 percent (Note 9.4).

8 Reporting

Report the following, as appropriate:

8.1 Aggregate description including source and size fraction tested.

8.2 Binder description including source, type and class.

8.3 Test condition (as received or air dried).

8.4 Binder stripping value to the nearest 1 %.

9 Notes on method

9.1 Before handling bituminous binder, mineral turpentine or acetone, the operator must consult the relevant Safety Data Sheet (SDS).

9.2 Where no requirement is stipulated for the class of binder to be used in the test, Class 170 bitumen complying with AS 2008 or MRTS 17 shall be used.

9.3 If necessary, the test plates may be placed in the oven for a short time to attain an even binder film distribution.

9.4 If the difference is greater than 10, the test should be repeated. However, if the aggregate composition is highly variable, the individual plate stripping values may be reported.

9.5 Where adhesion is such that the aggregate piece cannot be extracted by hand or using the pliers, careful upward levering of the aggregate piece using a screwdriver or similar may be used.

Superseded
Test Method Q212C: Binder stripping value - immersion tray

1 Source
This method was developed in-house and applies the principles of AS 1141.50-1998: Resistance to stripping of cover aggregate from binders.

2 Scope
This method describes the procedure for determining the resistance to stripping of binder from aggregate using the immersion tray test. It is applicable to the assessment of the adhesion promoting properties of bitumen anti-stripping agents.

3 Apparatus
The following apparatus is required:

3.1 Test plates, metal plates of 150 mm diameter with raised edges (for example, press-on lids from 4 litre containers).
3.2 Balance, of suitable capacity, having a resolution of at least 0.01 g and a limit of performance within the range of ± 0.05 g.
3.3 Drying oven of suitable capacity, having a temperature of 105-110°C and complying with AS 1289.0.
3.4 Oven of suitable capacity, capable of heating a sample of binder to a temperature of 135-140°C.
3.5 Water bath, thermostatically controlled at a temperature of 40 ± 1°C.
3.6 Sample container, a metal container of approximately 70 mm diameter and 250 mL volume.
3.7 Hotplate.
3.8 Pliers, suitable for extracting aggregate pieces from a bituminous binder.

4 Materials
The following materials are required (Note 9.1):

4.1 Aggregate, selected aggregate of 20 mm nominal size.
4.2 Bituminous binder, Class 170 bitumen complying with AS 2008 or MRTS 17, or other binder as specified.
4.3 Cutter, bitumen cutter oil complying with MRTS 19.
4.4 Cloth, suitable for cleaning test plates.
4.5 Mineral turpentine.
4.6 Acetone.

5 Preparation of test materials

5.1 Aggregates
Wash and dry 30 representative pieces of the dominant size fraction of the aggregate.
5.2 Binder
Heat about 200 g of the binder in the 135-140°C oven until it reaches pouring consistency.

5.3 Test plates
Remove any oil or residue from the test plates by cleaning each plate thoroughly with a cloth saturated in mineral turpentine, then rinse with acetone and allow to dry in a dust free environment.

6 Procedure
Perform the following procedure:

6.1 Weigh into the sample container, the mass of anti-stripping agent required to produce the targeted anti-stripping agent concentration in 100 to 140 g binder, to the nearest 0.01 g.

6.2 Weigh into the sample container the mass of binder needed to produce the required anti-stripping agent concentration, to the nearest 1 g.

6.3 Transfer the sample container and contents to the hotplate and heat gently. Stir vigorously with a glass stirring rod for about 5 minutes.

6.4 Calculate the mass of cutter required to produce a cutter content of 7.5 percent by volume, to the nearest 0.1 g as follows:

\[ M_C = \frac{7.5D_D M_B}{100D_B} \]

where

- \( M_C \) = mass of cutter (g)
- \( D_B \) = density of binder (t/m³)
- \( D_C \) = density of cutter (t/m³)
- \( M_B \) = mass of binder (g)

6.5 Add to the sample container the mass of cutter calculated in Step 6.4 and stir the contents vigorously to achieve complete solution (Note 9.2).

6.6 Check weigh the mass of the sample container and contents and add further cutter to compensate for any cutter loss during the heating and mixing process.

6.7 Combine repeated additions of cutter with continuous stirring until the required mass of cutter in the sample is obtained to the nearest 0.1 g (Note 9.3).

6.8 Pour 23.5 – 27.5 g portions of the prepared sample onto each of three test plates and spread the sample on each test plate as quickly as possible to form a continuous and even film distribution over the plate (Note 9.4).

6.9 Allow the three test plates to cool to room temperature in a dust free area and then immerse to a depth of at least 25 mm in the water bath for at least 20 minutes.

6.10 Select one of the test plates and firmly press 10 pieces of aggregate into the binder in the test plate while the plate remains immersed in the water bath. After a further 10 to 12 minutes of immersion, remove the test plate from the water bath.
6.11 Extract an aggregate piece from the binder by hand or using the pliers as follows (Note 9.5):

6.11.1 Extract the aggregate piece evenly, with a direct upward pull without any twisting or shoving motion.

6.11.2 Where only collar or edge adhesion has taken place, ensure that the binder retained at the edge of the aggregate piece does not contact or overlay its underside before assessment of stripping is made.

6.12 Examine the underside of the aggregate piece and note the amount of binder adhering to it.

6.13 Rate the quantity of binder adhering on a scale of 0 to 10, with 10 being full cover.

6.14 Repeat Steps 6.11 to 6.13 for each of the remaining aggregate pieces.

6.15 Sum the ratings for all 10 aggregate pieces and record the total as the binder adhesion in percent.

6.16 Repeat Steps 6.10 to 6.15 for the remaining two test plates (Notes 9.6 and 9.7).

7 Calculations

7.1 Calculate the stripping result for each test plate to the nearest 1 % by subtracting the binder adhesion result from 100.

7.2 If the difference between the stripping results of the three test plates is less than 20 %, calculate the average of the three results to the nearest 1 % and record it as the stripping value.

7.3 If the difference between the stripping results of the three test plates exceeds 20 % but two of the results agree within 10 %, calculate the average of these two results to the nearest 1 % and record it as the stripping value.

7.4 If the difference between the stripping results of the three test plates exceeds 20 % and no two results agree within 10 %, repeat the test.

8 Reporting

Report the stripping value to the nearest 1 %.

9 Notes on method

9.1 Before handling bituminous binder, mineral turpentine, acetone or cutter, the operator must consult the relevant Safety Data Sheet (SDS).

9.2 If the contents have cooled so that thorough mixing is difficult, gentle warming of the contents is permitted.

9.3 It is important that the correct quantity of cutter is added to the binder. Varying quantities of cutter will lead to varying binder viscosities which have considerable influence on the stripping value obtained.

9.4 If the sample on the test plate has cooled so that spreading of the sample to form a continuous film over the test plate is difficult, minimal warming of the test plate in the oven is permitted. However, under no circumstances should a hotplate be used for this purpose.

9.5 Where adhesion is such that the aggregate piece cannot be extracted by hand or using the pliers, careful upward levering of the aggregate piece using a screwdriver or similar may be used.
9.6 Alternatively, Steps 6.10 to 6.15 for the three test plates may be performed in parallel.

9.7 Where the stripping value for more than one aggregate type is required, the test plate may be returned to the water bath for 20 minutes and then reused for Steps 6.10 to 6.15. However, those areas on the binder surface which were previously occupied by aggregate pieces must be avoided. In this way, the test plate may be used for up to three aggregate types.
Test Method Q214: Particle density and water absorption of aggregate

1 Source

This method applies the principles of AS 1289.3.5.1: Determination of the soil particle density of a soil – Standard method to the determination of the density and water absorption of the total aggregate sample. There are also variations to the apparatus, procedures used and in the reporting intervals.

2 Scope

This method describes the procedure for the determination of the particle density and water absorption of an aggregate. The density and water absorption of the coarse fraction and the fine fraction are determined using separate procedures and a weighted average of these values is then used to determine the particle densities and water absorption of an aggregate. The method allows the proportions of the coarse and fine fractions to be determined by either weighing or particle size distribution.

3 Apparatus

The following apparatus is required:

3.1 Sieve, 4.75 mm complying with AS 1152.
3.2 Balance of suitable capacity, having a resolution of at least 1 g and with a limit of performance within the range of ± 5 g.
3.3 Containers of suitable size for drying the coarse and fine fraction subsamples prepared in Steps 4.1 and 4.2.
3.4 Drying oven of suitable capacity, having a temperature of 105-110°C and complying with AS 1141.2.

4 Procedure

The procedure shall be as follows:

4.1 Prepare the bulk sample as detailed in Section 5 of Test Method Q101 to produce two representative samples of appropriate size.

4.2 Prepare the first sample as detailed in Test Method Q101 Subsections 6.3 and 6.4 using a 4.75 mm sieve to produce an unwashed coarse fraction subsample and an unwashed fine fraction subsample. Ensure sufficient material is prepared to yield at least 10 kg retained 4.75 mm and 2000 g passing 4.75 mm.

4.3 Prepare the second sample to produce a particle size distribution subsample with a mass that complies with the minimum mass requirements of Test Method Q103B.

4.4 Thoroughly wash the coarse fraction, to remove any dust and other coatings.

4.5 Place the washed coarse fraction in a container and dry in the oven to a constant mass (Note 7.1).

4.6 Place the fine fraction in a container and dry in the oven to a constant mass (Note 7.1).

4.7 Using the subsample prepared in Step 4.3, determine the percent passing the 4.75 mm sieve (P_{4.75}) as detailed in Test Method Q103B.

4.7.1 Determine the apparent particle density of the coarse fraction and the fine fraction as detailed in Test Methods Q214A and Q214B respectively.
5 Calculations

The calculations shall be as follows as appropriate:

5.1 Proportions determined by weighing fractions

5.1.1 Determine the percent coarse fraction to the nearest 1% as follows:

\[
\frac{100m_c}{m_c + m_f} = \frac{100}{P_c}
\]

where

\[P_c\] = percent coarse fraction

\[m_c\] = mass of coarse fraction (g)

\[m_f\] = mass of fine fraction (g)

5.1.2 Determine the percent fine fraction to the nearest 1% as follows:

\[
\frac{100m_f}{m_c + m_f} = \frac{100}{P_f}
\]

where

\[P_f\] = percent fine fraction

\[m_c\] = mass of coarse fraction (g)

\[m_f\] = mass of fine fraction (g)

5.2 Proportions determined by particle size distribution

5.2.1 Determine the percent coarse fraction to the nearest 1% as follows:

\[P_c = 100 - P_{4.75}\]

where

\[P_c\] = percent coarse fraction

\[P_{4.75}\] = percentage passing the 4.75 mm sieve

5.2.2 Determine the percent fine fraction to the nearest 1% as follows:

\[P_f = P_{4.75}\]

where

\[P_f\] = percent fine fraction

\[P_{4.75}\] = percent passing the 4.75 mm sieve

5.3 Determine the particle density and water absorption of the aggregate as follows:

5.3.1 Determine the apparent particle density of aggregate as follows:

\[
\rho_A = \frac{100}{\frac{P_c + P_f}{\rho_c + \rho_f}}
\]

where

\[\rho_A\] = apparent particle density of aggregate (t/m³)
\[\rho_c = \text{apparent particle density (coarse fraction) (t/m}^3)\]
\[\rho_f = \text{apparent particle density (fine fraction) (t/m}^3)\]
\[p_c = \text{percent coarse fraction}\]
\[p_f = \text{percent fine fraction}\]

5.3.2 Determine the particle density on a dry basis of aggregate as follows:

\[\rho_D = \frac{100}{\frac{p_c + p_f}{\rho_c + \rho_f}}\]

where
\[\rho_D = \text{particle density on a dry basis of aggregate (t/m}^3)\]
\[\rho_c = \text{particle density on a dry basis (coarse fraction) (t/m}^3)\]
\[\rho_f = \text{particle density on a dry basis (fine fraction) (t/m}^3)\]
\[p_c = \text{percent coarse fraction}\]
\[p_f = \text{percent fine fraction}\]

5.3.3 Determine the particle density on a saturated surface-dry basis of aggregate as follows:

\[\rho_S = \frac{100}{\frac{p_c + p_f}{\rho_c + \rho_f}}\]

where
\[\rho_S = \text{particle density on a saturated surface-dry basis of aggregate (t/m}^3)\]
\[\rho_c = \text{particle density on a saturated surface-dry basis (coarse fraction) (t/m}^3)\]
\[\rho_f = \text{particle density on a saturated surface-dry basis (fine fraction) (t/m}^3)\]
\[p_c = \text{percent coarse fraction}\]
\[p_f = \text{percent fine fraction}\]

5.3.4 Determine the water absorption of aggregate as follows:

\[WA = \frac{p_c \cdot WA_c + p_f \cdot WA_f}{p_c + p_f}\]

where
\[WA = \text{water absorption of aggregate (t/m}^3)\]
\[WA_c = \text{water absorption (coarse fraction) (t/m}^3)\]
\[WA_f = \text{water absorption (fine fraction) (t/m}^3)\]
\[p_c = \text{percent coarse fraction}\]
\[p_f = \text{percent fine fraction}\]
6 Reporting

Report the following as appropriate:

6.1 Apparent particle density to the nearest 0.001 t/m³.
6.2 Particle density on a dry basis to the nearest 0.001 t/m³.
6.3 Particle density on a saturated surface-dry basis to the nearest 0.001 t/m³.
6.4 Water absorption to the nearest 0.01%.

7 Notes on method

7.1 A fraction is considered to have reached a constant mass when the difference between successive weighings, after a further 1 hour drying at 105-110°C, is not more than 1 percent of the total of the previous moisture losses.
Test Method Q214A: Particle density and water absorption of aggregate - fine fraction

1 Source

This method applies the principles of AS 1141.5: Particle density and water absorption of fine aggregates. It differs from this Australian Standard in allowing the calculation of apparent particle density, requiring duplicate tests and in the reporting interval. Precision estimates are based on values reported in ASTM C128: Specific Gravity and Absorption of Fine Aggregate.

2 Scope

This method describes the procedure for the determination of the apparent particle density, particle density on a dry basis, particle density on a saturated surface-dry basis and water absorption of the fine fraction of an aggregate. The passing 4.75 mm material is tested in this procedure.

3 Apparatus

Where appropriate, the working tolerances of particular apparatus are contained in Table 1.

The following apparatus is required:

3.1 Sieve, 4.75 mm complying with AS 1152.
3.2 Balance of suitable capacity, with a resolution of 0.01 g and with a limit of performance within the range of ± 0.05 g.
3.3 Oven of suitable capacity having a temperature of 105-110ºC and complying with AS 1141.2.
3.4 Tray with a smooth flat surface.
3.5 Fan capable of producing a current of warm air.
3.6 Conical mould made of any suitable metal, having an internal diameter of 38 mm at the top and 90 mm at the bottom and a height of 73 mm.
3.7 Tamping rod with a mass of approximately 350 g having a flat circular tamping face of approximately 25 mm diameter.
3.8 Volumetric flask of 500 mL capacity.
3.9 Constant temperature environment such as a water bath or environmental chamber maintained at a constant temperature within the range of 20 - 30ºC to within ± 1.0ºC.
3.10 Wash bottle.
3.11 Thermometer, a partial or total immersion thermometer or other suitable temperature measuring device with a temperature range of 0-50ºC and graduated to 1ºC or less with an uncertainty of no more than 0.5ºC.

4 Materials

The following materials are required:

4.1 Distilled water.
4.2 Filter paper or other absorbent material.
5 Procedure

The procedure shall be as follows:

5.1 Prepare a representative subsample of at least 2000 g passing the 4.75 mm sieve as detailed in Test Method Q101, Subsection 6.4 for fine fraction subsamples.

5.2 Place the fine fraction subsample in the oven and dry to a constant mass (Note 9.1).

5.3 Obtain two representative test portions of approximately 1 kg from the fine fraction subsample.

5.4 Determine the mass of a volumetric flask \( (m_1) \).

5.5 Immerse a test portion in water and allow it to soak for at least 24 hours.

5.6 At the end of the soaking period carefully drain off the excess water and spread the test portion on the tray.

5.7 Dry the test portion using a gentle current of warm air, stirring frequently to achieve uniform drying. Continue drying until the aggregate is in a free-flowing condition.

5.8 Assess the aggregate for the saturated surface-dry condition by loosely filling the mould with aggregate and lightly tamping the top surface with 25 blows of the tamping rod.

5.9 Lift the mould vertically. If the cone of fine aggregate retains its shape, there is free moisture present and the saturated surface-dry condition has not been reached (Note 9.2).

5.10 Continue drying the test portion and test the aggregate at appropriate intervals as detailed in Steps 5.8 and 5.9, until the aggregate slumps on removal of the mould. Slumping of the aggregate indicates that the aggregate has reached a saturated surface-dry condition.

5.11 Immediately obtain a subsample of approximately 500 g of the surface-dry aggregate and place it in the volumetric flask.

5.12 Determine the mass of the flask and saturated surface-dry test portion \( (m_2) \).

5.13 Fill the flask to just below the 500 mL mark with distilled water and roll and shake the flask to eliminate all air bubbles.

5.14 Place the flask in the constant temperature environment for a minimum of one hour and allow it to reach an equilibrium temperature. During this time, add distilled water from the wash bottle to bring the water to the 500 mL mark (Notes 9.3 and 9.4).

5.15 When the flask and contents have reached an equilibrium temperature, measure and record the temperature of the constant temperature environment to the nearest 1ºC.

5.16 Add distilled from the wash bottle, to bring the water level to the 500 mL mark.

5.17 Dry the outside of the flask and determine the mass of the flask, test portion and water \( (m_3) \).

5.18 Remove all the aggregate from the flask and dry the aggregate in the oven to a constant mass (Note 9.1).

5.19 Determine the mass of the dry aggregate \( (m_4) \).

5.20 Clean the flask and fill it to just below the 500 mL mark with distilled water (Note 9.5).

5.21 Place the flask in the constant temperature environment for a minimum of one hour and allow it to reach equilibrium temperature. During this time, add distilled water from the wash bottle to bring the water level to the 500 mL mark.

5.22 Dry the outside of the flask then determine the mass of the flask and water \( (m_5) \).
5.23 Repeat Steps 5.4 to 5.22 for the second test portion.

6 Calculations

6.1 Calculate apparent particle density, particle density on a dry basis and particle density on a saturated surface-dry basis, as required for each test portion as follows:

6.1.1 Apparent particle density:

\[
\rho_A = \frac{m_4}{(m_2 - m_1) - (m_1 - m_4)} \rho_w
\]

where

- \( \rho_A \) = apparent particle density (t/m³)
- \( \rho_w \) = density of water at the temperature of the constant temperature environment (t/m³) (see Table 2)
- \( m_1 \) = mass of flask (g)
- \( m_3 \) = mass of flask, test portion and water (g)
- \( m_4 \) = mass of dry test portion (g)
- \( m_5 \) = mass of flask and water (g)

6.1.2 Particle density on a dry basis:

\[
\rho_D = \frac{m_2}{(m_2 - m_1) - (m_1 - m_2)} \rho_w
\]

where

- \( \rho_D \) = particle density on a dry basis (t/m³)
- \( \rho_w \) = density of water at the temperature of the constant temperature environment (t/m³) (see Table 2)
- \( m_1 \) = mass of flask (g)
- \( m_2 \) = mass of flask and saturated surface-dry test portion (g)
- \( m_3 \) = mass of flask, test portion and water (g)
- \( m_4 \) = mass of dry test portion (g)
- \( m_5 \) = mass of flask and water (g)

6.1.3 Particle density on a saturated surface-dry basis:

\[
\rho_S = \frac{m_2 - m_1}{(m_2 - m_1) - (m_1 - m_2)} \rho_w
\]

where

- \( \rho_S \) = particle density on a saturated surface-dry basis (t/m³)
- \( \rho_w \) = density of water at the temperature of the constant temperature environment (t/m³) (see Table 2)
- \( m_1 \) = mass of flask (g)
- \( m_2 \) = mass of flask and saturated surface-dry test portion (g)
\[ m_3 = \text{mass of flask, test portion and water (g)} \]
\[ m_5 = \text{mass of flask and water (g)} \]

6.2 Compare corresponding density results from the two test portions and provided the difference does not exceed the relevant allowable difference in Table 3, average the results. Otherwise repeat the test.

6.3 Calculate the water absorption of each test portion as follows:

\[
WA = \frac{(m_2 - m_1) - m_4}{m_4} \times 100
\]

where

- \( WA \) = water absorption (%)
- \( m_1 \) = mass of flask (g)
- \( m_2 \) = mass of flask and saturated surface-dry test portion (g)
- \( m_4 \) = mass of dry test portion (g)

6.4 Compare the water absorption results from the two test portions and provided the difference does not exceed the relevant allowable difference in Table 3, average the results (Note 9.6). Otherwise repeat the test.

7 Reporting

Report the average of the following as appropriate.

7.1 Apparent particle density (fine fraction) to the nearest 0.001 t/m³.

7.2 Particle density on a dry basis (fine fraction) to the nearest 0.001 t/m³.

7.3 Particle density on a saturated surface-dry basis (fine fraction) to the nearest 0.001 t/m³.

7.4 Water absorption to the nearest 0.01%.

8 Precision

The precision of the test is shown in Table 4. These values, in 95% of cases, should not be exceeded by the difference between any two results, expressed as a percentage of the average value.

9 Notes on method

9.1 The fraction is considered to have reached a constant mass when the difference between successive weighings, after a further 1 hour drying at 105-110°C, is not more than 1 percent of the total of the previous moisture losses.

9.2 If the cone of aggregate slumps at the first test, the aggregate has been dried past the saturated surface-dry condition. In this case, thoroughly mix a few millilitres of water into the fine aggregate and permit the sample to stand in a sealed container for 30 minutes prior to retesting.

9.3 Store the wash bottle in the constant temperature environment in order to minimise equilibration time.
9.4 Remove any froth from the flask using filter paper or other absorbent material.

9.5 The mass of the bottle filled with water may be determined at regular intervals in the constant temperature environment or it may be determined immediately after the volume of aggregate has been determined. For either determination the temperature of the constant temperature environment must be the same as the temperature in Step 5.15.

9.6 For highly absorptive materials (absorption > 5%), a wider range of results may be accepted.

Table 1 – Dimensions and tolerances for equipment

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Dimension</th>
<th>Tolerance</th>
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</thead>
<tbody>
<tr>
<td>Conical mould</td>
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<tr>
<td>Internal diameter – top (mm)</td>
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<td>± 3.0</td>
</tr>
<tr>
<td>Internal diameter – bottom (mm)</td>
<td>90</td>
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</tr>
<tr>
<td>Internal height (mm)</td>
<td>73</td>
<td>± 3.0</td>
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Table 2 – Density of water

<table>
<thead>
<tr>
<th>Temperature (ºC)</th>
<th>Density (t/m³)</th>
<th>Temperature (ºC)</th>
<th>Density (t/m³)</th>
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<tbody>
<tr>
<td>20</td>
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Table 3 – Allowable difference between test portions

<table>
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<th>Property</th>
<th>Allowable difference</th>
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<tr>
<td>Apparent particle density (t/m³)</td>
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<tr>
<td>Particle density on a dry basis (t/m³)</td>
<td>0.032</td>
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<tr>
<td>Particle density on a saturated surface-dry basis (t/m³)</td>
<td>0.027</td>
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<td>Water absorption (%)</td>
<td>0.31</td>
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</table>

Table 4 – Acceptable range of two results expressed as a percentage of mean value

<table>
<thead>
<tr>
<th>Property</th>
<th>Repeatability</th>
<th>Reproducibility</th>
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</thead>
<tbody>
<tr>
<td>Apparent particle density (t/m³)</td>
<td>0.019</td>
<td>0.040</td>
</tr>
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<td>Particle density on a dry basis (t/m³)</td>
<td>0.023</td>
<td>0.047</td>
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<tr>
<td>Particle density on a saturated surface-dry basis (t/m³)</td>
<td>0.019</td>
<td>0.040</td>
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<tr>
<td>Water absorption (%)</td>
<td>0.22</td>
<td>0.47</td>
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</table>
Test Method Q214B: Particle density and water absorption of aggregate - coarse fraction

1 Source
This method applies the principles of AS 1141.6.1: Particle density and water absorption of coarse aggregates - Weighing-in-water method. It differs from this Australian Standard in allowing an additional weighing technique and in the reporting intervals. Precision estimates are based on values reported in ASTM C127: Specific Gravity and Absorption of Coarse Aggregate.

2 Scope
This method describes the procedure for the determination of the apparent particle density, particle density on a dry basis, particle density on a saturated surface-dry basis and water absorption of the coarse fraction of an aggregate. The retained 4.75 mm material is tested in this procedure with volume measurement being made using either below balance or above balance techniques.

3 Apparatus
The following apparatus is required:

3.1 Sieve, 4.75 mm complying with AS 1152.
3.2 Balance of suitable capacity, with a resolution of at least 0.1 g and with a limit of performance within the range of ± 0.5 g. For the below balance technique, a balance capable of below balance weighing is required (Subsection 4.6 only). For the above balance technique, a second balance is desirable.
3.3 Oven of suitable capacity having a temperature of 105-110ºC and complying with AS 1141.2.
3.4 Container of suitable capacity to contain the wire basket. An overflow is required (Subsection 4.6 only).
3.5 Balance bench, equipped with a hole for below balance weighing (Subsection 4.6 only).
3.6 Wire basket of suitable capacity to contain the test portion and a thin wire to suspend the basket.
3.7 Thermometer, a partial or total immersion thermometer or other suitable temperature measuring device with a temperature range of at least 0-50ºC and graduated to 1ºC or less with an uncertainty of no more than 0.5ºC.
3.8 Laboratory stand (Subsection 4.7 only).
3.9 Absorbent cloth and a fan (optional).

4 Procedure
The procedure shall be as follows:

4.1 Prepare a representative washed subsample of at least 10 kg retained on the 4.75 mm sieve as detailed in Test Method Q101, Subsection 6.3 for coarse fraction subsamples.
4.2 Place the coarse fraction subsample in the oven and dry to a constant mass (Note 8.1).
4.3 Obtain two representative test portions of approximately 5 kg from the coarse fraction subsample.
4.4 Determine the mass (m₁) of a test portion and immerse it in water for at least 24 hours.
4.5 Remove the aggregate from soaking and determine its saturated surface-dry mass as follows (Note 8.2):

4.5.1 Place the aggregate one particle deep on a dry cloth and roll and wipe the particles until all visible films of water have been removed but the surfaces of the aggregate still appear damp (Note 8.3).

4.5.2 Determine the mass of the saturated surface-dry test portion \( m_2 \).

4.6 Below balance technique

This method applies where the appropriate equipment is available to allow the test portion volume to be determined by suspending the portion below a balance in a container of water.

4.6.1 Place the container directly below the hole in the balance bench and fill it until water escapes from the overflow.

4.6.2 Attach the basket to the balance so that it is completely immersed in water, then tare the balance.

4.6.3 Transfer the test portion to the basket and agitate the aggregate particles to remove any entrapped air.

4.6.4 Determine the mass of the immersed test portion \( m_3 \).

4.6.5 Measure the temperature of the water in the container to the nearest 1ºC.

4.7 Above balance technique

This method applies where the appropriate equipment is available to allow the test portion volume to be determined by suspending the portion in a container of water placed on the balance pan.

4.7.1 Fill the container to a level which will allow all of the basket to be completely immersed and place the container on the balance.

4.7.2 Position the laboratory stand directly above the container. Suspend the basket from the stand such that it is completely immersed in water without touching any part of the container, then tare the balance.

4.7.3 Transfer the test portion to the basket and agitate the aggregate particles to remove any entrapped air.

4.7.4 Determine the mass of the immersed test portion \( m_3 \).

4.7.5 Measure the temperature of the water in the container to the nearest 1ºC.

4.7.6 Repeat Steps 4.4 to 4.6.5 or Steps 4.4 to 4.5.2 and 4.7.1 to 4.7.5 as appropriate for the second test portion.

5 Calculations

Calculate apparent particle density and particle densities as required for each test portion using the appropriate calculation as follows:
5.1 **Below balance weighing**

5.1.1 Apparent particle density:

\[
\rho_A = \frac{m_1}{m_1 - m_3} \rho_w
\]

where
- \( \rho_A \) = apparent particle density (t/m³)
- \( \rho_w \) = density of water at the test temperature (t/m³) (Table 1)
- \( m_1 \) = mass of dry test portion (g)
- \( m_3 \) = mass of fully immersed test portion (g)

5.1.2 Particle density on a dry basis:

\[
\rho_D = \frac{m_1}{m_2 - m_3} \rho_w
\]

where
- \( \rho_D \) = particle density on a dry basis (t/m³)
- \( \rho_w \) = density of water at the test temperature (t/m³) (Table 1)
- \( m_1 \) = mass of dry test portion (g)
- \( m_2 \) = mass of saturated surface-dry test portion (g)
- \( m_3 \) = mass of fully immersed test portion (g)

5.1.3 Particle density on a saturated surface-dry basis:

\[
\rho_S = \frac{m_2}{m_2 - m_3} \rho_w
\]

where
- \( \rho_S \) = particle density on a saturated surface-dry basis (t/m³)
- \( \rho_w \) = density of water at the test temperature (t/m³) (Table 1)
- \( m_2 \) = mass of saturated surface-dry test portion (g)
- \( m_3 \) = mass of fully immersed test portion (g)

5.2 **Above balance weighing**

5.2.1 Apparent particle density:

\[
\rho_A = \frac{m_1}{m_3 - (m_2 - m_1)} \rho_w
\]

where
- \( \rho_A \) = apparent particle density (t/m³)
- \( \rho_w \) = density of water at the test temperature (t/m³) (Table 1)
- \( m_1 \) = mass of dry test portion (g)
5.2.2 Particle density on a dry basis:

\[ \rho_D = \frac{m_1}{m_3} \rho_w \]

where
- \(\rho_D\) = particle density on a dry basis (t/m³)
- \(\rho_w\) = density of water at the test temperature (t/m³) (Table 1)
- \(m_1\) = mass of dry test portion (g)
- \(m_3\) = mass of fully immersed test portion (g)

5.2.3 Particle density on a saturated surface-dry basis:

\[ \rho_S = \frac{m_2}{m_3} \rho_w \]

where
- \(\rho_S\) = particle density on a saturated surface-dry basis (t/m³)
- \(\rho_w\) = density of water at the test temperature (t/m³) (Table 1)
- \(m_2\) = mass of saturated surface-dry test portion (g)
- \(m_3\) = mass of fully immersed test portion (g)

5.3 Compare corresponding density results from the two test portions and provided the difference does not exceed the relevant allowable difference in Table 2, average the results. Otherwise repeat the test.

5.4 Calculate the water absorption of each test portion as follows:

\[ WA = \left( \frac{m_2 - m_1}{m_1} \right) \times 100 \]

where
- \(WA\) = water absorption (%)
- \(m_2\) = mass of saturated surface-dry test portion (g)
- \(m_1\) = mass of dry test portion (g)

5.5 Compare the water absorption results from the two test portions and provided the difference does not exceed the relevant allowable difference in Table 2, average the results (Note 8.4). Otherwise repeat the test.

6 Reporting

Report the average of the following as appropriate.

6.1 Apparent particle density (coarse fraction) to the nearest 0.001 t/m³.
6.2 Particle density on a dry basis (coarse fraction) to the nearest 0.001 t/m³.
6.3 Particle density on a saturated surface-dry basis (coarse fraction) to the nearest 0.001 t/m³.
6.4 Water absorption to the nearest 0.01%.

7 Precision

The precision of the test is shown in Table 3. These values, in 95% of cases, should not be exceeded by the difference between any two results, expressed as a percentage of the average value.

8 Notes on method

8.1 The fraction is considered to have reached a constant mass when the difference between successive weighings, after a further 1 hour drying at 105-110°C, is not more than 1 percent of the total of the previous moisture losses.
8.2 Where only the apparent particle density is required and below balance weighing is being used, it is not necessary to surface dry the aggregate particles.
8.3 A gentle current of air may be used to accelerate drying but care must be taken to avoid over-drying.
8.4 For highly absorptive materials (absorption > 5%), a wider range of results may be accepted.

Table 1 - Density of water

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Density (t/m³)</th>
<th>Temperature (°C)</th>
<th>Density (t/m³)</th>
<th>Temperature (°C)</th>
<th>Density (t/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.9998</td>
<td>14</td>
<td>0.9992</td>
<td>28</td>
<td>0.9962</td>
</tr>
<tr>
<td>1</td>
<td>0.9999</td>
<td>15</td>
<td>0.9991</td>
<td>29</td>
<td>0.9959</td>
</tr>
<tr>
<td>2</td>
<td>0.9999</td>
<td>16</td>
<td>0.9989</td>
<td>30</td>
<td>0.9957</td>
</tr>
<tr>
<td>3</td>
<td>1.0000</td>
<td>17</td>
<td>0.9988</td>
<td>31</td>
<td>0.9953</td>
</tr>
<tr>
<td>4</td>
<td>1.0000</td>
<td>18</td>
<td>0.9986</td>
<td>32</td>
<td>0.9950</td>
</tr>
<tr>
<td>5</td>
<td>1.0000</td>
<td>19</td>
<td>0.9984</td>
<td>33</td>
<td>0.9947</td>
</tr>
<tr>
<td>6</td>
<td>0.9999</td>
<td>20</td>
<td>0.9982</td>
<td>34</td>
<td>0.9944</td>
</tr>
<tr>
<td>7</td>
<td>0.9999</td>
<td>21</td>
<td>0.9980</td>
<td>35</td>
<td>0.9940</td>
</tr>
<tr>
<td>8</td>
<td>0.9999</td>
<td>22</td>
<td>0.9978</td>
<td>36</td>
<td>0.9937</td>
</tr>
<tr>
<td>9</td>
<td>0.9998</td>
<td>23</td>
<td>0.9975</td>
<td>37</td>
<td>0.9933</td>
</tr>
<tr>
<td>10</td>
<td>0.9997</td>
<td>24</td>
<td>0.9973</td>
<td>38</td>
<td>0.9930</td>
</tr>
<tr>
<td>11</td>
<td>0.9996</td>
<td>25</td>
<td>0.9970</td>
<td>39</td>
<td>0.9926</td>
</tr>
<tr>
<td>12</td>
<td>0.9995</td>
<td>26</td>
<td>0.9968</td>
<td>40</td>
<td>0.9922</td>
</tr>
<tr>
<td>13</td>
<td>0.9994</td>
<td>27</td>
<td>0.9965</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2 – Allowable difference between test portions

<table>
<thead>
<tr>
<th>Property</th>
<th>Allowable difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apparent particle density (t/m³)</td>
<td>0.020</td>
</tr>
<tr>
<td>Particle density on a dry basis (t/m³)</td>
<td>0.025</td>
</tr>
<tr>
<td>Property</td>
<td>Allowable difference</td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Particle density on a saturated surface-dry basis (t/m³)</td>
<td>0.020</td>
</tr>
<tr>
<td>Water absorption (%)</td>
<td>0.25</td>
</tr>
</tbody>
</table>

**Table 3 – Acceptable range of two results expressed as a percentage of mean value**

<table>
<thead>
<tr>
<th>Property</th>
<th>Repeatability</th>
<th>Reproducibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apparent particle density (t/m³)</td>
<td>0.014</td>
<td>0.023</td>
</tr>
<tr>
<td>Particle density on a dry basis (t/m³)</td>
<td>0.028</td>
<td>0.027</td>
</tr>
<tr>
<td>Particle density on a saturated surface-dry basis (t/m³)</td>
<td>0.014</td>
<td>0.023</td>
</tr>
<tr>
<td>Water absorption (%)</td>
<td>0.18</td>
<td>0.29</td>
</tr>
</tbody>
</table>
Test Method Q215: Crushed particles of aggregate

1 Source

This method was developed in-house using techniques evolved through internal departmental research investigations.

2 Scope

This method describes a procedure for determining the percentage by mass of crushed particles in aggregate derived from rounded gravel. It involves the visual assessment of particles retained on the 4.75 mm sieve which have two or more crushed faces.

3 Definitions

3.1 Crushed face – a mechanically fractured face which is rough in texture with sharp edges.

3.2 Crushed particle – a particle having two or more crushed faces, the combined surface area of which is judged to be at least 50% of the total surface area of the particle.

4 Apparatus

The following apparatus is required:

4.1 Balance of suitable capacity, having a resolution of at least 1 g and with a limit of performance within the range of ± 5 g.

4.2 Sieves, 37.5 mm, 26.5 mm, 19.0 mm, 16.0 mm, 13.2 mm, 9.50 mm, 6.70 mm and 4.75 mm as required, complying with AS 1152.

4.3 Drying oven of suitable capacity, having a temperature of 105-110°C and complying with AS 1141.2.

4.4 Sample dividers.

4.5 Sieve brushes.

4.6 Container of suitable size, for drying the test portion.

4.7 Dishes and trays.

5 Procedure

The procedure shall be as follows:

5.1 Particle size distribution

5.1.1 Prepare the bulk sample as detailed in Section 5 of Test Method Q101 to obtain a test portion which, when dry, will comply with the minimum mass requirement of Test Method Q103B Table 1.

5.1.2 Place the test portion in the container and dry in the oven to a constant mass (Note 8.1).

5.1.3 Determine the particle size distribution of the sample as detailed in Test Method Q103B (Note 8.2).

5.2 Crushed particles

5.2.1 Combine the size fractions retained on the sieves as necessary, into the fractions shown in Table 1.
5.2.2 Include all fractions which constitute five or more per cent of the sample mass and are larger than 4.75 mm.

5.2.3 Determine the mass of each test fraction \(m_1\).

5.2.4 Using either a sample divider or by cone and quartering, obtain a test portion from each fraction to be tested:
   a) of at least 200 pieces of the predominant fraction (Note 8.3), and
   b) of at least 100 pieces or the complete fraction for each of the remaining fractions, whichever provides the fewer pieces for testing.

5.2.5 Determine the mass of each test portion \(m_2\).

5.2.6 Test each test portion by:
   a) spreading the test portion on a clean flat surface of sufficient area to permit easy inspection
   b) examining each particle and setting aside those judged to be crushed particles from the rest of the test portion.

5.2.7 Retain the crushed particles from each test portion and determine the mass \(m_3\).

6 Calculations

6.1 Calculate the total mass of sample from the particle size distribution as follows:

\[ M_T = \sum m_i \]

where \(M_T\) = mass of sample from particle size distribution (g)
\(m_i\) = mass of each test fraction (g)

6.2 Calculate the percentage of crushed particles in each test portion as follows:

\[ P = \frac{m_3}{m_2} \times 100 \]

where \(P\) = percentage of crushed particles in the test fraction
\(m_3\) = mass of crushed particles in the test portion (g)
\(m_2\) = mass of the test portion (g)

6.3 Calculate the weighted percentage of crushed particles in each test fraction as follows:

\[ P_w = \frac{P \times m_i}{M_T} \]

where \(P_w\) = weighted percentage of crushed particles in the test fraction
\(P\) = percentage of crushed particles in the test fraction
\(m_i\) = mass of the test fraction (g)
\(M_T\) = mass of sample from particle size distribution (g)
6.4 Calculate the percentage of crushed particles as follows:

\[ P_s = \sum P_w \]

where:
- \( P_s \) = crushed particles (%)
- \( P_w \) = weighted percentage of crushed particles in each test fraction

7 Reporting

Report the crushed particles to the nearest 1%.

8 Notes on method

8.1 The material is considered to have reached a constant mass when the difference between successive weighings, after a further 1 hour drying at 105-110°C, is not more than 1 percent of the total of the previous moisture losses.

8.2 For ease in determining the percentage crushed particles, it is advisable to keep the fractions retained on each sieve separated during the performance of Test Method Q103B.

8.3 If insufficient sample has been prepared in Step 5.1.3 such that a test portion does not satisfy the requirements of Step 5.2.4, then a further representative sample of that fraction shall be prepared until satisfactory test portions of all fractions to be tested have been obtained.

Table 1 – Test fractions

<table>
<thead>
<tr>
<th>Size fractions (mm)</th>
<th>Passing</th>
<th>Retained</th>
</tr>
</thead>
<tbody>
<tr>
<td>37.5</td>
<td>26.5</td>
<td></td>
</tr>
<tr>
<td>26.5</td>
<td>19.0</td>
<td></td>
</tr>
<tr>
<td>19.0</td>
<td>13.2</td>
<td></td>
</tr>
<tr>
<td>13.2</td>
<td>9.50</td>
<td></td>
</tr>
<tr>
<td>9.50</td>
<td>4.75</td>
<td></td>
</tr>
</tbody>
</table>
Test Method Q216: Degree of aggregate precoating

1 Source
This method was developed in-house using techniques evolved through internal departmental research investigations.

2 Scope
This method describes a procedure for the visual assessment of the percentage of aggregate surface covered by a precoating agent. It is applicable to aggregate retained on the 4.75 mm sieve.

3 Apparatus
The following apparatus is required:

3.1 Sieve, 4.75 mm, complying with AS 1152.
3.2 Drying oven of suitable capacity, having a temperature of 45-50°C and complying with AS 1141.2.
3.3 Container of suitable size, for drying the test portion.
3.4 Suitable gloves, for handling the precoated aggregate (Note 7.1).

4 Procedure
The procedure shall be as follows:

4.1 Prepare the bulk sample as detailed in Section 5 of Test Method Q101 to produce a representative test portion of appropriate size.
4.2 Place the test portion in the container and dry in the oven.
4.3 Screen the test portion on a 4.75 mm sieve to produce an unwashed coarse fraction.
4.4 Using either a sample divider or by cone and quartering, obtain a test portion from the material retained on the 4.75 mm sieve, of at least 100 particles.
4.5 Spread the test portion on a clean flat surface of sufficient area to permit easy inspection.
4.6 Assess the proportion of the surface area of each particle covered by the precoating agent and record the value to the nearest 10 percentage units (\(a_i\)).
4.7 Retain the particles and determine the number of particles in the test portion (\(n\)).

5 Calculations
5.1 Calculate the degree of aggregate precoating as follows:

\[
P_{\text{PC}} = \frac{\sum a_i}{n}
\]

where

- \(P_{\text{PC}}\) = degree of aggregate precoating (%)
- \(a_i\) = percentage of surface area of each particle covered by precoating agent
- \(n\) = number of particles in the test portion
6 Reporting

Report the degree of aggregate precoating to the nearest 1%.

7 Notes on method

7.1 Before handling the precoated aggregate, the operator must consult the relevant Safety Data Sheet (SDS) for the precoating agent used.
Test Method Q217: Weak particles in aggregate

1 Source

This method applies the principles of AS 1141.32: Weak particles (including clay lumps and soft and friable particles) in coarse aggregates. It differs from this standard in that testing is performed on material ≥ 4.75 mm, the measurement excludes any dust adhering to the aggregate or generated during the test, and the proportion of weak particles is expressed as a percentage by number.

2 Scope

This method describes the procedure for determining the number of weak particles in a coarse aggregate material, expressed as a percentage of the total number of aggregate particles. Weak particles include clay lumps and particles that are soft and friable.

3 Apparatus

The following apparatus is required:

3.1 Sieve, 4.75 mm complying with AS 1152.
3.2 Riffle, of suitable size.
3.3 Container, of suitable size.

4 Procedure

The procedure shall be as follows:

4.1 Prepare the bulk sample as detailed in Section 5 of Test Method Q101 to produce a representative sample of appropriate size.

4.2 Sieve the sample over a 4.75 mm sieve, taking care to minimise any breakdown of particles including clay lumps and soil aggregations.

4.3 Riffle the material retained on the 4.75 mm sieve to obtain a representative test portion of at least 300 particles, again taking care to minimise any breakdown of particles including clay lumps and soil aggregations.

4.4 Record the number of particles in the test portion (N_1).

4.5 Spread the test portion in a single layer on the bottom of the container, cover the particles with water and allow them to soak overnight.

4.6 Drain the water from the container and firmly press each particle against the bottom of the container using finger pressure. Record the number of particles that break or deform under finger pressure (N_2).

5 Calculations

Calculate the proportion of weak particles in the sample as follows:

\[ W = \frac{100N_2}{N_1} \]

where \( W \) = weak particles expressed as a proportion of the total number of aggregate particles (%)


\[ N_2 = \text{number of weak particles in the test portion} \]
\[ N_1 = \text{total number of particles in the test portion} \]

6 Reporting

Report the proportion of weak particles to the nearest 0.1\%.
Test Method Q221A: Loose unit mass of aggregate

1 Source
This method is based on AS 1141.4: Bulk density of aggregate. It differs from this Australian Standard in aggregate preparation details and in some minor procedural techniques.

2 Scope
This method describes the procedure for the determination of the loose unit mass of aggregate. The test shall normally be performed on aggregate dried to constant mass as described herein, but may be performed at other moisture conditions if specifically required.

3 Apparatus
The following apparatus is required:

3.1 Balance of suitable capacity, providing a resolution and a limit of performance as detailed in Table 1.
3.2 Cylindrical measure of appropriate volume, complying with the requirements of Table 1.
3.3 Oven of suitable capacity, having a temperature of 105–110ºC and complying with AS 1141.2.
3.4 Scoop, flat bottomed.
3.5 Container, of suitable size for drying aggregate.
3.6 Straightedge, about 500 mm long, 25 mm wide and 3 mm thick, preferably with a bevelled edge.

4 Procedure
The procedure shall be as follows:

4.1 Determine the nominal size of the aggregate by assessing the sieve size at which not more than 10 per cent of the particles are larger.

4.2 Prepare the sample as detailed in Section 5 of Test Method Q101 to obtain a test portion which, when dry, will slightly overfill the appropriate measure listed in Table 1.

4.3 Place the test portion in the container and dry in the oven until the test portion has reached a constant mass (Note 8.1).

4.4 Determine the loose mass of aggregate to fill the measure as follows:

4.4.1 Determine the mass of the measure ($m_1$).

4.4.2 Fill the measure in one layer by allowing the aggregate to fall freely from the scoop held at height approximately 50 mm above the top of the measure. As each scoopful is being placed, move the scoop around the perimeter of the measure to provide a roughly symmetrical distribution pattern and to avoid segregation of the aggregate.

4.4.3 When the measure is filled, level the surface with the straightedge so that the portions of aggregate projecting above the top of the measure are approximately balanced by voids of about the same volume below the top of the measure.

4.4.4 Determine the mass of aggregate and the measure ($m_2$).
5  Calculations

5.1 Calculate the loose unit mass of aggregate as follows:

\[
\rho_l = \frac{m_2 - m_1}{V}
\]

where

- \( \rho_l \) = loose unit mass (t/m\(^3\))
- \( m_2 \) = mass of aggregate and measure (g)
- \( m_1 \) = mass of measure (g)
- \( V \) = volume of measure (cm\(^3\)) (Note 8.2)

6  Reporting

Report the following values and general information:

6.1 Loose unit mass of the aggregate to the nearest 0.01 t/m\(^3\).
6.2 Moisture condition of the aggregate, if not oven dried.

7  Precision

7.1 Repeatability

The results of duplicate tests by the same operator are acceptable if they do not differ by more than 2% of the average value.

8  Notes on method

8.1 The material is considered to have reached a constant mass when the difference between successive weighings, after a further 1 hour drying at 105-110°C, is not more than 1 percent of the total of the previous moisture losses.

8.2 The volume of the measure is to be determined from the mass of water to fill the measure and the water density at the temperature of determination.

Table 1 – Measure and balance requirements

<table>
<thead>
<tr>
<th>Aggregate nominal size (mm)</th>
<th>Nominal measure capacity (litre)</th>
<th>Minimum internal diameter (mm)</th>
<th>Minimum internal depth (mm)</th>
<th>Balance resolution (g)</th>
<th>Limit of performance range (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 20</td>
<td>25</td>
<td>350</td>
<td>250</td>
<td>10</td>
<td>± 50</td>
</tr>
<tr>
<td>5-20</td>
<td>10</td>
<td>250</td>
<td>220</td>
<td>10</td>
<td>± 50</td>
</tr>
<tr>
<td>&lt; 5</td>
<td>5</td>
<td>200</td>
<td>170</td>
<td>1</td>
<td>± 5</td>
</tr>
</tbody>
</table>
Test Method Q221B: Compacted unit mass of aggregate

1 Source

This method is based on AS 1141.4: Bulk density of aggregate. It differs from this Australian Standard in aggregate preparation details and in some minor procedural techniques.

2 Scope

This method describes the procedure for the determination of the compacted unit mass of aggregate. The test shall normally be performed on aggregate dried to constant mass as described herein, but may be performed at other moisture conditions if specifically required.

3 Apparatus

The following apparatus is required:

3.1 Balance of suitable capacity, providing a resolution and a limit of performance as detailed in Table 1.
3.2 Cylindrical measure of appropriate volume, complying with the requirements of Table 1.
3.3 Oven of suitable capacity, having a temperature of 105-110°C and complying with AS 1141.2.
3.4 Tamping rod, metal rod 16 ± 1 mm in diameter, approximately 600 mm long and having at least one end tapered for a distance of approximately 25 mm to a spherical shape having a diameter of approximately 10 mm.
3.5 Scoop, flat bottomed.
3.6 Container, of suitable size for drying aggregate.
3.7 Straightedge, about 500 mm long, 25 mm wide and 3 mm thick, preferably with a bevelled edge.

4 Procedure

The procedure shall be as follows:

4.1 Determine the nominal size of the aggregate by assessing the sieve size at which not more than 10 per cent of the particles are larger.

4.2 Prepare the sample as detailed in Section 5 of Test Method Q101 to obtain a test portion which, when dry, will slightly overfill the appropriate measure listed in Table 1.

4.3 Place the test portion in the container and dry in the oven until the test portion has reached a constant mass (Note 8.1).

4.4 Determine the compacted mass of aggregate to fill the measure as follows:

4.4.1 Determine the mass of the measure (m₁).
4.4.2 Fill the measure to about one-third of its capacity. Roughly level the surface of the aggregate and tamp with 25 strokes of the tamping rod, but avoiding striking the bottom of the measure with the rod.
4.4.3 Add a further quantity of aggregate to bring the measure to about two-thirds full. Roughly level the surface and tamp with 25 strokes of the tamping rod, endeavouring to just penetrate the underlying layer with the first few strokes.

Superseded
4.4.4 Fill the measure to overflowing and roughly level the surface of the aggregate. Tamp with 25 strokes of the tamping rod, endeavouring to just penetrate the underlying layer with the first few strokes.

4.4.5 Level the surface with the straightedge so that portions of aggregate projecting above the top of the measure are approximately balanced by voids of about the same volume below the top of the measure.

4.4.6 Determine the mass of aggregate and the measure \( m_2 \).

5 Calculations

5.1 Calculate the compacted unit mass of aggregate as follows:

\[
\rho_c = \frac{m_2 - m_1}{V}
\]

where

- \( \rho_c \) = compacted unit mass (t/m³)
- \( m_2 \) = mass of aggregate and measure (g)
- \( m_1 \) = mass of measure (g)
- \( V \) = volume of measure (cm³) (Note 8.2)

6 Reporting

Report the following values and general information:

6.1 Compacted unit mass of the aggregate to the nearest 0.01 t/m³.

6.2 Moisture condition of the aggregate, if not oven dried.

7 Precision

7.1 Repeatability

The results of duplicate tests by the same operator are acceptable if they do not differ by more than 1% of the average value.

8 Notes on method

8.1 The material is considered to have reached a constant mass when the difference between successive weighings, after a further 1 hour drying at 105-110°C, is not more than 1 percent of the total of the previous moisture losses.

8.2 The volume of the measure is to be determined from the mass of water to fill the measure and the water density at the temperature of determination.
### Table 1 – Measure and balance requirements

<table>
<thead>
<tr>
<th>Aggregate nominal size (mm)</th>
<th>Nominal measure capacity (litre)</th>
<th>Minimum internal diameter (mm)</th>
<th>Minimum internal depth (mm)</th>
<th>Balance resolution (g)</th>
<th>Limit of performance range (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 20</td>
<td>25</td>
<td>350</td>
<td>250</td>
<td>10</td>
<td>± 50</td>
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<tr>
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<td>10</td>
<td>250</td>
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<td>10</td>
<td>± 50</td>
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<tr>
<td>&lt; 5</td>
<td>5</td>
<td>200</td>
<td>170</td>
<td>1</td>
<td>± 5</td>
</tr>
</tbody>
</table>
Test Method Q224A: Sugar in aggregate - phenol-sulphuric acid

1 Source
This method was developed in-house and is based on a procedure described in the Laboratory Manual for Queensland Sugar Mills (5th Edition), pages 130 to 131.

2 Scope
This method sets out a procedure for the quantitative measurement of the sugar content of aggregate. It involves extraction of carbohydrate and any water-soluble matter from the aggregate using distilled water, filtering the sample solution and reacting the filtrate with concentrated sulphuric acid. The concentration of carbohydrate in the sample is determined quantitatively using a UV-Vis spectrophotometer. The test is sensitive to 1 ppm.

3 Apparatus
The following apparatus is required:

3.1 UV-Vis spectrophotometer.
3.2 Drying oven of suitable capacity, having a temperature of 105-110°C and complying with AS 1141.2.
3.3 Fume cupboard.
3.4 Balances:
   3.4.1 Balance of suitable capacity, having a resolution of at least 0.01 g and with a limit of performance within the range of ± 0.05 g.
   3.4.2 Balance of suitable capacity, having a resolution of at least 0.001 g and with a limit of performance within the range of ± 0.005 g.
3.5 Mechanical horizontal shaker.
3.6 Volumetric flasks, of 25 mL, 100 mL and 1000 mL capacity.
3.7 Auto-pipettes, 50 mL capacity with a resolution to 0.1 mL, 10 mL capacity with a resolution to 0.01 mL and 1 mL capacity with a resolution to 0.001 mL.
3.8 Glass weighing boats, of 10 mL capacity.
3.9 Conical flask, of 250 mL capacity fitted with a stopper.
3.10 Vials, of 25 mL capacity fitted with a screw cap.
3.11 Syringe filter, 30 mm diameter with pore size of 0.22 µm, acetate or equivalent.
3.12 Disposable syringe of 10 mL capacity with a leur lock.
3.13 Wash bottle.

4 Reagents
All reagents shall be analytical grade (Note 8.1).

4.1 Concentrated sulphuric acid (≥ 98%).
4.2 1000 ppm standard sucrose solution:
   • Weigh 1.000 g sucrose into a 10 mL glass weighing boat and transfer it into a 1000 mL volumetric flask using multiple rinsings with distilled water. Dilute to the mark and mix well.

4.3 5, 10, 25, 50, 100 and 250 ppm standard sucrose solutions:
   • Pipette 0.50 mL, 1.00 mL, 2.50 mL, 5.00 mL, 10.00 mL and 25.00 mL of the 1000 ppm standard sucrose solution into separate 100 mL volumetric flasks. Dilute each to the mark with distilled water and mix well.

4.4 5% phenol solution:
   • Weigh 1.250 g of phenol crystals into a 10 mL glass weighing boat and transfer it into a 25 mL volumetric flask using multiple rinsings with distilled water. Dilute to the mark and mix well (Note 8.2).

5 Procedure

5.1 Instrument calibration (Note 8.3)
   5.1.1 Pipette 1.00 mL of a standard sucrose solution, for example 5 ppm, into a vial, add 1.00 mL of phenol solution and swirl to mix.
   5.1.2 With the pipette discharge tip 2 to 3 cm above the centre of the surface of the liquid, carefully pipette (drop by drop) 5.00 mL of concentrated sulphuric acid into the vial with continuous swirling to assist mixing (Note 8.4).
   5.1.3 Allow the solution to cool to room temperature.
   5.1.4 Repeat Steps 5.1.1 to 5.1.3 for each of the remaining standard sucrose solutions, for example, 10 ppm, 25 ppm, 50 ppm, 100 ppm and 250 ppm, and for distilled water (0 ppm).
   5.1.5 Using the UV-Vis spectrophotometer in accordance with the relevant operating instructions, determine the absorbance at 489 nm for each of the solutions prepared in Steps 5.1.1 to 5.1.4.
   5.1.6 Using the data obtained from the 0 to 250 ppm solutions in Step 5.1.5, determine the linear relationship between absorbance and sugar content in the following form (Note 8.5):

\[
A= kC
\]

where

- \( A \) = absorbance at 489 nm
- \( k \) = constant
- \( C \) = sugar content (ppm)

5.2 Sample preparation and testing

5.2.1 Oven dry the sample. Normal overnight drying in a 105-110°C oven is sufficient.

5.2.2 Weigh 100.0 g of a representative test portion of the sample into a 250 mL conical flask and add 100.0 mL distilled water.

5.2.3 Insert the stopper and shake the contents on the horizontal shaker for 60 minutes.

5.2.4 Filter about 100.0 mL of the mixture through a 0.22 µm syringe filter into a vial (the filtered solution should be water clear).

5.2.5 Pipette 1.00 mL of the filtered solution and 1.00 mL of 5% phenol solution into another vial and swirl to mix.
5.2.6 With the pipette discharge tip 2 to 3 cm above the centre of the surface of the liquid, carefully pipette (drop by drop) 5.00 mL of concentrated sulphuric acid into the vial with continuous swirling to assist mixing (Note 8.4).

5.2.7 Allow the solution to cool to room temperature.

5.2.8 Using the UV-Vis spectrophotometer in accordance with the relevant operating instructions, determine the absorbance of the solution at 489 nm (Note 8.6).

6 Calculations

Using the value of absorbance obtained for the sample solution in Step 5.2.8 and the instrument calibration determined in Step 5.1.6, calculate the sugar content to the nearest 0.1 ppm.

7 Reporting

Report the sugar content of the sample to the nearest 0.1 ppm.

8 Notes on method

8.1 Before handling reagents, the operator must consult the relevant Safety Data Sheet (SDS).

8.2 The 5% phenol solution has a shelf life of only one day.

8.3 As recommended by the instrument supplier, the instrument calibration described in Steps 5.1.1 to 5.1.6 needs only to be performed six monthly. However, an internal standard sample should always be tested as "unknown" for each batch of testing to ensure the accuracy of the test. Recalibration needs to be carried out when the internal standard test fails to deliver the "true" sugar content of the standard.

8.4 This reaction is highly exothermic and extreme caution needs to be exercised during addition of the acid. This step should be performed in a fume cupboard together with the use of other appropriate protective equipment.

8.5 Most UV-Vis spectrophotometers have built-in software to determine absorbance/concentration relationships and sample concentrations derived from these relationships. In such cases, the calibration need not be calculated and the sugar content of the sample may be read directly from the instrument.

8.6 The brand of UV-Visible cells used can influence the UV-Visible test results, although the effect is generally very small. This factor should not be ignored, especially when the sugar content is less than 10 ppm. Attention needs to be given to ensure that the same cells (same brand quartz cells) are used for both reference and unknown samples. Plastic cells should never be used for sugar testing.
Test Method Q224B: Sugar in aggregate - alpha-napthol

1 Source

This method, sometimes referred to as the Molisch test, was developed in-house and is based on a procedure described in the *Laboratory Manual for Queensland Sugar Mills* (5th Edition), pages 92 to 93.

2 Scope

This method sets out a procedure for detecting sugar in aggregate. It involves extraction of carbohydrate and any water-soluble matter from the aggregate using distilled water, filtering the sample solution and reacting the filtrate with concentrated sulphuric acid in the presence of $\alpha$-naphthol reagent. The concentration of carbohydrate in the sample is reflected by the intensity of a violet ring which appears at the junction of two layers of liquid.

The method provides for both a qualitative indication and a semi-quantitative measurement of sugar content. The sensitivity of the test is about 10-20 ppm for soil/sand filtrates and about 5 ppm for pure sucrose aqueous solutions. Where a quantitative determination of sugar content is required, Test Method Q224A should be used.

3 Apparatus

The following apparatus is required:

3.1 Drying oven of suitable capacity, having a temperature range of 60-100°C (semi-quantitative test only).

3.2 Fume cupboard.

3.3 Balances:

3.3.1 Balance of suitable capacity, having a resolution of at least 0.01 g and with a limit of performance within the range of \(\pm 0.05\) g.

3.3.2 Balance of suitable capacity, having a resolution of at least 0.001 g and with a limit of performance within the range of \(\pm 0.005\) g.

3.4 Mechanical horizontal shaker.

3.5 Volumetric flasks, of 25 mL, 100 mL and 1000 mL capacity.

3.6 Auto-pipettes, of 5 mL and 10 mL capacity, resolution to 0.01 mL (semi-quantitative test only).

3.7 Pipettes, of 5 mL capacity.

3.8 Glass weighing boats, of 10 mL capacity (semi-quantitative test only).

3.9 Conical flasks, of 250 mL capacity fitted with a stopper.

3.10 Pasteur pipettes.

3.11 Glass filter funnels, test tubes and test tube rack.

3.12 Wash bottle.

4 Materials

The following material is required:

4.1 Filter paper, Whatman No. 42 or equivalent.
5 Reagents

All reagents shall be analytical grade and the distilled water shall have a resistivity greater than 200 ohm m (Note 9.1).

5.1 Concentrated sulphuric acid (≥ 98%) (Note 9.1).

5.2 1000 ppm standard sucrose solution (semi-quantitative test only).

- Weigh 1.000 g sucrose into a 10 mL glass weighing boat and transfer it into a 1000 mL volumetric flask using multiple rinsings with distilled water. Dilute to the mark and mix well.

5.3 25, 50, 100 and 250 ppm standard sucrose solutions (semi-quantitative test only) (Note 9.2).

- Pipette 0.50 mL, 1.00 mL, 2.50 mL, 5.00 mL, 10.00 mL and 25.00 mL of the 1000 ppm standard sucrose solution into separate 100 mL volumetric flasks. Dilute each to the mark with distilled water and mix well.

5.4 α-Naphthol solution.

- Weigh 5.0 g α-naphthol into a 10 mL glass weighing boat and transfer it into a 25 mL volumetric flask using multiple rinsings with ethyl alcohol. Dilute to the mark and mix well (Note 9.3).

6 Procedure: qualitative indication

6.1 Weigh 100.0 g of a representative sample into a 250 mL conical flask and add 100.0 g distilled water.

6.2 Insert the stopper and shake the contents on the horizontal shaker for 60 minutes.

6.3 Filter the mixture through a Whatman No. 42 filter paper (or equivalent) into a 250 mL conical flask and stopper the flask.

6.4 Pipette 5 mL of the filtrate into a test tube, add five drops of α-naphthol solution and swirl to mix.

6.5 Incline the test tube and carefully and slowly add 5 mL concentrated sulphuric acid so that two clearly defined liquid layers are formed (Note 9.4).

6.6 Allow five minutes to elapse after the addition of the sulphuric acid, then examine the interface between the two layers. Record the presence or otherwise of any violet colouration.

7 Procedure: semi-quantitative measurement

7.1 Oven dry the sample until it has reached constant mass (Note 9.5).

7.2 Weigh 100.0 g of a representative test portion of the sample into a 250 mL conical flask and add 100 g distilled water.

7.3 Insert the stopper and shake the contents on the horizontal shaker for 60 minutes.

7.4 Filter the mixture through a Whatman No. 42 filter paper (or equivalent) into a 250 mL conical flask and stopper the flask.

7.5 Pipette 5.00 mL of the filtrate into a test tube, add five drops of α-naphthol solution and swirl to mix.

7.6 Incline the test tube and carefully and slowly add 5.00 mL concentrated sulphuric acid so that two clearly defined liquid layers are formed (Note 9.4).
7.7 Allow five minutes to elapse after the addition of the last drop of sulphuric acid, then compare the colour of the sample solution with that of the reference standards given in Figure 1. Record the concentration of the two reference standards spanning the nearest match (Note 9.6).

7.8 Prepare the two standard sucrose solutions at the concentrations noted in Step 7.7.

7.9 Pipette 5.00 mL from each of the sample solution (Step 7.4) and two standard sucrose solutions into separate test tubes, add five drops of α-naphthol solution to each test tube and swirl to mix.

7.10 Incline each test tube and carefully and slowly add 5.00 mL concentrated sulphuric acid so that two clearly defined liquid layers are formed (Note 9.4). Position each test tube in a test tube rack.

7.11 Allow five minutes to elapse after the addition of the last drop of sulphuric acid, then compare the colour of the sample solution with that of the standard sucrose solutions and record the concentration of the nearest match (Notes 9.7 and 9.8).

8 Reporting

8.1 Qualitative indication
Report the presence of sugar as positive if any violet colouration was observed in Step 6.6. Otherwise, report it as negative.

8.2 Semi-quantitative measurement
Report the sugar content corresponding to the nearest match in one of the following forms:

a) Sugar = 0 ppm (no violet colouration)
b) 0 ppm < Sugar < 10 ppm
c) ppm < Sugar < 25 ppm
d) 25 ppm < Sugar < 50 ppm
e) 50 ppm < Sugar < 100 ppm
f) 100 ppm < Sugar < 250 ppm
g) Sugar > 250 ppm.

9 Notes on method

9.1 Before handling reagents, the operator must consult the relevant Safety Data Sheet (SDS).

9.2 Only two of these solutions which most closely match the sample solution may be required.

9.3 The α-naphthol solution has a shelf life of about one week and should be stored in the dark when not in use.

9.4 This step should be carried out in a fume cupboard together with the use of other appropriate personal protective equipment (PPE).

9.5 The sample is considered to have reached a constant mass when the difference between successive weighings, after a further 1 hour drying at 105-110°C, is not more than 1 percent of the total of the previous moisture losses.

9.6 If the colour of the sample solution does not match the colours of the printed reference standards, the intensity of colour should be used to select the two concentrations providing the nearest match.
9.7 Since it is not possible to directly compare all three solutions five minutes after the addition of the last drop of concentrated sulphuric acid, some subjective judgement will be required.

9.8 Any unusual variations in colour from the standard sucrose solutions generally indicate that the sample contains other water soluble salts, anions or cations. If the colour of the sample solution does not match the colours of the standard sucrose solutions, the intensity of colour should be used to select the concentration providing the nearest match.

**Figure 1 – Reference standards**

10 ppm

25 ppm

50 ppm

100 ppm
250 ppm
Test Method Q225: Dustiness of cover aggregate

1 Source

This method applies the principles of AS 1141.11: Particle size distribution by sieving. It differs from this standard in that aggregates are always washed prior to dry sieving, techniques are limited to hand sieving only and a finer reporting interval is used.

2 Scope

This method describes the procedure for characterising the dust portion of unprecoated cover aggregate by determining the particle size distribution of the fine material following washing and dry sieving.

3 Apparatus

The following apparatus is required:

3.1 Balance of suitable capacity, having at least the resolution and a limit of performance within the range detailed in Table 1 (Note 8.1).

3.2 Sieves:

3.2.1 The range of sieves specified for the nominal aggregate size but also including 4.75 mm, 2.36 mm, 1.18 mm, 0.600 mm, 0.300 mm, 0.150 mm and 0.075 mm complying with AS 1152.

3.2.2 Reinforced 0.075 mm sieve complying with AS 1152 (Note 8.2).

3.3 Sieve brushes.

3.4 Drying oven of suitable capacity, having a temperature of 105-110°C and complying with AS 1141.2.

3.5 Container, of suitable size for washing and oven drying.

4 Materials

The following materials are required:

4.1 Dispersing agent:

4.1.1 Prepare by dissolving 33 g of sodium hexametaphosphate (LR Grade) and 7 g of anhydrous sodium carbonate (LR Grade) or 18.9 g of sodium carbonate decahydrate (LR Grade) in one litre of water (Notes 8.3 and 8.4).

5 Procedure

The procedure shall be as follows:

5.1 Determine the nominal size of the aggregate by assessing the sieve size at which not more than 10 percent of the particles are larger. Prepare the sample as detailed in Section 5 of Test Method Q101 to obtain a test portion which, when dry, will comply with the minimum mass requirement of Table 1.

5.2 Weigh the container and record its mass (\( m_1 \)).

5.3 Place the test portion in the container and dry in the oven to constant mass (Note 8.5). Record the mass of the container and test portion (\( m_2 \)).
5.4 Add sufficient clean potable water to cover the test portion. For materials which contain clay, dispersing agent which does not react with the test portion may be added to the water.

5.5 Vigorously agitate the contents without spilling the water to take the fine material into suspension and immediately pour the wash water through two sieves nested together, consisting of a guard sieve such as a 2.36 mm sieve at the top and the reinforced 0.075 mm sieve below. Avoid, as far as possible, decantation of the coarse particles of the test portion.

5.6 Continue agitation and washing until the water in the container is clean.

5.7 Wash the material retained on the 0.075 mm sieve until the wash water becomes clear. The passing 0.075 mm material is allowed to run to waste.

5.8 Return all the washed 0.075 mm sieve material to the container and decant excess water, ensuring no fines are lost.

5.9 Place the container and material in the oven and dry until the material has reached constant mass (Note 8.5).

5.10 Sieve the dried test portion by hand through the nominated sieves in order of decreasing aperture size down to and including the 0.075 mm. Ensure no sieve is overloaded by reference to Table 2.

5.11 Sieve the material using a lateral and vertical motion accompanied by a slight jarring action to keep the material moving over the sieves. It may be necessary to unblock the sieves from time to time using the hand or, in the case of fine sieves, a sieve brush (Note 8.6).

5.12 Continue this agitation until no more than a further 1 per cent by mass of residue on any individual sieve will pass that sieve during a further 1 minute of continuous hand sieving.

5.13 Weigh the aggregate retained on each sieve and record its mass ($m_r$).

6 Calculations

6.1 Calculate the cumulative mass retained on each sieve as follows:

$$M = \sum m_r$$

where

- $M_r$ = cumulative mass retained on each sieve (g)
- $m_r$ = individual mass retained on each sieve with an aperture size larger than or equal to the particular sieve (g)

6.2 Calculate the cumulative percent retained on each sieve to the nearest 0.1 as follows:

$$P = \frac{100M}{m_2 - m_1}$$

where

- $P$ = cumulative per cent retained on each sieve
- $M$ = cumulative mass retained on each sieve (g)
- $m_2$ = mass of container and dry aggregate (g)
- $m_1$ = mass of container (g)
6.3 Calculate the per cent passing each sieve to the nearest 0.1 as follows:

\[ P_p = 100 - P \]

where \( P_p \) = percent passing each sieve

\( P \) = cumulative per cent retained on each sieve

7 Reporting

Report the percent passing each sieve to the nearest 0.1% for results 10% or greater and to the nearest 0.01% for results less than 10%.

8 Notes on method

8.1 The balance used in the procedure is normally dependent on the nominal size of the aggregate, however, for sieve sizes 2.36 mm and smaller, the balance must have a resolution of 0.1 g and a limit of performance range within \( \pm 0.5 \) g.

8.2 Because of the ease with which a 0.075 mm sieve can be damaged, the use of a special washing sieve, in which the sieve cloth is reinforced underneath with a coarser sieve or punched plate screen, is recommended.

8.3 Before handling sodium hexametaphosphate, anhydrous sodium carbonate or sodium carbonate decahydrate, the operator must consult the relevant Safety Data Sheet (SDS).

8.4 This solution is unstable and must be freshly prepared approximately once a month with the preparation and expiry dates recorded on the container.

8.5 The material is considered to have reached a constant mass when the difference between successive weighings, after a further 1 hour drying at 105-110°C, is not more than 1 percent of the total of the previous moisture losses.

8.6 Care shall be taken not to apply pressure to the surface of the sieve. Brushes with stiff or worn-down bristles must not be used.

**Table 1 – Test portion and balance requirements**

<table>
<thead>
<tr>
<th>Aggregate nominal size (mm)</th>
<th>Minimum test portion mass (g)</th>
<th>Balance resolution (g)</th>
<th>Balance limit of performance range (g)</th>
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</thead>
<tbody>
<tr>
<td>28</td>
<td>10000</td>
<td>10</td>
<td>( \pm 50 )</td>
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<td>20</td>
<td>5000</td>
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<td>3000</td>
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</tr>
<tr>
<td>10</td>
<td>1000</td>
<td>1</td>
<td>( \pm 5 )</td>
</tr>
<tr>
<td>7</td>
<td>600</td>
<td>0.1</td>
<td>( \pm 0.5 )</td>
</tr>
<tr>
<td>5</td>
<td>500</td>
<td>0.1</td>
<td>( \pm 0.5 )</td>
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</tbody>
</table>
Table 2 – Recommended maximum sieve loadings

<table>
<thead>
<tr>
<th>Aperture Size (mm)</th>
<th>200 mm diameter (g)</th>
<th>300 mm diameter (g)</th>
</tr>
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<td>26.5</td>
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<td>1200</td>
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<td>1050</td>
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<td>13.2</td>
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<td>250</td>
<td>600</td>
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<td>6.70</td>
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<td>500</td>
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<td>40</td>
<td>-</td>
</tr>
<tr>
<td>0.075</td>
<td>25</td>
<td>-</td>
</tr>
</tbody>
</table>

Superseded
Test Method Q226: Precoating agent absorption and adsorption of cover aggregate

1 Source
This method was developed in-house using techniques evolved through an internal departmental research investigation.

2 Scope
This method describes the procedure for the determination of precoating agent absorption and adsorption of cover aggregate. For 14 mm and larger nominal size aggregate, the retained 9.50 mm material is tested by this procedure while for 10 mm nominal size aggregate, the retained 6.70 mm material is tested.

3 Apparatus
Where appropriate, the working tolerances of particular apparatus are contained in Table 1.

The following apparatus is required:

3.1 Sieves:
3.1.1 9.50 mm or 6.70 mm depending on the nominal size of the aggregate and complying with AS 1152.
3.1.2 Reinforced 0.075 mm sieve complying with AS 1152 (Note 8.1).

3.2 Balances:
3.2.1 Balance of suitable capacity, with a resolution of at least 0.01 g and with a limit of performance within the range of ± 0.05 g.
3.2.2 Balance of suitable capacity, with a resolution of at least 0.1 g and with a limit of performance within the range of ± 0.5 g.

3.3 Drying oven of suitable capacity, having a temperature of 105-110°C and complying with AS 1141.2.

3.4 Thermometer, a partial or total immersion thermometer or other suitable temperature measuring device with a temperature range of at least 0-50°C and graduated to 1°C or less with an uncertainty of no more than 0.5°C.

3.5 Beakers, two of about 300 mL capacity.

3.6 Tumbling machine, capable of rotating the prescribed container end over end at 70 revolutions per minute.

3.7 Cylindrical plastic container, 100 mm diameter and 150 mm height (internal dimensions). It should include an airtight lid of sufficient strength to contain the aggregate sample during the precoating operation.

3.8 Pipette of suitable capacity, having a resolution of 0.01 mL

4 Materials
The following materials are required:

4.1 Lint free cloth.
4.2 Mineral turpentine (Note 8.2)
4.3 Acetone (Note 8.2)

5 Procedure

The procedure shall be as follows:

5.1 Preparing test portions

5.1.1 Prepare the bulk sample as detailed in Section 5 of Test Method Q101 to produce a representative sample of appropriate size.

5.1.2 Further prepare the sample to produce as follows:
   a) subsample retained on either the 9.50 mm or 6.70 mm sieve as detailed in Test Method Q101, Subsection 6.3 for coarse fraction subsamples of at least 10 kg.
   b) subsample retained of sufficient quantity for the determination of loose unit mass.

5.1.3 Place the subsample prepared in Step 5.1.2 b) in the oven and dry to a constant mass (Note 8.3).

5.1.4 Determine the loose unit mass of the subsample (\( \rho \)) as detailed in Test Method Q221A.

5.2 Precoating of the test portions

5.2.1 Obtain two representative test portions of 100 ± 1 g from the coarse fraction subsample prepared in Step 5.1.2 a).

5.2.2 Determine the mass of the cylindrical plastic container (\( m_1 \)).

5.2.3 Place one test portion into the cylindrical plastic container and determine the mass of the test portion and cylindrical plastic container (\( m_2 \)).

5.2.4 Calculate the required volume of precoating agent to add to the container as follows:

\[
V = \frac{0.1A}{\rho}
\]

where
- \( V \) = Volume of precoating agent (mL) (Note 8.4)
- \( A \) = Precoating application rate (L/m³), normally 20 L/m³ unless otherwise specified
- \( \rho \) = Aggregate loose unit mass (t/m³) as determined in Step 5.1.4

5.2.5 Using the pipette, transfer the calculated volume of precoating agent (\( V \)) to the cylindrical plastic container and secure the lid.

5.2.6 Place the cylindrical plastic container into the tumbling machine and rotate for 175 revolutions.

5.3 Determination of absorption and adsorption

5.3.1 Determine the mass of the first beaker (\( m_3 \)).

5.3.2 Place the precoated aggregate, one particle deep, onto a clean dry metal tray. Pick up each of the aggregate particles with a pair of tweezers, use a flicking motion to remove excess precoating agent from the particle and place it in the first beaker.

5.3.3 Determine the total mass of the first beaker, aggregate, adsorbed and absorbed precoating agent (\( m_4 \)).
5.3.4 Determine the mass of a second beaker (m₅).

5.3.5 Place the precoated aggregate from the first beaker, one particle deep, onto a clean lint-free cloth and roll and wipe the precoated aggregate until all visible precoating agent has been removed from the surface of the particles.

5.3.6 Place the precoated aggregate into the second beaker and determine the mass of the second beaker, aggregate and absorbed precoating agent (m₆).

5.3.7 Fill the second beaker with mineral turpentine until the aggregate is covered. Agitate the contents of the beaker and pour the suspension over the reinforced 0.075 mm sieve.

5.3.8 Wash the material retained on the 0.075 mm sieve until the mineral turpentine shows no discolouration.

5.3.9 Add mineral turpentine to the second beaker and repeat Steps 5.3.7 to 5.3.8 until the aggregate retained in the beaker and that retained on the 0.075 mm sieve is clean.

5.3.10 Return all washed material on the 0.075 mm sieve to the second beaker and decant any excess mineral turpentine.

5.3.11 Rinse the contents of the second beaker with acetone. Decant any excess acetone.

5.3.12 Place the second beaker on a hotplate and dry the aggregate and cool to room temperature.

5.3.13 Determine the mass of the second beaker and aggregate (m₇).

5.4 Repeat Steps 5.2.2 to 5.3.13 using the second test portion.

6 Calculations

6.1 Calculate the precoating agent absorption for each test portion as follows:

\[ A_b = \frac{100(m_6 - m_5)}{m_7 - m_5} \]

where

\[ A_b \] = precoating agent absorption (%)

\[ m_6 \] = mass of second beaker, aggregate and absorbed precoating agent (g)

\[ m_7 \] = mass of second beaker and aggregate (g)

\[ m_5 \] = mass of second beaker (g)

6.2 Calculate the precoating agent adsorption for each test portion as follows:

\[ A_d = \frac{100[m_4 - (m_6 - m_5) - m_7]}{(m_7 - m_5)} \]

where

\[ A_d \] = precoating agent adsorption (%)

\[ m_4 \] = mass of first beaker, aggregate, absorbed and adsorbed precoating agent (g)

\[ m_6 \] = mass of second beaker, aggregate and absorbed precoating agent (g)

\[ m_5 \] = mass of second beaker (g)
\[ m_3 = \text{mass of first beaker (g)} \]
\[ m_7 = \text{mass of second beaker and aggregate (g)} \]

6.3 For both the absorption and adsorption results, compare the values from the two test portions and, if they do not differ by more than 0.25%, average the results. Otherwise repeat the test.

7 Reporting

Report the average of the following as appropriate:

7.1 Precoating agent absorption to the nearest 0.01%.

7.2 Precoating agent adsorption to the nearest 0.01%.

8 Notes on method

8.1 Because of the ease with which a 0.075 mm sieve can be damaged, the use of a special washing sieve, in which the sieve cloth is reinforced underneath with a coarser sieve or punched plate screen, is recommended.

8.2 Before handling mineral turpentine or acetone, the operator must consult the relevant Safety Data Sheet (SDS).

8.3 The material is considered to have reached a constant mass when the difference between successive weighings, after a further 1 hour drying at 105-110°C, is not more than 1 percent of the total of the previous moisture losses.

8.4 For the calculation it is assumed the mass of the test portion \( (m_7 - m_1) \) is \( 100 \pm 1 \) g.

Table 1 – Dimensions and tolerances for equipment

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Dimension</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tumbling machine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed (revolutions/min)</td>
<td>70</td>
<td>± 5</td>
</tr>
<tr>
<td>Cylindrical plastic container</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal diameter (mm)</td>
<td>100</td>
<td>± 5</td>
</tr>
<tr>
<td>Internal height (mm)</td>
<td>150</td>
<td>± 10</td>
</tr>
</tbody>
</table>
Test Method Q227: Pull-out force for surfacing aggregate

1 Source
This method has been adapted from one of the techniques described from a similar test published in the 1994 South African Sabita Manual: Technical Guidelines for Seals using Homogeneous Modified Binders.

2 Scope
This method provides for the determination of an average pull-out force required to dislodge cover aggregate pieces from a bituminous binder on a sprayed seal to assess the level of bonding of the aggregate to the binder surface. Data on pull-out force could prove useful in general sealing work in indicating the degree of early trafficking control required on freshly laid seals.

3 Apparatus
The following apparatus is required:

3.1 Spring balance, having a capacity of 1000 g, with a resolution of at least 10 g, fitted with a zeroing adjustment (Notes 8.1 and 8.2).

3.2 Crocodile clip, 50 mm in length, with maximum stiffness in grip and with an attached wire or string line, approximately 0.5 m long.

3.3 Infrared thermometer, with a resolution of at least 0.2 ºC over the range from 10ºC to 80ºC.

3.4 Safety glasses.

4 Preparation for testing

4.1 Select at least twelve test positions of approximately equal spacing along a length of seal of essentially homogeneous condition (Note 8.3).

4.2 Connect the crocodile clip to the spring balance by the attached line.

4.3 Hold the spring balance such that the zero point of the spring balance scale is at about eye level (Note 8.4).

4.4 Attach the crocodile clip to an individual loose stone of a size representative of that to be tested, zero the spring balance and discard the stone.

5 Procedure
Perform the following at each test position:

5.1 Measure and record the surface temperature (T) to the nearest 0.2ºC using the infrared thermometer.

5.2 Select a typically bound stone from each test position and attach the crocodile clip to the stone. The stone selected should be of suitable shape to permit effective gripping of the clip.

5.3 Wearing the safety glasses, slowly raise the upper portion of the balance using a smooth action to apply a pull-out rate of about 20 g/second. Monitor the scale carefully and continue the load application until the stone becomes detached (Note 8.5).

5.4 Record the maximum force reading as the pull-out force ($F_p$).
5.5 Estimate the amount of embedment into the binder of the detached stone by the height of binder on the stone and record this value as a percentage of the height of the stone. For this purpose, record a value of 50% for a stone half embedded in the binder and a value of 10% if only the complete base of the stone is coated with binder (Note 8.6).

6 Calculations
6.1 Apply a temperature correction factor to the pull-out force recorded at each test position to correct the pull-out force to 40°C as follows (Note 8.7):

\[ \log f_2 = \log f_1 - 0.05(40-T) \]

where \( f_2 \) = pull-out force (g) corrected to 40°C
\( f_1 \) = pull-out force (g)
T = surface temperature (°C)

6.2 Examine the values of log pull-out force corrected to 40°C for all test positions and eliminate any values which are extraordinarily high or low in comparison to the remaining values within the data set.

6.3 Average the remaining values of the log pull-out force and take the antilog of this average value to determine the typical pull-out force over the site.

6.4 Determine the average height of binder on the stones used to determine the typical pull-out force over the site.

7 Reporting
Report the following values and general information:

7.1 Typical pull-out force to the nearest 10 g.
7.2 Average height of binder to the nearest 1%.

8 Notes on method
8.1 A Kern Model No. 41000 is regarded as a suitable spring balance.
8.2 When field conditions provide pull-out forces generally above 1000 g, for example, cooler temperatures, large or strongly interlocked aggregate pieces, tough binders and so on, an alternative spring balance of higher force capacity will be required.

8.3 The general location of each test position may be determined by pacing the appropriate distance.
8.4 The tester will normally carry out testing in either a sitting or squatting position.
8.5 If the stone twists during the test to cause a significantly reduced pull-out force, the result should be discarded and another stone tested from the same general area of the test position.

8.6 In many instances, the stone is not embedded evenly within the binder and, for such cases, the recorded height is an estimated average around all sides of the stone.

8.7 The temperature correction factor of -0.05 used relates to conventional binders.
Test Method Q228: Mill abrasion of aggregate

1 Source
This method is based on a test procedure described in "CP Rail specification for evaluating processed rock, slag and gravel ballasts (Appendix A)", Canadian Pacific Ltd, Montreal, 1981. It differs from this procedure in only minor procedural variations.

2 Scope
This method describes the procedure for determining the mill abrasion value of coarse aggregates using a wet attrition technique. If required the method also allows the calculation of an abrasion number using the mill abrasion value and the Los Angeles value.

3 Apparatus
Where appropriate, the working tolerances of particular apparatus are contained in Table 1.

The following apparatus is required:

3.1 Drying oven of suitable capacity, having a temperature of 105-110°C and complying with AS 1141.2.

3.2 Wire brush.

3.3 Jaw crusher.

3.4 Scalloping screen, a 9.50 mm sieve is suitable.

3.5 Sieves, 37.5 mm, 26.5 mm, 19.0 mm and 4.75 mm as required, complying with AS 1152.

3.6 Containers suitable for washing test fractions.

3.7 Balance of suitable capacity, having a resolution of at least of 1 g and a limit of performance within the range of ± 5 g.

3.8 Sample splitters.

3.9 Measuring cylinder of suitable capacity.

3.10 Mill abrasion tumbler capable of revolving a 5 litre porcelain jar about its longitudinal axis at 33 ± 2 revolutions per minute for a total of 10,000 revolutions. The jar shall be fitted with a lid to hold water and shall have an external diameter of 230 mm.

3.11 Reinforced 0.075 mm sieve of 300 mm diameter and complying with AS 1152.

3.12 Oven tray.

4 Materials
The following material is required:

4.1 Distilled water.

5 Sample preparation
Prepare the sample as follows:

5.1 Thoroughly wash and dry the sample before using the wire brush to remove any adhering fines or soft weathered rock.

5.2 Crush the sample by gradually reducing the maximum particle size to 50 mm.
5.3 Sieve the crushed sample over an appropriately sized scalping screen and discard any material passing the screen.

5.4 If the material retained on the scalping screen is not homogenous, remove and discard any particles which are at variance with the bulk of the sample (Note 9.1).

5.5 Further crush the retained material, gradually reducing its size until nearly all material passes the 37.5 mm sieve and a range of particle sizes in keeping with the requirements of Table 2 is produced.

5.6 Prepare a representative subsample to provide a test portion containing the fractions as follows:

5.6.1 Screen the subsample through each of the sieves listed in Table 2, in turn. Discard the material retained on the largest sieve and the material passing the smallest sieve.

5.6.2 Place the fractions in separate wash containers and wash each fraction using clean water until all coatings of fines have been removed from the surface of the particles and the wash water is clear (Note 9.2).

5.7 Place each washed fraction in the oven and dry until a constant mass has been reached (Note 9.3).

5.8 Reduce each dried fraction to the required mass as per Table 2, using appropriately sized sample splitters as detailed in Test Method Q101. Combine the two fractions to produce the test portion and determine the mass of the test portion ($m_1$).

6  Procedure

6.1 Place the test portion in the porcelain jar, together with 3 litres of distilled water.

6.2 Place the lid on the porcelain jar and secure the assembly in the tumbler.

6.3 Operate the tumbler for 10,000 revolutions.

6.4 Decant the wash water from the porcelain jar into the nested 4.75 mm and 0.075 mm sieves.

6.5 Remove the larger particles from the jar by hand and place on the 4.75 mm sieve.

6.6 Wash out the jar with water and continue to wash the particles with the wash water from the jar until the water from the jar is clear.

6.7 Continue washing the particles on each sieve until the wash water passing the 0.075 mm sieve is clear.

6.8 Place the washed material into a drying tray and dry the material retained on the 0.075 mm sieve until a constant mass is reached and record the dry mass ($m_2$).

7  Calculations

7.1 Calculate the mill abrasion value as follows:

$$MA = \frac{m_1 - m_2}{m_1} \times 100$$

where

- $MA$ = Mill Abrasion value
- $m_1$ = original washed and dried test portion (g)
\[ m_2 = \text{dried sample retained 0.075 mm (g)} \]

7.2 If required, calculate the Abrasion Number using the results from the Los Angeles Test and the Mill Abrasion Test as follows:

\[ AN = \text{LAA} + (5 \times \text{MA}) \]

where

- \( AN \) = Abrasion Number
- \( \text{LAA} \) = Los Angeles Abrasion value (from test method AS 1141.23)
- \( \text{MA} \) = Mill Abrasion value

8 Reporting

Report the following values:

8.1 Report the Mill Abrasion value to the nearest 0.1.

8.2 Report the Abrasion Number to the nearest whole number, if required.

9 Notes on method

9.1 The scalping process is intended to simulate the anticipated quarry practice by removing from the sample such material which would not be representative of the quarried product. The aperture of the scalping screen should be selected on this basis.

9.2 Some discrete rock particles will slowly break down when agitated in water. This is evidenced by discolouration of the wash water. In such cases, discontinue washing after all coatings of fines have been removed.

9.3 Each fraction is considered to have reached a constant mass when the difference between successive weighings, after a further 1 hour drying at 105-110°C, is not more than 1 percent of the total of the previous moisture losses.

Table 1 – Working tolerances for apparatus

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Value</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mill abrasion tumbler</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed (rpm)</td>
<td>33</td>
<td>±2</td>
</tr>
<tr>
<td>Porcelain Jar</td>
<td></td>
<td></td>
</tr>
<tr>
<td>External diameter (mm)</td>
<td>230</td>
<td>±10</td>
</tr>
<tr>
<td>Volume (L)</td>
<td>5</td>
<td>nominal</td>
</tr>
</tbody>
</table>

Table 2 – Mass of fractions required for test portion

<table>
<thead>
<tr>
<th>Particle size (mm)</th>
<th>Mass of fraction (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>37.5 – 26.5</td>
<td>1500 ± 15</td>
</tr>
<tr>
<td>26.5 – 19.0</td>
<td>1500 ± 15</td>
</tr>
</tbody>
</table>

Superseded
Test Method Q229A: Resistance to degradation by abrasion of fine aggregate

1 Source
This method is based on a test method ASTM D7428: Resistance of fine aggregate to degradation by abrasion in the Micro-Deval apparatus. It differs from this procedure in the sizing of test fraction, not using a reference aggregate, performing the test in duplicate and other minor procedural variations.

2 Scope
This method describes the procedure for determining the resistance to abrasion of fine aggregate using a wet attrition technique. The method uses a combination of abrasion and grinding with steel balls in the presence of water using a Micro-Deval apparatus.

3 Apparatus
Where appropriate, the working tolerances of particular apparatus are contained in Table 1.

The following apparatus is required:

3.1 Drying oven of suitable capacity, having a temperature of 105-110°C and complying with AS 1141.2.

3.2 Sieves:
3.2.1 4.75 mm, 2.36 mm, 1.18 mm, 0.600 mm, 0.300 mm, 0.150 and 0.075 mm as required, complying with AS 1152.
3.2.2 Reinforced 0.075 mm sieve complying with AS 1152 (Note 9.1).

3.3 Containers suitable for washing test fractions.

3.4 Balance of suitable capacity, having a resolution of at least of 0.1 g and a limit of performance within the range of ± 0.5 g.

3.5 Sample splitters.

3.6 Measuring cylinder of suitable capacity with graduations no larger than 50 mL.

3.7 Micro-Deval abrasion machine capable of revolving a 5 litre abrasion jar about its longitudinal axis at 100 ± 5 revolutions per minute for a total of 1,500 revolutions.

3.8 Abrasion jar, stainless steel of 5 litre capacity fitted with a lid to hold water. The jar shall have an external diameter of 198 mm and an internal height of 173.5 mm. The inside and outside surfaces shall be smooth and have no observable ridges or indentations.

3.9 Abrasion charge consisting of stainless steel ball of 9.5 mm diameter and sufficient number to provide a 1250 g charge for each jar.

3.10 Oven tray.

4 Materials
The following materials are required:

4.1 Distilled water.

4.2 Silica sand.
5 Sample preparation
Prepare the sample as follows:

5.1 Prepare the bulk sample as detailed in Section 5 of Test Method Q101 to produce a representative sample of appropriate size.

5.2 Further prepare the sample to produce sufficient washed materials to produce two subsamples of the size and quantity specified in Table 2 as detailed in Test Method Q101, Subsection 6.5 for specified fraction subsamples (Note 9.2).

5.3 Place the washed subsamples in the drying oven, dry to a constant mass (Note 9.3) and allow to cool to room temperature.

5.4 Combine the washed and dried subsamples to produce the test portions.

6 Procedure
The procedure shall be as follows:

6.1 Determine the mass of the test portion (m₁).

6.2 Place the test portion in the abrasion jar, together with 0.75 ± 0.05 litres of distilled water (Note 9.4).

6.3 Store the abrasion jar in an air-conditioned room at 23 ± 3°C for at least 1 hour.

6.4 Add the mass of charge specified in Table 2 to the abrasion jar. Place the lid on the abrasion jar and place the abrasion jar in the abrasion machine.

6.5 Operate the machine for the appropriate number of revolutions specified in Table 2.

6.6 Remove the abrasion jar from the machine.

6.7 Decant the wash water from the abrasion jar into the nested 1.18 mm and 0.075 mm sieves.

6.8 Carefully pour the sample and abrasion charge over the sieves. Wash out the jar with water until the water from the jar is clear. Take care to remove the entire sample from the jar.

6.9 Continue washing and agitation of the particles with the wash water from the jar until the water from the jar is clear and all material smaller than 0.075 mm passes that sieve.

6.10 Remove the abrasion charge from the washed sample.

6.11 Place washed material retained on the 1.18 mm and 0.075 mm sieves in a drying tray and dry the material until a constant mass is reached and record the dry mass (m₂).

6.12 Repeat Steps 6.1 to 6.11 for the second test portion.

7 Calculations
7.1 Calculate the percent loss as follows:

\[ PL = \frac{m₁ - m₂}{m₁} \times 100 \]

where
- PL = percent loss (%)
- m₁ = original washed and dried test portion (g)
- m₂ = dried sample retained 0.075 mm (g)
7.2 Calculate the percent loss from the two test portions.

8 Reporting

Report the percent loss to the nearest 0.1%.

9 Notes on method

9.1 Because of the ease with which a 0.075 mm sieve can be damaged, the use of a special washing sieve, in which the sieve cloth is reinforced underneath with a coarser sieve or punched plate screen, is recommended.

9.2 Some discrete rock particles will slowly break down when agitated in water. This is evidenced by discolouration of the wash water. In such cases, discontinue washing after all coatings of fines have been removed.

9.3 Each fraction is considered to have reached a constant mass when the difference between successive weighings, after a further 1 hour drying at 105-110°C, is not more than 1 percent of the total of the previous moisture losses.

9.4 Before using the abrasion jar and charge for the first time, condition the abrasion jar and charge by running the apparatus with 500 g of silica sand and 0.75 litres of distilled water for four hours. It may be necessary from time to time to re-condition the abrasion jar and charge. The conditioning process should give the abrasion jar and charge a “frosted” appearance.

### Table 1 – Working tolerances for apparatus

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Value</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micro-Deval abrasion machine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed (rpm)</td>
<td>100 ±5</td>
<td></td>
</tr>
<tr>
<td>Abrasion charge</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter (mm)</td>
<td>9.5 ±0.5</td>
<td></td>
</tr>
<tr>
<td>Abrasion Jars</td>
<td></td>
<td></td>
</tr>
<tr>
<td>External diameter (mm)</td>
<td>198 ±4</td>
<td></td>
</tr>
<tr>
<td>Internal height (mm)</td>
<td>173.5 ±3.5</td>
<td></td>
</tr>
<tr>
<td>Volume (L)</td>
<td>5</td>
<td>nominal</td>
</tr>
</tbody>
</table>

### Table 2 – Mass of fractions, abrasion charge and revolutions required for test portion

<table>
<thead>
<tr>
<th>Maximum size (mm)</th>
<th>Fraction size (mm)</th>
<th>Mass of fraction (g)</th>
<th>Mass of charge (g)</th>
<th>Revolutions (rpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.75</td>
<td>4.75 - 2.36</td>
<td>50 ± 0.5</td>
<td>1250 ± 5</td>
<td>1,500 ± 10</td>
</tr>
<tr>
<td></td>
<td>2.36 – 1.18</td>
<td>125 ± 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.18 – 0.600</td>
<td>125 ± 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.600 – 0.300</td>
<td>100 ± 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.300 – 0.150</td>
<td>75 ± 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.150 – 0.075</td>
<td>25 ± 0.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Test Method Q229B: Resistance to degradation by abrasion of coarse aggregate

1 Source
This method is based on a test method AASHTO T327: Resistance of coarse aggregate to degradation by abrasion in the Micro-Deval apparatus. It differs from this procedure in the sizing of test fraction, not using a reference aggregate, performing the test in duplicate and other minor procedural variations.

2 Scope
This method describes the procedure for determining the resistance to abrasion of coarse aggregate using a wet attrition technique. The method uses a combination of abrasion and grinding with steel balls in the presence of water using a Micro-Deval apparatus.

3 Apparatus
Where appropriate, the working tolerances of particular apparatus are contained in Table 1.

The following apparatus is required:
3.1 Drying oven of suitable capacity, having a temperature of 105-110°C and complying with AS 1141.2.
3.2 Sieves, 19.0 mm, 16.0 mm, 13.2 mm, 9.50 mm, 6.70 mm, 4.75 mm and 1.18 mm as required, complying with AS 1152.
3.3 Containers suitable for washing test fractions.
3.4 Balance of suitable capacity, having a resolution of at least of 0.1 g and a limit of performance within the range of ± 0.5 g.
3.5 Sample splitters.
3.6 Measuring cylinder of suitable capacity with graduations no larger than 50 mL.
3.7 Micro-Deval abrasion machine capable of revolving a 5 litre abrasion jar about its longitudinal axis at 100 ± 5 revolutions per minute for a total of 9,500 to 12,000 revolutions.
3.8 Abrasion jar, stainless steel of 5 litre capacity fitted with a lid to hold water. The jar shall have an external diameter of 198 mm and an internal height of 173.5 mm. The inside and outside surfaces shall be smooth and have no observable ridges or indentations.
3.9 Abrasion charge consisting of stainless steel ball of 9.5 mm diameter and sufficient number to provide a 5000 g charge for each jar.
3.10 Oven tray.

4 Materials
The following material is required:

4.1 Distilled water.

5 Sample preparation
Prepare the sample as follows:
5.1 Prepare the bulk sample as detailed in Section 5 of Test Method Q101 to produce a representative sample of appropriate size.

5.2 Further prepare the sample to produce sufficient washed materials to produce two subsamples of the size and quantity specified in Table 2 as detailed in Test Method Q101, Subsection 6.5 for specified fraction subsamples (Note 9.1).

5.3 Place the washed subsamples in the drying oven, dry to a constant mass (Note 9.2) and allow to cool to room temperature.

5.4 Combine the washed and dried subsamples to produce the test portions.

6 Procedure

The procedure shall be as follows:

6.1 Determine the mass of the test portion \( (m_1) \).

6.2 Place the test portion in the abrasion jar, together with 2.00 ± 0.05 litres of distilled water.

6.3 Store the abrasion jar in an air-conditioned room at 23 ± 3°C for at least 1 hour.

6.4 Add the mass of charge specified in Table 2 to the abrasion jar. Place the lid on the abrasion jar and place the abrasion jar in the abrasion machine.

6.5 Operate the machine for the appropriate number of revolutions specified in Table 2.

6.6 Remove the abrasion jar from the machine.

6.7 Decant the wash water from the abrasion jar into the nested 4.75 mm and 1.18 mm sieves.

6.8 Carefully pour the sample and abrasion charge over the sieves. Wash out the jar with water until the water from the jar is clear. Take care to remove the entire sample from the jar.

6.9 Continue washing and agitation of the particles with the wash water from the jar until the water from the jar is clear and all material smaller than 1.18 mm passes that sieve.

6.10 Remove the abrasion charge from the washed sample.

6.11 Place washed material retained on the 4.75 mm and 1.18 mm sieves in a drying tray and dry the material until a constant mass is reached and record the dry mass \( (m_2) \).

6.12 Repeat Steps 6.1 to 6.11 for the second test portion.

7 Calculations

7.1 Calculate the abrasion loss as follows:

\[
AL = \frac{m_1 - m_2}{m_1} \times 100
\]

where

- \( AL \) = abrasion loss (%)
- \( m_1 \) = original washed and dried test portion (g)
- \( m_2 \) = dried sample retained 1.18 mm (g)
7.2 Calculate the average abrasion loss from the two test portions.

8 Reporting

Report the following:

8.1 Abrasion loss to the nearest 0.1%.

8.2 Maximum size of aggregate tested (mm).

9 Notes on method

9.1 Some discrete rock particles will slowly break down when agitated in water. This is evidenced by discolouration of the wash water. In such cases, discontinue washing after all coatings of fines have been removed.

9.2 Each fraction is considered to have reached a constant mass when the difference between successive weighings, after a further 1 hour drying at 105-110°C, is not more than 1 percent of the total of the previous moisture losses.

Table 1 – Working tolerances for apparatus

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Value</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micro-Deval abrasion machine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed (rpm)</td>
<td>100</td>
<td>± 5</td>
</tr>
<tr>
<td>Abrasion charge</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter (mm)</td>
<td>9.5</td>
<td>± 0.5</td>
</tr>
<tr>
<td>Abrasion Jars</td>
<td></td>
<td></td>
</tr>
<tr>
<td>External diameter (mm)</td>
<td>198</td>
<td>± 4</td>
</tr>
<tr>
<td>Internal height (mm)</td>
<td>173.5</td>
<td>± 3.5</td>
</tr>
<tr>
<td>Volume (L)</td>
<td>5</td>
<td>nominal</td>
</tr>
</tbody>
</table>

Table 2 – Mass of fractions, abrasion charge and revolutions required for test portion

<table>
<thead>
<tr>
<th>Maximum size (mm)</th>
<th>Fraction size (mm)</th>
<th>Mass of fraction (g)</th>
<th>Mass of charge (g)</th>
<th>Revolutions (rpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>19.0</td>
<td>19.0 – 16.0</td>
<td>375 ± 1</td>
<td>5000 ± 5</td>
<td>12,000 ± 100</td>
</tr>
<tr>
<td></td>
<td>16.0 – 13.2</td>
<td>375 ± 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>13.2 – 9.5</td>
<td>750 ± 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16.0</td>
<td>13.2 – 9.5</td>
<td>750 ± 3</td>
<td>5000 ± 5</td>
<td>10,500 ± 100</td>
</tr>
<tr>
<td></td>
<td>9.5 – 6.7</td>
<td>375 ± 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6.7 – 4.75</td>
<td>375 ± 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13.2</td>
<td>9.5 – 6.7</td>
<td>750 ± 3</td>
<td>5000 ± 5</td>
<td>9,500 ± 100</td>
</tr>
<tr>
<td></td>
<td>6.7 – 4.75</td>
<td>750 ± 3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Test Method Q230: Particle size distribution and shape – rock

1 Source
This method applies the principles of ASTM Test Method D5519: Standard Test Method for Particle Size Analysis of Natural and Man-Made Riprap Materials and AS 1141.14: Particle shape by proportional caliper.

2 Scope
This method describes the procedure for taking samples of rock to be used for products such as rock pitching, rip rap, gabion rock, mattress rock and spill through rock to determine, in the field, the particle size distribution and if required the shape of the rock.

3 Definitions
3.1 Elongated rock is one having a ratio of length to width greater than the calliper ratio adopted.
3.2 Flat rock is one having a ratio of width to thickness greater than the calliper ratio adopted.
3.3 Flat and elongated rock is one having a ratio of length to width and a ratio of width to thickness greater than the calliper ratio adopted.
3.4 Length, width and thickness are, respectively, the greatest, intermediate and least dimensions of any rock, as measured along mutually perpendicular directions, that is, they are the principal dimensions of the circumscribing rectangular prism.
3.5 Non-cubical rock is one having a ratio of length to thickness greater than the calliper ratio adopted.

4 Apparatus
Where appropriate, the working tolerances of particular apparatus are contained in Tables 1 and 2.

The following apparatus is required:

4.1 Weighing device:
4.1.1 Platform balance of suitable capacity, with a readability and limit of performance of not less than the requirements of Table 1, or
4.1.2 Registered weighbridge of suitable capacity, with a verified scale interval (e) of at least 20 kg and a maximum permissible error (MPE) within the range of ± 100 kg.

4.2 Sieves and/or templates:

4.3 Single opening templates made from steel rod or bar or similar rigid material, with square apertures of 500 mm, 300 mm, 250 mm, 200 mm and 150 mm. Hand grips or handle may be added for ease of use.

4.4 Sieves, perforated plate sieves, 120 mm, 100 mm and 75.0 mm complying with AS 1152.

4.5 Transport vehicle capable of conveying the individual or groups of the individual sorted rock from the sampling point to the test area and from the test area to the weighbridge.

4.6 Handling equipment such as forklift or loaders, or similar, for sampling, transporting, assisting in the sorting, loading for transport, weighing and other tasks associated with the test.

4.7 Tape measure for determining particle size dimensions to estimate mass.
4.8 Test area, sufficiently large to allow placement of the test sample, areas, bins or containers to place the sorted materials and adequate to allow the transport vehicle and handling equipment to operate safely. The test area should have a smooth surface, such as concrete, to prevent the loss of fines and provide a suitable working surface.

4.9 Proportional callipers, of suitable size with ratio’s of 2:1 and 3:1.

4.10 Containers suitable for holding and weighing finer fractions.

4.11 Spray paint for marking larger rock.

4.12 Tags and markers or small signs for identifying fractions.

4.13 Hand tools including crowbars, shovels and so on.

4.14 Gloves, glasses and dust masks.

5 Sampling

5.1 Taking into account the type of material to be sampled and the type and scope of testing, prepare a sampling plan to provide a representative sample of the material. The plan must be appropriate for existing conditions, available resources and requirements of the specification. The sampling process must provide a representative sample of the material.

5.2 Using a tape measure estimate the maximum particle size within the material. Determine the minimum mass of sample from Table 1 or by calculation (Note 10.1).

5.2.1 Determine the mass of the empty truck from a registered weighbridge \( m_1 \) or the mass of empty containers using a balance \( m_1 \).

5.2.2 A single sample is taken for testing and placed in the transport vehicle or containers.

5.2.3 Determine the mass of the truck and sample \( m_2 \) from a registered weighbridge or the mass of containers and sample using a balance \( m_2 \).

6 Procedure

6.1 Particle size distribution

6.1.1 In order to determine the sieves/templates required, it is necessary to consult any applicable specification for the material under test. The number of sieves/templates used should not be less than four.

6.1.2 Move the sample to the test location and for samples with rocks larger than 200 mm spread the sample in a thin layer.

6.1.3 Determine the mass of the truck/containers to be used for holding each fraction and record the mass \( m_3 \).

6.1.4 Place each individual rock on a sieve or template to determine the sizes that the rock will pass and be retained on. Alternately the template may be placed over the rock to determine its size. If rock shape is being determined as detailed in Subsection 6.2, test each rock with the proportional calliper to determine if it is flat, elongated and flat and elongated.

6.1.5 Either place the rocks into separate piles or containers for each fraction. Tools or mechanical equipment may be used to move larger rocks, or alternatively, larger rocks may be marked using a colour code rather than sorting and moving them. This eliminates the need to move a rock before loading and weighing. If rock shape is being determined as detailed in Subsection...
6.2, it may be necessary further separate each fraction into additional piles or containers for the flat, elongated and flat and elongated rocks.

6.1.6 As each container is filled, weigh on the balance and record the mass of the container and fraction \( m_a \).

6.1.7 For coarse fractions, load the material for a fraction onto the truck. Determine the mass of the truck and fraction from a registered weighbridge \( m_a \).

6.1.8 Continue size separation and weighing until the total gradation sample has been processed.

6.2 Particle shape

6.2.1 Include all fractions which constitute ten or more percent of the sample mass and are larger than 75.0 mm.

6.2.2 Select the proportional calliper with the required ratio (Note 10.2).

6.2.3 Test each of the rocks in each of the fractions prepared for measurement, using the proportional calliper as follows:

a) Set the largest opening equal to the width of the rock. If the thickness of the rock can be placed within the smaller opening, the particle is deemed to be flat.

b) Set the largest opening equal to the length of the rock. If the width of the rock can be placed within the smaller opening, the particle is deemed to be elongated.

c) Set the largest opening equal to the length of the rock. If the thickness of the rock can be placed within the smaller opening, the particle is deemed to be non-cubical.

d) Retain the rocks and sort the rocks in each fraction being measured into the following four types, flat, elongated, flat and elongated, non-cubical and neither flat nor elongated nor non-cubical.

6.2.4 Determine the masses of the flat \( m_3 \), elongated \( m_4 \), flat and elongated types \( m_5 \) and non-cubical \( m_6 \).

7 Calculations

7.1 Particle size distribution

7.1.1 Calculate the mass retained for each fraction as follows:

\[
m_r = \sum (m_a - m_c)
\]

where \( m_r \) = individual mass retained for each fraction (kg)
\( m_a \) = mass of truck/container and fraction (kg)
\( m_c \) = mass of truck/container (kg)

7.1.2 Calculate the cumulative mass retained for each fraction as follows:

\[
M = \sum m_r
\]

where \( M \) = cumulative mass retained in each fraction (kg)
\( m_r \) = individual mass retained for each fraction (kg)
7.1.3 Calculate the cumulative percent retained for each fraction as follows:

\[ P_r = \frac{100M}{\sum (m_2 - m_i)} \]

where

- \( P_r \) = cumulative percent retained for each fraction (%)
- \( M \) = cumulative mass retained in each fraction (kg)
- \( m_2 \) = mass of truck/container and sample (kg)
- \( m_i \) = mass of truck/container (kg)

7.1.4 Calculate the percent passing each fraction (to nearest 0.1%) as follows:

\[ P = 100 - P_r \]

where

- \( P \) = cumulative percent passing for each fraction (%)
- \( P_r \) = cumulative percent retained for each fraction (%)

7.2 Misshapen rocks

7.2.1 Calculate the total mass of sample to be from the particle size distribution from fractions which constitute ten or more percent of the sample mass and are larger than 75.0 mm as follows:

\[ M_T = \sum m_i \]

where

- \( M_T \) = mass of sample from particle size distribution (kg)
- \( m_i \) = individual mass retained for each test fraction (kg)

7.2.2 For each test fraction calculate the percentage of flat rocks as follows:

\[ P_f = \frac{m_f}{m_i} \times 100 \]

where

- \( P_f \) = percentage of flat rocks
- \( m_f \) = mass of flat rocks in each test fraction (kg)
- \( m_i \) = individual mass retained for each test fraction (kg)

7.2.3 For each test fraction calculate the percentage of elongated rocks as follows:

\[ P_e = \frac{m_e}{m_i} \times 100 \]

where

- \( P_e \) = percentage of elongated rocks
- \( m_e \) = mass of elongated rocks in each test fraction (kg)
- \( m_i \) = individual mass retained for each test fraction (kg)
7.2.4 For each test fraction calculate the percentage of flat and elongated rocks as follows:

\[ p_{fe} = \frac{m_s}{m_r} \times 100 \]

where  
- \( p_{fe} \) = percentage of flat and elongated rocks 
- \( m_s \) = mass of flat and elongated rocks in each test fraction (kg) 
- \( m_r \) = individual mass retained for each test fraction (kg)

7.2.5 For each test fraction calculate the percentage of non-cubical rocks as follows:

\[ p_{nc} = \frac{m_6}{m_r} \times 100 \]

where  
- \( p_{nc} \) = percentage of non-cubical rocks 
- \( m_6 \) = mass of non-cubical rocks in each test fraction (kg) 
- \( m_r \) = individual mass retained for each test fraction (kg)

7.2.6 For each test fraction calculate the weighted percentage of flat rocks as follows:

\[ p_{wfr} = \frac{p_f m_r}{M_T} \]

where  
- \( p_{wfr} \) = weighted percentage of flat rocks 
- \( p_f \) = percentage of flat rocks 
- \( m_r \) = individual mass retained for each test fraction (kg) 
- \( M_T \) = mass of sample from particle size distribution (kg)

7.2.7 For each test fraction calculate the weighted percentage of elongated rocks as follows:

\[ p_{we} = \frac{p_e m_r}{M_T} \]

where  
- \( p_{we} \) = weighted percentage of elongated rocks 
- \( p_e \) = percentage of elongated rocks 
- \( m_r \) = individual mass retained for each test fraction (kg) 
- \( M_T \) = mass of sample from particle size distribution (kg)
7.2.8 For each test fraction calculate the weighted percentage of flat and elongated as follows:

\[ P_{Wfe} = \frac{P_{fe} \cdot m_r}{M_T} \]

where
- \( P_{Wfe} \) = weighted percentage of flat and elongated rocks
- \( P_{fe} \) = percentage of flat and elongated rocks
- \( m_r \) = individual mass retained for each test fraction (kg)
- \( M_T \) = mass of sample from particle size distribution (kg)

7.2.9 For each test fraction calculate the weighted percentage of flat and elongated as follows:

\[ P_{Wnc} = \frac{P_{nc} \cdot m_r}{M_T} \]

where
- \( P_{Wnc} \) = weighted percentage of non-cubical rocks
- \( P_{nc} \) = percentage of non-cubical rocks
- \( m_r \) = individual mass retained for each test fraction (kg)
- \( M_T \) = mass of sample from particle size distribution (kg)

7.3 Calculate the misshapen rocks as follows:

\[ MR = P_{WF} + P_{We} + \sum P_{Wfe} \]

where
- \( MR \) = misshapen rocks (%)
- \( P_{WF} \) = weighted percentage of flat rocks
- \( P_{We} \) = weighted percentage of elongated rocks
- \( P_{Wfe} \) = weighted percentage of flat and elongated rocks

7.4 Calculate the non-cubical rocks as follows:

\[ NCR = \sum P_{Wnc} \]

where
- \( NCR \) = non-cubical rocks (%)
- \( P_{WF} \) = weighted percentage of flat rocks
- \( P_{We} \) = weighted percentage of elongated rocks
- \( P_{Wfe} \) = weighted percentage of flat and elongated rocks
8 Records

Record the following information for each sample.

8.1 Date of sampling.
8.2 Material type.
8.3 Source of material.
8.4 Nominal size (mm).
8.5 Sampling location including GPS reference if required.
8.6 Amount of material represented.
8.7 For material sampled in stockpile, the lot identification.
8.8 Name of sampler.
8.9 Reference to the sampling plan.
8.10 For material in a stockpile, a dimensioned plan of the lot showing sample location together with points of reference.
8.11 Any other relevant information.

9 Reporting

9.1 For sampling report the following:

9.1.1 Date of sampling.
9.1.2 Material type.
9.1.3 Source of material.
9.1.4 Sampling location.
9.1.5 Lot identification.
9.1.6 Reference to the sampling plan.

9.2 For testing report the following values and information:

9.2.1 The percent passing each fraction shall be reported to the nearest 1 percent.
9.2.2 The misshapen rocks in the sample to the nearest 1 percent (if required).
9.2.3 The weighted percentage of flat, elongated and flat and elongated rocks and non-cubical rocks to the nearest 0.1 percent (if required).
9.2.4 Calliper ratio’s used.

10 Notes on method

10.1 The mass of the test sample should be large enough to ensure a representative gradation is obtained with a desired level of accuracy. It should be large enough so that the addition or loss of the largest rock would not change the results by more than a specified percentage. For example if the largest expected rock is 400 mm, then to provide an effect on the test results of 1% or less the sample size should be greater than 13,164 kg while an effect of 2% or less would require a sample size of 6,582 kg. Sample size can be calculated as follows:
\[ m_{\text{min}} = \frac{1}{2} \left( 1 + \frac{\pi}{6} \right) D^2 \rho_{\text{st}} 1000 \frac{100}{P} \]

where

- \( m_{\text{min}} \) = minimum sampler size (kg)
- \( D \) = diameter of largest expected rock (m)
- \( \rho_{\text{st}} \) = apparent particle density (t/m³)
- \( P \) = effect on accuracy of addition/loss of largest rock (%)

For Table 1 of this method the effect on accuracy is assumed to be 2% and the apparent particle density is 2.700 t/m³.

10.2 A separate calliper ratio may be required for non-cubical rocks.

**Table 1 – Test portion and balance requirements**

<table>
<thead>
<tr>
<th>Maximum particle size (mm)</th>
<th>Minimum test portion mass (kg)</th>
<th>Balance resolution (kg)</th>
<th>Balance limit of performance (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>12000</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>300</td>
<td>5600</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>250</td>
<td>1600</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>200</td>
<td>800</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>150</td>
<td>300</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>120</td>
<td>150</td>
<td>0.01 ± 0.05</td>
<td>± 0.05</td>
</tr>
<tr>
<td>100</td>
<td>100</td>
<td>0.01 ± 0.05</td>
<td>± 0.05</td>
</tr>
</tbody>
</table>

**Table 2 – Template size requirements**

<table>
<thead>
<tr>
<th>Nominal aperture size (mm)</th>
<th>Tolerance for aperture (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>± 6.0</td>
</tr>
<tr>
<td>300</td>
<td>± 6.0</td>
</tr>
<tr>
<td>250</td>
<td>± 5.0</td>
</tr>
<tr>
<td>200</td>
<td>± 4.0</td>
</tr>
<tr>
<td>150</td>
<td>± 3.0</td>
</tr>
</tbody>
</table>
Materials Testing Manual

Part 7: Asphalt
Test Method Q301: Sampling of asphalt mix

This test shall be performed in accordance with AS 2891.1.1: Sampling – Loose asphalt.
Test Method Q302A: Dry coring of bound materials

This test shall be performed in accordance with AS 2891.1.2: Sampling – Coring method using the method described in Subsection 7.3.
Test Method Q302B: Wet coring of bound materials

This test shall be performed in accordance with AS 2891.1.2: Sampling – Coring method using the method described in Subsection 7.2.
Test Method Q303A: Preparation of asphalt core samples

1 Source

This method was developed in-house and applies techniques evolved through internal departmental research investigations.

2 Scope

This method describes the procedure for the preparation of asphalt core samples prior to testing. It involves cleaning, separation and sectioning of the core samples as appropriate.

3 Apparatus

The following apparatus is required:

3.1 Hammer and bolster (optional).
3.2 Masonry saw (optional).
3.3 Stiff wire brush.
3.4 Marking crayon.

4 Procedure

Prepare the core sample using either a hammer and bolster, or masonry saw as follows.

4.1 Hammer and bolster

4.1.1 Remove any base material, seal, tack coat or other foreign matter from the core sample using the hammer and bolster. Care must be taken when chipping to avoid damaging the sample.

4.1.2 Brush the top and bottom surfaces of the core sample with the wire brush to remove any remaining foreign matter and to expose fresh binder.

4.1.3 Where different asphalt layers within the core sample are required to be separated, perform the following procedure:
   a) Place the bolster along the junction of the two layers and strike firmly with the hammer.
   b) Rotate the sample through 180° and repeat Step 4.1.3 a).
   c) Rotate the sample through 90° and repeat Step 4.1.3 a).
   d) Repeat Steps 4.1.3 b) and 4.1.3 c) until the two layers are separated.

4.1.4 If required, air dry the core sample or core sample sections as appropriate to constant mass (Note 5.1).

4.1.5 Mark the core sample or core sample sections as appropriate with an identification number.

4.2 Masonry saw

4.2.1 Cut any base material, seal, tack coat or other foreign matter from the core sample using the masonry saw, ensuring that as much of the sample as possible remains (Notes 5.2, 5.3 and 5.4).
4.2.2 Where the core sample is required to be sectioned or where different asphalt layers within the core sample are required to be separated, perform the following procedure:
   a) Cut the core sample at the required position(s) using the masonry saw (Notes 5.2 and 5.3).
   b) Remove any loose material from the cut section(s) using the wire brush.
4.2.3 If required, air dry the core sample or core sample sections as appropriate to constant mass (Note 5.1).
4.2.4 Mark the core sample or core sample sections as appropriate with an identification number.

5 Notes on method
5.1 The core sample must be dry if the tests to be performed on it may be influenced by moisture content, for example, compacted density, voids properties. When air drying, a core sample is considered to have reached a constant mass when the difference between successive weighings, after a further 24 hours drying, is not more than 0.03 percent.
5.2 Where the cutting depth of the saw blade is smaller than the diameter of the core sample, the sample shall be rotated slowly during the cutting process.
5.3 Either water or dry ice can usually be used to cool the saw blade. Where the core sample is to be tested for properties which may be affected by water penetration into the sample, for example, compacted density, voids properties, cooling by dry ice is preferred. Otherwise, the core sample shall be air dried to constant mass in accordance with Note 5.1.
5.4 The intention is that all material not belonging to the asphalt layer is removed. This may result in the loss of some of the asphalt from the layer. Where measurement of layer thickness is required, such measurement will then need to be performed prior to cutting the core sample.
Test Method Q303B: Preparation of asphalt mix from a core sample

1 Source
This method was developed in-house using basic asphalt sampling principles and techniques evolved through internal departmental research investigations.

2 Scope
This method describes the procedure for obtaining a representative sample of the asphalt within a compacted asphalt pavement from a core sample taken from the pavement.

3 Apparatus
The following apparatus is required:

3.1 Oven, of suitable capacity, having a temperature of about 150°C.
3.2 Sampling tube, rigid metal tube of 125 mm internal diameter having a bevelled or sharpened edge at one end and a length of about 200 mm.
3.3 Sample tray, a flat-bottomed tray of sufficient capacity to contain the mix comprising the asphalt core sample.

4 Procedure
The procedure shall be as follows:

4.1 Determine which of the top and bottom surfaces of the core sample has the greater surface texture and place the core sample on the sample tray with this surface downwards.
4.2 Place the sample tray containing the core sample in the oven.
4.3 Heat the core sample just sufficiently to allow ready separation of the mix particles without binder drainage or loss of shape (Note 5.1).
4.4 Remove the sample tray containing the softened but intact core sample from the oven.
4.5 Carefully position the bevelled or sharpened end of the sampling tube centrally against the upper surface of the core sample. With sufficient downward force and gentle rotation back and forth, carefully ease the sampling tube through the entire length of the core sample, progressively removing material on the outside of the tube and ensuring that:
   a) if most of a particle is on the inside of the tube, the particle is included with the mix within the tube
   b) if most of a particle is on the outside of the tube, the particle is included with the mix outside the tube, and
   c) if a particle is bisected by the tube, the particle should be included with the mix either within the tube or outside the tube so that 50% of all such particles are included with the mix within the tube and 50% with the mix outside the tube.
4.6 Discard all mix outside the sampling tube.
4.7 Retain the mix within the sampling tube as a representative portion of the mix within the core sample.
5 Notes on method

5.1 The heating time will vary according to the sample dimensions. For 150 mm diameter core samples, a heating time of 15 to 30 minutes at 150°C is usually adequate.
Test Method Q304A: Permeability of asphalt - ponding method

1 Source
This method was developed in-house using techniques evolved through internal departmental research investigations (Waters, T.J., “Permeability of Asphalt – Ponding Method”, Report TT306, 1999).

2 Scope
This method describes the procedure for the laboratory determination of the permeability of asphalt using the ponding method. It is applicable to cylindrical asphalt specimens of 100 mm or 150 mm diameter which have been either cored from the pavement or manufactured in the laboratory. It is restricted to asphalt having permeability values within the range of 0.1 to 3000 µm/s.

3 Apparatus
The following apparatus is required:

3.1 Balance of suitable capacity, with a resolution of at least 0.1 g and with a limit of performance within the range of ± 0.5 g.

3.2 Laboratory permeameter, a clear perspex cylinder of known internal diameter having a wall thickness of about 3 mm and a length of 225 mm with etched measuring marks at 165 mm and 185 mm (Figure 1). The external diameter of the cylinder shall be either 100 mm or 150 mm, matching the diameter of the asphalt specimen.

3.3 Funnel, of appropriate dimensions to contain the asphalt specimen (Figure 1).

3.4 Tripod, of appropriate dimensions to support the collection funnel, sample and cylinder above the beaker.

3.5 Beaker, of 200 mL capacity.

3.6 Container, of 1 L capacity and fitted with a pouring lip.

3.7 Stopwatch or other suitable timing device, with a resolution not exceeding 0.1 seconds.

3.8 Spatula, to apply silicone sealant to the cylinder and sample.

3.9 Calliper, suitable for measuring the dimensions of the asphalt specimen, with a resolution not exceeding 0.1 mm and complying with AS 1984 or JIS B 7507.

4 Materials
4.1 Silicone sealant (Note 8.1).

5 Procedure
The procedure shall be as follows:

5.1 If the specimen is not dry or has been extracted using Test Method Q302B, air dry the specimen to constant mass (Note 8.2).

5.2 Measure the thickness of the specimen using the calliper at eight evenly distributed points around the perimeter and calculate the average thickness to the nearest 0.1 mm.

5.3 Measure the diameter of the specimen using the calliper at four evenly distributed points around the perimeter and calculate the average diameter to the nearest 0.1 mm.
5.4 Apply a thin layer of silicone sealant to completely seal the circumferential wall of the asphalt specimen.

5.5 Apply silicone sealant to the bottom edge of the cylinder and place the cylinder centrally on top of the specimen. Use additional sealant as required to seal the join between the cylinder and the specimen, ensuring that the sealant does not penetrate inside the cylinder.

5.6 Allow the silicone sealant to cure to a firm and tack-free state.

5.7 Position the funnel in the tripod and then seat the test specimen and attached cylinder in the funnel in an upright position.

5.8 Using the container, pour water into the cylinder until the water level is above 185 mm.

5.9 Allow the water to run through the specimen for 5 minutes or until the water level drops about 50 mm (Note 8.3).

5.10 Pour additional water into the cylinder until the water level is just above 185 mm.

5.11 Record the time taken for the water level to drop from 185 mm to 165 mm to the nearest 0.1 seconds.

5.12 Repeat Steps 5.10 to 5.11 twice (Notes 8.4 and 8.5).

6 Calculations

6.1 Calculate the average of the three time measurements to the nearest 0.1 seconds.

6.2 Calculate the volume of the cylinder between the 165 mm and 185 mm marks to the nearest 0.1 mL as follows:

\[ V = \frac{\pi D^2}{200} \]

where \( V \) = volume of cylinder between 165 mm and 185 mm marks (mL), \( D \) = internal diameter of cylinder (mm)

6.3 Calculate the flow rate as follows (Note 8.5):

\[ F = \frac{V}{t} \]

where \( F \) = flow rate (mL/s), \( V \) = volume of cylinder between 165 mm and 185 mm marks (mL), \( t \) = average time for water level to drop from 185 mm to 165 mm (s)

6.4 Calculate the effective head of water as follows (Note 8.5):

\[ h_e = \frac{h_1 + h_2}{2} \]

where \( h_e \) = effective head (mm), \( h_1 \) = initial head (mm), \( h_2 \) = final head (mm)
In the usual case when the initial head is 185 mm and the final head is 165 mm, the effective head will be 175 mm.

6.5 Calculate the hydraulic gradient as follows:

\[ i = \frac{h_e + L}{L} \]

where
- \( i \) = hydraulic gradient
- \( h_e \) = effective head (mm)
- \( L \) = thickness of specimen (mm)

6.6 Calculate the cross-sectional area of the specimen as follows:

\[ A_s = \left( \frac{\pi D_s^2}{4} \right) \times 10^{-6} \]

where
- \( A_s \) = cross-sectional area of specimen (m²)
- \( D_s \) = diameter of specimen (mm)

6.7 Calculate the permeability as follows:

\[ k = \frac{F}{A_s i} \]

where
- \( k \) = permeability (µm/s)
- \( F \) = flow rate (mL/s)
- \( A_s \) = cross-sectional area of specimen (m²)
- \( i \) = hydraulic gradient

7 Reporting

Report the following values and general information:

7.1 Whether the sample is a core or a laboratory prepared specimen.
7.2 Test location including a longitudinal (chainage) and a lateral (offset) reference, where the sample is a core.
7.3 Mix and compaction details, where the sample is a laboratory prepared specimen.
7.4 Permeability to three significant figures (µm/s).
7.5 The permeability category and description (Table 1).

8 Notes on method

8.1 Before handling the silicone sealant, the operator must consult the relevant Safety Data Sheet (SDS).
8.2 A sample is considered to have reached a constant mass when the difference between successive weighings, after a further 24 hours air drying, is not more than 0.03 percent.
8.3 If there is no change in the water level after 5 minutes, omit Steps 5.10 to 5.12 and Clause 6, and record the permeability as 0 µm/s.

8.4 For asphalt of very low permeability (Table 1), a single time measurement will suffice and Steps 5.12 and 6.1 may be omitted.

8.5 Steps 5.10 to 5.12 provide a measure of the flow rate of water through the specimen. Where the flow rate is slow (say less than 0.05 mL/s), an alternative approach may be used involving a single measurement of the volume of water collected in a beaker positioned beneath the specimen over a specified time period. The effective head will then be the average of the initial and final head over the period when the water volume is collected beneath the specimen.

Table 1 – Permeability category and description

<table>
<thead>
<tr>
<th>Permeability (µm/s)</th>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-</td>
<td>Impermeable</td>
</tr>
<tr>
<td>0.01 - 0.10</td>
<td>A1</td>
<td>Very low permeability</td>
</tr>
<tr>
<td>0.11 - 1.00</td>
<td>A2</td>
<td>Low permeability</td>
</tr>
<tr>
<td>1.00 - 10.0</td>
<td>B</td>
<td>Moderately permeable</td>
</tr>
<tr>
<td>10.1 - 100</td>
<td>C</td>
<td>Permeable</td>
</tr>
<tr>
<td>101 - 1000</td>
<td>D</td>
<td>Moderately free draining</td>
</tr>
</tbody>
</table>
Figure 1 – Laboratory permeameter

(Directions in millimetres)
Test Method Q304B: Assessment of asphalt permeability

1 Source
This method was developed in-house but utilises test specimen preparation based on AS 2891.2.2: Sample preparation - Compaction of asphalt test specimens using a gyratory compactor, and permeability testing in accordance with Test Method Q304A.

2 Scope
This method sets out the procedure for determining the permeability of asphalt mix corresponding to a specific level of relative compaction. It involves establishing the relationship between permeability and air voids through permeability testing of asphalt test specimens prepared at three compaction levels using a gyratory compactor.

3 Apparatus
Where appropriate, the working tolerances of particular apparatus are contained in Table 1.

The following apparatus is required:

3.1 Gyratory compactor, capable of applying a vertical loading stress of 240 kPa to a test specimen in a mould at a rate of 60 rpm and at a fixed angle of 2° for 100 mm diameter specimens and 3° for 150 mm diameter specimens measured at the centre of the height of the mould. The compactor shall be fitted with the means for providing a continuous readout of test specimen height with the number of compaction cycles.

3.2 Specimen mould assembly, as described in AS 2891.2.2 for 100 mm and 150 mm diameter test specimens.

3.3 Wearing discs, steel discs of thickness 0.9 mm and diameter 99.8 mm or 149.8 mm as appropriate.

3.4 Specimen extractor, of suitable design to enable the test specimen to be removed intact from the mould.

3.5 Oven, thermostatically controlled at a temperature of 150°C.

3.6 Balance of a suitable capacity, having a resolution of at least 0.1 g and with a limit of performance within the range of ± 0.5 g.

3.7 Thermometer, a partial immersion thermometer or other suitable temperature measuring device having a temperature range which includes 150°C, and graduated to 1°C or less with an uncertainty of no more than 0.5°C.

3.8 Assorted mixing and handling apparatus, such as steel trays, trowels, spatulas and scoops.

4 Materials

4.1 Paper discs, having a diameter of about 100 mm.

4.2 Lubricant, suitable light oil for lubricating the paper discs (Note 8.1).

5 Procedure
The procedure shall be as follows:

5.1 Determine the maximum density of the mix in accordance with Test Method Q307A.
5.2 Select a target relative compaction level of 91% as determined in accordance with Test Method Q314.

5.3 Select the appropriate specimen mould assembly for the particular mix nominal size and place it in the oven for a period of at least 1 hour.

5.4 Remove the mould assembly from the oven and position a lubricated paper disc on the lower wearing disc in the mould.

5.5 Using the maximum density of the mix, the dimensions of the mould assembly and the test specimen height relevant to the mix nominal size in Table 2, estimate the quantity of mix required to provide the target relative compaction level.

5.6 Transfer this quantity of mix into the mould and return the mould assembly to the oven for 60 ± 10 minutes.

5.7 Remove the mould assembly from the oven, place a thermometer in the mix and measure the temperature. Provided that the temperature is within 150 ± 3°C, level the mix in the mould and place a lubricated paper disc on the mix surface (Note 8.2).

5.8 Place the upper wearing disc and top platen on the mix in the mould, position the mould assembly in the gyratory compactor and lock the mould assembly in place.

5.9 Compact the mix in the mould assembly until the test specimen height relevant to the mix nominal size in Table 2 is reached.

5.10 Remove the mould assembly from the gyratory compactor and take off the upper platen.

5.11 Allow the mould to cool sufficiently in air and then remove the test specimen from the mould using the specimen extractor, while ensuring the test specimen remains intact and shows no deformation.

5.12 Determine the compacted density and air voids of the test specimen in accordance with Test Method Q306C and Test Method Q311 respectively.

5.13 Repeat Steps 5.3 to 5.12 until three test specimens are prepared having an air voids of 9 ± 1%.

5.14 Repeat Steps 5.3 to 5.12 using a target compaction level of 93% until three test specimens are prepared having an air voids of 7 ± 1%.

5.15 Repeat Steps 5.3 to 5.12 using a target compaction level of 95% until three test specimens are prepared having an air voids of 5 ± 1%.

5.16 Remove the silicone sealant from each of the nine test specimens and determine the permeability of each in accordance with Test Method Q304A.

6 Calculations

6.1 Using the permeability and air voids results for each test specimen, determine the linear regression relationship between log permeability and air voids (Note 8.3).

6.2 Accept the relationship determined in Step 6.1 provided that its coefficient of determination ($r^2$) satisfies the relevant minimum value of Table 3. Otherwise, test additional test specimens prepared at appropriate air voids within the range of 5 to 9%, as described in Steps 5.3 to 5.12 and 5.16 to 6.1, until the requirements of Table 3 are met.

6.3 Where required, calculate the permeability value corresponding to a specific value of air voids from this relationship.
7 Reporting

Report the following:

7.1 The air voids and permeability test results for each test specimen.
7.2 The linear regression relationship between log permeability and air voids.
7.3 Where required, the permeability value corresponding to a specific value of air voids to the nearest 1 µm/s.

8 Notes on method

8.1 Before handling the oil, the operator must consult the relevant Safety Data Sheet (SDS).
8.2 If the temperature of the mix falls below the compaction temperature range, the mix may be reheated. This will involve returning the mould assembly containing the mix to the oven until it reaches oven temperature and then repeating Step 5.7.
8.3 Where a test specimen is determined to be impermeable or have very low permeability as defined in Test Method Q304A, a permeability value of 0.1 µm/s shall be assumed.

Table 1 - Specifications and working tolerances of apparatus

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Value</th>
<th>Working tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gyratory compactor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Load application rate</td>
<td>rpm</td>
<td>60</td>
<td>± 5</td>
</tr>
<tr>
<td>Wearing disk</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter</td>
<td>mm</td>
<td>99.8 or 149.8</td>
<td>± 0.1</td>
</tr>
<tr>
<td>Thickness</td>
<td>mm</td>
<td>0.9</td>
<td>± 0.02</td>
</tr>
<tr>
<td>Oven</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td>ºC</td>
<td>150</td>
<td>± 5</td>
</tr>
</tbody>
</table>

Table 2 - Test specimen height

<table>
<thead>
<tr>
<th>Mix nominal size</th>
<th>Unit</th>
<th>Value</th>
<th>Working tolerance</th>
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</thead>
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<tr>
<td>DG14</td>
<td>mm</td>
<td>50</td>
<td>± 2</td>
</tr>
<tr>
<td>DG20</td>
<td>mm</td>
<td>65</td>
<td>± 2</td>
</tr>
<tr>
<td>DG28</td>
<td>mm</td>
<td>90</td>
<td>± 2</td>
</tr>
</tbody>
</table>

Table 3 - Coefficient of determination ($r^2$) minimum values

<table>
<thead>
<tr>
<th>Number of test results</th>
<th>Minimum value</th>
<th>Number of test results</th>
<th>Minimum value</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>0.636</td>
<td>15</td>
<td>0.411</td>
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<tr>
<td>10</td>
<td>0.585</td>
<td>16</td>
<td>0.388</td>
</tr>
<tr>
<td>11</td>
<td>0.540</td>
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</tr>
<tr>
<td>12</td>
<td>0.501</td>
<td>18</td>
<td>0.348</td>
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<td>13</td>
<td>0.467</td>
<td>19</td>
<td>0.331</td>
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<tr>
<td>14</td>
<td>0.437</td>
<td>20</td>
<td>0.315</td>
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</table>
Test Method Q305: Stability, flow and stiffness of asphalt - Marshall

1 Source
This method is based on AS 2891.5: Determination of stability and flow - Marshall Procedure. It differs from this Australian Standard by extending the range of asphalt mixes tested with companion alterations to test specimen preparation, apparatus requirements and some other procedural variations.

2 Scope
This method sets out the procedure for preparing test specimens of freshly mixed asphalt (either produced in the laboratory or at a mixing plant) by the Marshall procedure and determining stability, flow and stiffness values of the specimens using the Marshall apparatus. It is applicable to asphalt mixes not exceeding 28 mm nominal size.

3 Apparatus
Where appropriate, the working tolerances of particular apparatus are contained in Tables 1, 2, 5 and Figure 1.

The following apparatus is required:

3.1 Specimen mould assembly, consisting of the following:

3.1.1 For asphalt of nominal mix size ≤ 20 mm, a cylindrical steel or brass compaction mould having an internal diameter of 101.6 mm, a height of 89 mm and a thickness of 6 mm; a mould base with a thickness of 18 mm and an extension collar having an internal diameter of 101.6 mm, a height of 70 mm and a thickness of 6 mm.

3.1.2 For asphalt of nominal mix size > 20 mm, a cylindrical steel or brass compaction mould having an internal diameter of 150.0 mm, a height of 89 mm and a thickness of 8 mm; a mould base with a thickness of 18 mm and an extension collar having an internal diameter of 150.0 mm, a height of 70 mm and a thickness of 8 mm.

3.2 Hand compaction hammer, consisting of the following:

3.2.1 For asphalt of nominal mix size ≤ 20 mm, a flat circular tamping face having a diameter of 98.5 mm, and a sliding weight with a mass of 4.53 kg and a free fall of 457 mm (Notes 9.1, 9.2 and 9.3).

3.2.2 For asphalt of nominal mix size > 20 mm, a flat circular tamping face having a diameter of 149.0 mm, and a sliding weight with a mass of 9.92 kg and a free fall of 460 mm (Notes 9.1, 9.2 and 9.3).

3.3 Hand compaction pedestal, consisting of the following:

3.3.1 For asphalt of nominal mix size ≤ 20 mm, a wooden block, of approximate dimensions 200 mm square and 450 mm thick, capped by a steel plate of approximate dimensions 300 mm square and 25 mm thick. The air dry density of the wooden block shall be 720 kg/m³. The plate shall be securely attached to the block which shall be secured to a solid concrete floor or slab. Suitable guides for restraining the compaction mould and locating the compaction hammer centrally during compaction may be attached to the block.

3.3.2 For asphalt of nominal mix size > 20 mm:
   a) a wooden block as described in Step 3.3.1, or
b) a concrete block, of approximate dimensions 360 mm square and 610 mm thick. Suitable guides for restraining the compaction mould and locating the compaction hammer centrally during compaction may be attached to the block.

3.4 Specimen extrusion jack, consisting of a hydraulic jack fitted with a plate on the ram and located within a metal frame. The dimensions of the plate shall be 100 mm diameter and 6 mm thick for 101.6 mm test specimens, and 148 mm diameter and 12 mm thick for 150 mm diameter test specimens. The frame shall retain the mould during extrusion of a test specimen.

3.5 Breaking head, consisting of upper and lower cylindrical segments each having an accurately machined inside cylinder face. The lower segment shall be mounted on a base having two perpendicular guide pins extending upwards. Guide bushes on the upper segment shall be located to direct the segments together without binding or loose motion on the guide pins.

3.6 Marshall testing machine, gear driven at a constant speed to give a rate of travel on the platen of 51 mm/min when the force is being applied, and capable of applying forces up to at least 22 kN. The machine shall be fitted with one of the following measurement systems (Note 9.4):

3.6.1 An elastic proving ring and two flow gauges. The proving ring shall be inserted between the breaking head and the loading beam or crosshead to measure the force on the test specimen. It shall have a capacity of at least 22 kN with a resolution of at least 0.002 mm and complying with a Class A device for forces up to 4.5 kN and complying with a Class B device for forces between 4.5 kN and its maximum loading. The flow gauges shall be placed on the guide pins of the breaking head and shall be capable of measuring the vertical deformation of the test specimen from the onset of load. The gauges shall have a scale interval of no more than 0.1 mm.

3.6.2 A load cell and transducer and appropriate continuous recording device of a capacity and accuracy at least equivalent to that of the proving ring and flow gauges described in Step 3.6.1.

3.7 Water bath, mechanically agitated and maintained at a temperature of 60ºC. The bath shall be at least 150 mm deep and shall be fitted with a perforated shelf about 50 mm from the bottom.

3.8 Oven, thermostatically controlled at an operating temperature corresponding to the appropriate compaction temperature specified in Table 3.

3.9 Hotplate, suitable for heating the mixing apparatus.

3.10 Balance of suitable capacity, with a resolution of at least 0.1 g and with a limit of performance within the range of ± 0.5 g.

3.11 Thermometer, a partial immersion thermometer or other suitable temperature measuring device having a temperature range which includes the appropriate range of Table 3, and graduated to 1ºC or less with an uncertainty of no more than 0.5ºC.

3.12 Measuring device, suitable for the measurement of the height of test specimens and with a resolution not exceeding 1 mm.

3.13 Marker.

3.14 Mixing apparatus, such as steel tray, steel trowel, spatulas and scoop.

4 Materials

The following materials are required:

4.1 Lubricant, suitable grease or viscous oil for lubricating the compaction moulds (Note 9.5).
4.2 Paper segments, of sufficient size to cover the mould base.

5 Preparation

Perform the following for each test specimen to be prepared:

5.1 Bring the oven to an operating temperature corresponding to the compaction temperature specified for the binder and asphalt type in Table 3.

5.2 Assemble the compaction mould (Note 9.6).

5.3 Place the compaction mould in the oven for approximately 1 hour.

5.4 Place the appropriate mixing apparatus on the hotplate.

5.5 Using the expected compacted density for the mix, calculate the required mass of the mix for the compaction mould to give the desired specimen height of 63.5 mm (Note 9.7).

5.6 Prepare the mix in accordance with Subsection 4.2 of Test Method Q301.

5.7 Remove the compaction mould from the oven and position a paper segment on the base within the mould.

5.8 Transfer the mix into the mould and level the surface of the mix, taking care to avoid segregation.

5.9 Place the mould in the oven for 60 ± 5 minutes.

5.10 Remove the mould from the oven and measure the mix temperature (Note 9.8). Provided that the temperature of the mix is within the compaction temperature range specified in Table 3, position a paper segment on the surface of the mix (Note 9.9).

5.11 Transfer the compaction mould to the compaction pedestal and compact the mix using the specified number of blows of the compaction hammer at a rate of 60 to 70 blows per minute with the hammer axis held vertically (Notes 9.2 and 9.10).

5.12 Remove the collar and base, and reassemble the compaction mould with the test specimen inverted (Note 9.11).

5.13 Compact the mix further using the specified number of blows of the compaction hammer at a rate of 60 to 70 blows per minute (Notes 9.2 and 9.10).

5.14 Remove the collar and base plate from the compaction mould and paper segments from the test specimen (where relevant), and mark the face of the test specimen clearly with an identification number (Note 9.12).

5.15 Allow the mould to cool in air and then extrude the test specimen.

6 Testing of specimens

6.1 Remove any lip formed around the edges of each test specimen without damage to the test specimen.

6.2 Measure the height of each test specimen at four points evenly spaced around the specimen and calculate the average height to the nearest 1 mm. Discard any test specimen having an average height outside the range of 57 to 70 mm (Note 9.13).

6.3 Clean the inside surfaces of the breaking head and lightly grease the guide pins.

6.4 Place the breaking head segments (where practicable) and test specimens in the water bath for 30 to 40 minutes.
6.5 Remove the breaking head segments from the water bath (where relevant) and complete Steps 6.6 and 6.7 within 30 seconds (Note 9.14).

6.6 Remove a test specimen from the water bath and place it centrally on its side in the lower segment of the breaking head. Place the upper segment of the breaking head on the test specimen and place the complete assembly centrally on the Marshall testing machine.

6.7 Zero the measurement system, start the Marshall testing machine and perform the test as follows:

6.7.1 For the proving ring and flow gauge system, apply the load until shear failure causes the proving ring dial gauge reading to decrease. Remove the flow gauges immediately from the breaking head and record the dial gauge reading to the nearest division and the flow gauge readings to the nearest 0.1 mm.

6.7.2 For the load cell and transducer system, where there is provision to capture and review load cell and transducer readings at specific time intervals, perform the following:
   a) Apply the load and record load cell and transducer readings at intervals of 0.01 s until shear failure causes the load cell reading to decrease.
   b) Determine the first four successive load cell readings where:
      i. the range of the four readings does not exceed 0.1 kN, or
      ii. the range of the four readings exceeds 0.1 kN but the fourth reading is lower than the first reading.
   c) Record the first of these four successive readings as the test load cell reading.
   d) Determine the transducer reading corresponding to the test load cell reading, adjust it for any seating error and record the adjusted reading as the test transducer reading.

6.7.3 For the load cell and transducer system, where there is no provision to capture and review load cell and transducer readings at specific time intervals, apply the load until shear failure causes the load cell reading to decrease. Record the load cell and transducer readings corresponding to the maximum load cell reading (Note 9.15).

6.8 Repeat Steps 6.6 and 6.7 for each of the remaining test specimens.

7 Calculations

7.1 Stability

7.1.1 Calculate the load (L) applied to each test specimen at shear failure to the nearest 0.1 kN using as appropriate:
   a) the recorded dial gauge reading and the calibration relationship for the proving ring as determined in Step 6.7.1, or
   b) the test load cell reading as determined in Step 6.7.2.

7.1.2 Calculate the stability of each test specimen to the nearest 0.1 kN as follows:

\[ S = LF \]

where

- \( S \) = stability of test specimen (kN)
- \( L \) = load at shear failure (kN)
- \( F \) = correction factor of Table 4 according to the height of the test specimen
7.1.3 Calculate the stability of the asphalt as the average of the test specimen stability values to the nearest 0.1 kN.

7.2 **Flow**

7.2.1 Calculate the flow of each test specimen at shear failure to the nearest 0.1 mm using as appropriate:

a) the average of the two flow gauge readings recorded in Step 6.7.1, or

b) the test transducer reading as determined in Step 6.7.2.

7.2.2 Calculate the flow of the asphalt as the average of the test specimen flow values to the nearest 0.1 mm.

7.3 **Stiffness**

Calculate the stiffness of the asphalt to the nearest 0.1 kN/mm as follows:

\[
\text{Stiffness} = \frac{\text{stability of the asphalt}}{\text{flow of the asphalt}}
\]

8 **Reporting**

Report the following:

8.1 Stability to the nearest 0.1 kN.

8.2 Flow to the nearest 0.1 mm.

8.3 Stiffness to the nearest 0.1 kN/mm.

8.4 The number of blows applied to each face of the test specimens during compaction.

9 **Notes on method**

9.1 Where a mechanical compactor is used instead of the hand compactor, the mass, free fall and design of the hammer foot should be identical to those of the hand compaction hammer and the automatic compactor should be securely anchored to a concrete base.

9.2 Where a mechanical compactor is used, it should be calibrated against hand compaction to determine the number of blows equivalent to the specified number of blows of hand compaction. Calibration checks should be performed on a regular basis and the difference between the density results obtained using the mechanical and hand compaction method should be no greater than 0.01 t/m³. Calibration should be conducted using quartered samples of the mix.

9.3 To ensure free fall of the weight is maintained, the shaft of the hammer should be thoroughly cleaned and dried after each set of compaction blows.

9.4 The apparatus described in Step 3.6.1 is unsuitable for testing stone mastic asphalt and that described in Step 3.6.2 must be used for this purpose.

9.5 Before handling the lubricant, the operator must consult the relevant Safety Data Sheet (SDS).

9.6 The cylinder, base and collar may be lightly greased prior to assembly to prevent asphalt mix adhering to the mould.

9.7 For 101.6 and 150 mm diameter moulds, approximately 1250 and 2750 g respectively are usually required.
9.8 For mixes susceptible to loss of binder by the draindown effect, for example, open graded asphalt, the mix in the mould may be tipped out, then returned to the mould and levelled to evenly distribute the binder, taking care to avoid segregation.

9.9 The paper segment may be lightly greased prior to placement on the mix to prevent asphalt mix adhering to the compaction hammer.

9.10 Where the number of blows is not specified, 50 blows shall be used.

9.11 Where the paper segments have been lightly greased, they may be removed from the test specimen.

9.12 For coarsely graded mixes, for example, open graded asphalt, removal of the base plate may be delayed until the mould has cooled.

9.13 Any discarded test specimen should be replaced with an additional test specimen prepared in accordance with Steps 5.1 to 6.2.

9.14 If Steps 6.6 and 6.7 are not completed within 30 seconds of removal from the water bath and no load has been applied to the test specimen, the breaking head (where practicable) and test specimen shall be returned to the water bath for at least 10 minutes and Steps 6.5 to 6.7 shall be repeated. If the test specimen has been removed from the water bath for more than five minutes, Steps 6.4 to 6.7 shall be repeated.

9.15 For some asphalt mix types, for example, stone mastic asphalt, the load cell reading may not decrease after shear failure. In cases where the plotted curve plateaus or continues to increase at a near constant rate following shear failure, the recorded load cell and transducer readings shall correspond to the point where the curve generally attains its ultimate constant slope. In this case, any seating error must be deducted from the transducer reading.

Table 1 – Compaction equipment dimensions

<table>
<thead>
<tr>
<th>Compaction equipment</th>
<th>Mix nominal size (mm)</th>
<th>≤ 20</th>
<th>Tolerance</th>
<th>&gt; 20</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compaction mould</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal diameter of cylinder (mm)</td>
<td>101.6</td>
<td>± 0.2</td>
<td></td>
<td>150.0</td>
<td>± 0.2</td>
</tr>
<tr>
<td>Internal diameter of collar (mm)</td>
<td>101.6</td>
<td>± 0.2</td>
<td></td>
<td>150.0</td>
<td>± 0.2</td>
</tr>
<tr>
<td>Wall thickness (mm)</td>
<td>6</td>
<td>minimum</td>
<td></td>
<td>8</td>
<td>minimum</td>
</tr>
<tr>
<td>Compaction hammer</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass of sliding weight (kg)</td>
<td>4.53</td>
<td>± 0.02</td>
<td></td>
<td>9.92</td>
<td>± 0.05</td>
</tr>
<tr>
<td>Free fall of sliding weight (mm)</td>
<td>457</td>
<td>± 1</td>
<td></td>
<td>460</td>
<td>± 3</td>
</tr>
<tr>
<td>Diameter of tamping face (mm)</td>
<td>98.5</td>
<td>± 0.1</td>
<td></td>
<td>149</td>
<td>± 0.2</td>
</tr>
<tr>
<td>Compaction pedestal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wooden block, air dry density (kg/m³)</td>
<td>720</td>
<td>± 50</td>
<td></td>
<td>720</td>
<td>± 50</td>
</tr>
</tbody>
</table>
### Table 2 – Test apparatus requirements

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Requirement</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marshall testing machine</td>
<td>51</td>
<td>± 3</td>
</tr>
<tr>
<td>Rate of travel (mm/min)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water bath</td>
<td>Temperature (ºC)</td>
<td>60</td>
</tr>
<tr>
<td>Oven</td>
<td>Temperature (ºC)</td>
<td>Table 3</td>
</tr>
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</table>

### Table 3 – Mix compaction temperatures

<table>
<thead>
<tr>
<th>Binder</th>
<th>Asphalt type</th>
<th>Compaction temperature (ºC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 170 bitumen</td>
<td>Dense graded</td>
<td>142 ± 3</td>
</tr>
<tr>
<td>Class 170 bitumen</td>
<td>Open graded</td>
<td>120 ± 3</td>
</tr>
<tr>
<td>Class 320 bitumen</td>
<td>Dense graded, stone mastic</td>
<td>150 ± 3</td>
</tr>
<tr>
<td>Class 320 bitumen</td>
<td>Open graded</td>
<td>125 ± 3</td>
</tr>
<tr>
<td>Class 600 bitumen</td>
<td>Dense graded</td>
<td>155 ± 3</td>
</tr>
<tr>
<td>M1000/320 multigrade bitumen</td>
<td>Dense graded</td>
<td>155 ± 3</td>
</tr>
<tr>
<td>Polymer modified binder</td>
<td>Dense graded, stone mastic</td>
<td>160 ± 3</td>
</tr>
<tr>
<td>Polymer modified binder</td>
<td>Open graded</td>
<td>140 ± 3</td>
</tr>
</tbody>
</table>

### Table 4 – Factors for correcting Marshall stability for specimen height

<table>
<thead>
<tr>
<th>Specimen height (mm)</th>
<th>Correction factor (F)</th>
<th>Specimen height (mm)</th>
<th>Correction factor (F)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>101.6 mm</td>
<td>150 mm</td>
<td></td>
</tr>
<tr>
<td>57</td>
<td>1.19</td>
<td>1.3</td>
<td>64</td>
</tr>
<tr>
<td>58</td>
<td>1.16</td>
<td>1.25</td>
<td>65</td>
</tr>
<tr>
<td>59</td>
<td>1.13</td>
<td>1.2</td>
<td>66</td>
</tr>
<tr>
<td>60</td>
<td>1.1</td>
<td>1.15</td>
<td>67</td>
</tr>
<tr>
<td>61</td>
<td>1.07</td>
<td>1.11</td>
<td>68</td>
</tr>
<tr>
<td>62</td>
<td>1.04</td>
<td>1.06</td>
<td>69</td>
</tr>
<tr>
<td>63</td>
<td>1.01</td>
<td>1.02</td>
<td>70</td>
</tr>
</tbody>
</table>
Figure 1 – Example of typical Marshall breaking head

Table 5 – Breaking head dimensions (mm)

<table>
<thead>
<tr>
<th>mould diameter</th>
<th>a</th>
<th>Typical dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>101.6</td>
<td>19</td>
<td>9.5</td>
</tr>
<tr>
<td>150</td>
<td>17.5</td>
<td>14.3</td>
</tr>
</tbody>
</table>
Test Method Q306A: Compacted density of dense graded asphalt - wax sealed

1 Source
This method is based on AS 2891.9.1: Determination of bulk density of compacted asphalt – waxing procedure.

2 Scope
This method describes a procedure for determining the compacted density of asphalt. It is applicable to dense graded asphalt either compacted in the laboratory or cut from the pavement.

3 Apparatus
The following apparatus is required:

3.1 Balance, a top pan balance of suitable capacity, with a resolution of at least 0.1 g and with a limit of performance within the range of ± 0.5 g. For testing in accordance with Subsection 5.2, the balance shall also be capable of below balance weighing.

3.2 Balance bench, equipped with a hole for below balance weighing.

3.3 Thermometer, a partial or total immersion thermometer or other suitable temperature measuring device having a temperature range which includes the test temperature, and graduated to 1ºC or less with an uncertainty of no more than 0.5ºC.

3.4 Attachment, a non-absorbent device to suspend the asphalt sample, for example, nylon or wire loop, wire support frame.

3.5 Paraffin wax bath, of sufficient capacity to completely contain the asphalt sample, and able to maintain the wax at a temperature of 10 ± 2ºC above its melting point.

3.6 Wire basket, able to support the asphalt sample on its side within the paraffin wax bath (Subsection 5.1.4 a) only).

3.7 Brush, a paint brush of about 13 mm width to apply the wax sealant to the sample.

3.8 Water container, fitted with an overflow and of suitable dimensions to allow the sample to be completely immersed without contacting any part of the container (Subsection 5.2 only).

3.9 Water container, of sufficient volume to contain the asphalt sample (Subsection 5.3 only).

3.10 Laboratory stand and clamp (Subsection 5.3 only).

4 Material
The following material is required:

4.1 Paraffin wax, of known density to the nearest 0.001 t/m³ (Note 8.1).

5 Procedure
The procedure shall be as follows:

5.1 Sample preparation

5.1.1 Where the sample is a core sample, prepare it in accordance with Test Method Q303A.

5.1.2 Air dry the sample to constant mass (Notes 8.2 and 8.3).

5.1.3 Determine the mass of the sample (m₁).
5.1.4 Coat the entire sample with wax using either of the following:

a) Wire basket method
   i. Place the sample on its side in the wire basket and carefully lower the sample into the wax bath until it is complete immersed (Note 8.4).
   ii. Immediately remove the wire basket and sample from the bath and allow the sample to cool (Note 8.5).
   iii. Remove the sample from the wire basket and brush molten wax from the wax bath onto any unsealed areas of the sample.
   iv. Allow the sample to cool to room temperature.

b) Hand dipping method
   i. Dip the sample in the wax bath to half sample height (Note 8.6).
   ii. Remove the sample from the wax bath and allow the wax to cool, ensuring no contact between the wax and any other surface (Note 8.5).
   iii. Dip the sample in the wax bath to coat the unwaxed portion of the sample (Note 8.6).
   iv. Remove the sample from the wax bath and allow the wax to cool to room temperature, ensuring no contact between the cooling wax and any other surface (Note 8.5).
   v. Where required, brush molten wax from the wax bath onto any unsealed areas of the sample and allow the wax to cool to room temperature.

5.1.5 Determine the mass of the sealed sample ($m_2$).

5.2 Density measurement using below balance weighing

5.2.1 Place the container directly below the hole in the balance bench, fill it until water escapes from the overflow and allow the excess water to run to waste.

5.2.2 When water has ceased dripping from the overflow, fit the attachment to the balance, allow the remainder of the attachment to be immersed in the water container, and zero the balance.

5.2.3 Using the attachment, suspend the sealed sample from the balance and gently lower it into the water container until completely immersed, taking care to ensure that the suspended sample hangs free of the sides and bottom of the container.

5.2.4 Add additional water if necessary until water escapes from the overflow, and allow the excess water to run to waste.

5.2.5 When water has ceased dripping from the overflow, determine the mass of the immersed sealed sample ($m_3$).

5.2.6 Record the temperature of the water in the container to the nearest 1ºC.

5.3 Density measurement using above balance weighing

5.3.1 Add sufficient water to the container to completely immerse the sample. Place the container and water on the balance and zero the balance.

5.3.2 Position the laboratory stand and clamp so that the clamp is directly above the container on the balance.
5.3.3 Suspend the sealed sample from the clamp and gently lower it into the water container until completely immersed, taking care to ensure that the suspended sample hangs free of the sides and bottom of the container.

5.3.4 Determine the mass of the immersed sealed sample and attachment \( m_3 \), noting the height of water on the attachment at the time of weighing.

5.3.5 Remove the sample from the water container and zero the balance.

5.3.6 With the attachment immersed to the same depth as noted in Step 5.3.4, determine the mass of the suspended attachment \( m_4 \).

5.3.7 Record the temperature of the water in the container to the nearest 1°C.

6 Calculations

6.1 Below balance weighing

Calculate the compacted density of the sample as follows:

\[
D_c = \frac{m_1}{\frac{(m_3-m_1)}{D_w} - \frac{(m_2-m_1)}{D_s}}
\]

where

- \( D_c \) = compacted density of sample \((t/m^3)\)
- \( m_1 \) = mass of sample \((g)\)
- \( m_2 \) = mass of sealed sample \((g)\)
- \( m_3 \) = mass of immersed sealed sample \((g)\)
- \( D_w \) = density of water at test temperature \((t/m^3)\) (Table 1)
- \( D_s \) = density of wax sealant \((t/m^3)\)

6.2 Above balance weighing

Calculate the compacted density of the sample as follows:

\[
D_c = \frac{m_1}{\frac{(m_3-m_1)}{D_w} - \frac{(m_4-m_1)}{D_s}}
\]

where

- \( D_c \) = compacted density of sample \((t/m^3)\)
- \( m_1 \) = mass of sample \((g)\)
- \( m_2 \) = mass of sealed sample \((g)\)
- \( m_3 \) = mass of immersed sealed sample and attachment \((g)\)
- \( m_4 \) = mass of immersed attachment \((g)\)
- \( D_w \) = density of water at test temperature \((t/m^3)\) (Table 1)
\[ D_s = \text{density of wax sealant (t/m}^3\) \]

7 Reporting

Report the compacted density of the sample to the nearest 0.001 t/m³.

8 Notes on method

8.1 Before handling any wax, the operator must consult the relevant Safety Data Sheet (SDS).

8.2 A core sample may be assumed to be dry and not require drying to constant mass where:

- The core sample has been taken from the asphalt pavement using Test Method Q302A, and
- The asphalt pavement from which the core sample has been taken has remained dry since placement.

8.3 A sample is considered to have reached a constant mass when the difference between successive weighings, after a further 24 hours air drying, is not more than 0.03 percent.

8.4 During the waxing process, it is important that no air is trapped between the wax layer and the surface of the sample. It is equally important that wax does not penetrate the internal voids of the sample. The waxing process must then be conducted carefully and rapidly with good temperature control.

8.5 Should cracking of the wax occur during the coating process, the cracked wax must be removed and Step 5.1.4 repeated. Where necessary, the temperature of the wax in the bath may be increased to ensure a crack-free coating is obtained.

8.6 For core samples, the sample should be held with its curved surface down.

Table 1 – Density of water

<table>
<thead>
<tr>
<th>Temperature (ºC)</th>
<th>Density (t/m³)</th>
<th>Temperature (ºC)</th>
<th>Density (t/m³)</th>
<th>Temperature (ºC)</th>
<th>Density (t/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.9998</td>
<td>14</td>
<td>0.9992</td>
<td>28</td>
<td>0.9962</td>
</tr>
<tr>
<td>1</td>
<td>0.9999</td>
<td>15</td>
<td>0.9991</td>
<td>29</td>
<td>0.9959</td>
</tr>
<tr>
<td>2</td>
<td>0.9999</td>
<td>16</td>
<td>0.9989</td>
<td>30</td>
<td>0.9957</td>
</tr>
<tr>
<td>3</td>
<td>1.0000</td>
<td>17</td>
<td>0.9988</td>
<td>31</td>
<td>0.9953</td>
</tr>
<tr>
<td>4</td>
<td>1.0000</td>
<td>18</td>
<td>0.9986</td>
<td>32</td>
<td>0.9950</td>
</tr>
<tr>
<td>5</td>
<td>1.0000</td>
<td>19</td>
<td>0.9984</td>
<td>33</td>
<td>0.9947</td>
</tr>
<tr>
<td>6</td>
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<td>34</td>
<td>0.9944</td>
</tr>
<tr>
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<td>35</td>
<td>0.9940</td>
</tr>
<tr>
<td>8</td>
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<td>36</td>
<td>0.9937</td>
</tr>
<tr>
<td>9</td>
<td>0.9998</td>
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<td>0.9973</td>
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<td>0.9970</td>
<td>39</td>
<td>0.9926</td>
</tr>
<tr>
<td>12</td>
<td>0.9995</td>
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<td>0.9968</td>
<td>40</td>
<td>0.9922</td>
</tr>
<tr>
<td>13</td>
<td>0.9994</td>
<td>27</td>
<td>0.9965</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Test Method Q306B: Compacted density of dense graded asphalt - presaturation

This test shall be performed in accordance with AS 2891.9.2: Determination of bulk density of compacted asphalt – Presaturation method.
Test Method Q306C: Compacted density of asphalt - silicone sealed

1 Source

This method was developed in-house using techniques evolved through internal departmental research investigations (Waters T.J., "Voids in Asphalitic Concrete", Report TT99, February 1986). It applies the principles of Test Method Q306A-2001: Compacted Density of Dense Graded Asphalt (Wax Sealed).

2 Scope

This method describes a procedure for determining the compacted density of asphalt. It is applicable to asphalt samples of all asphalt types either compacted in the laboratory or cut from the pavement. The method is non-destructive and removal of the sealant following testing allows the sample to be tested for other properties.

3 Apparatus

The following apparatus is required:

3.1 Balance, a top pan balance of suitable capacity, with a resolution of at least 0.1 g and with a limit of performance within the range of ± 0.5 g. For testing in accordance with Subsection 5.2, the balance shall also be capable of below balance weighing.

3.2 Balance bench, equipped with a hole for below balance weighing.

3.3 Thermometer, a partial or total immersion thermometer or other suitable temperature measuring device having a temperature range which includes the test temperature, and graduated to 1°C or less with an uncertainty of no more than 0.5°C.

3.4 Attachment, a non-absorbent device to suspend the asphalt sample, for example, nylon or wire loop, wire support frame.

3.5 Spatula, to apply the sealant to the sample.

3.6 Fan, an electric fan to disperse vapours emanating from the sealant during the curing period.

3.7 Water container, fitted with an overflow and of suitable dimensions to allow the sample to be completely immersed without contacting any part of the container (Subsection 5.2 only).

3.8 Water container, of sufficient volume to contain the asphalt sample (Subsection 5.3 only).

3.9 Laboratory stand and clamp (Subsection 5.3 only).

4 Material

The following material is required:

4.1 Sealant, an acetic cure silicone sealant of known density to the nearest 0.001 t/m³ (Note 8.1).

5 Procedure

The procedure shall be as follows:

5.1 Sample preparation

5.1.1 Where the sample is a core sample, prepare it in accordance with Test Method Q303A.

5.1.2 Air dry the sample to constant mass (Notes 8.2 and 8.3).
5.1.3 Determine the mass of the sample ($m_1$).

5.1.4 Apply silicone sealant to approximately one half of the surface area of the sample to achieve a smooth and even finish (Note 8.4).

5.1.5 Place the sample in front of a fan and allow the sealant to cure to a firm and tack-free state.

5.1.6 Apply silicone sealant to the remainder of the sample to achieve a smooth and even finish (Note 8.4), ensuring that the total mass of sealant applied to the sample is within the appropriate range specified in Table 1.

5.1.7 Allow the sealant to cure (Note 8.5).

5.1.8 Inspect the sealed sample, apply silicone sealant to any unsealed areas and allow the sealant to cure.

5.1.9 Determine the mass of the sealed sample ($m_2$).

5.2 Density measurement using below balance weighing

5.2.1 Place the container directly below the hole in the balance bench, fill it until water escapes from the overflow and allow the excess water to run to waste.

5.2.2 When water has ceased dripping from the overflow, fit the attachment to the balance, allow the remainder of the attachment to be immersed in the water container, and zero the balance.

5.2.3 Using the attachment, suspend the sealed sample from the balance and gently lower it into the water container until completely immersed, taking care to ensure that the suspended sample hangs free of the sides and bottom of the container.

5.2.4 Add additional water if necessary until water escapes from the overflow, and allow the excess water to run to waste.

5.2.5 When water has ceased dripping from the overflow, determine the mass of the immersed sealed sample ($m_3$).

5.2.6 Record the temperature of the water in the container to the nearest 1°C.

5.3 Density measurement using above balance weighing

5.3.1 Add sufficient water to the container to completely immerse the sample. Place the container and water on the balance and zero the balance.

5.3.2 Position the laboratory stand and clamp so that the clamp is directly above the container on the balance.

5.3.3 Suspend the sealed sample from the clamp and gently lower it into the water container until completely immersed, taking care to ensure that the suspended sample hangs free of the sides and bottom of the container.

5.3.4 Determine the mass of the immersed sealed sample and attachment ($m_3$), noting the height of water on the attachment at the time of weighing.

5.3.5 Remove the sample from the water container and zero the balance.

5.3.6 With the attachment immersed to the same depth as noted in Step 5.3.4, determine the mass of the suspended attachment ($m_4$).

5.3.7 Record the temperature of the water in the container to the nearest 1°C.
6 Calculations

6.1 Below balance weighing

Calculate the compacted density of the sample as follows:

\[ D_c = \frac{m_i}{\left( \frac{m_3 - m_2}{D_w} \right) \left( \frac{m_2 - m_1}{D_s} \right)} \]

where

- \( D_c \) = compacted density of sample (t/m³)
- \( m_i \) = mass of sample (g)
- \( m_2 \) = mass of sealed sample (g)
- \( m_3 \) = mass of immersed sealed sample (g)
- \( D_w \) = density of water at test temperature (t/m³) (Table 2)
- \( D_s \) = density of silicone sealant (t/m³)

6.2 Above balance weighing

Calculate the compacted density of the sample as follows:

\[ D_c = \frac{m_i}{\left( \frac{m_4 - m_3}{D_w} \right) \left( \frac{m_3 - m_1}{D_s} \right)} \]

where

- \( D_c \) = compacted density of sample (t/m³)
- \( m_i \) = mass of sample (g)
- \( m_2 \) = mass of sealed sample (g)
- \( m_3 \) = mass of immersed sealed sample and attachment (g)
- \( m_4 \) = mass of immersed attachment (g)
- \( D_w \) = density of water at test temperature (t/m³) (Table 2)
- \( D_s \) = density of silicone sealant (t/m³)

7 Reporting

Report the compacted density of the sample to the nearest 0.001 t/m³.

8 Notes on method

8.1 Before handling any sealant the operator must consult the relevant Safety Data Sheet (SDS).

8.2 A core sample may be assumed to be dry and not require drying to constant mass where:

- The core sample has been taken from the asphalt pavement using Test Method Q302A, and
- The asphalt pavement from which the core sample has been taken has remained dry since placement.
8.3 A sample is considered to have reached a constant mass when the difference between successive weighings, after a further 24 hours air drying, is not more than 0.03 percent.

8.4 During the application of the silicone sealant, it is important that no air is trapped between the silicone sealant layer and the surface of the sample.

8.5 For 100 mm diameter asphalt cores or laboratory manufactured samples, the minimum curing period may be determined from the following expression:

\[ C = \frac{(M-30)}{10} + 0.5 \]

where  
- \( C \) = minimum curing time (hours)  
- \( M \) = mass of silicone sealant to the nearest 5 g

For 150 mm diameter asphalt cores or laboratory manufactured samples, the minimum curing period for the same mass of sealant will be about 0.54°C. For other asphalt samples, the minimum curing period may be estimated from the above expression using relative surface area considerations.

### Table 1 – Required mass of silicone sealant for test specimens

<table>
<thead>
<tr>
<th>Specimen height (mm)</th>
<th>Specimen diameter 100 mm</th>
<th>Specimen diameter 150 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 5</td>
<td>5-8</td>
<td>&gt; 8</td>
</tr>
<tr>
<td>Specimen air void content (%)</td>
<td>Mass of silicone sealant (g)</td>
<td>Specimen air void content (%)</td>
</tr>
<tr>
<td>20 - 30</td>
<td>30 - 45</td>
<td>40 - 60</td>
</tr>
<tr>
<td>21 - 30</td>
<td>25 - 35</td>
<td>35 - 50</td>
</tr>
<tr>
<td>31 - 40</td>
<td>30 - 40</td>
<td>40 - 55</td>
</tr>
<tr>
<td>41 - 50</td>
<td>35 - 45</td>
<td>45 - 60</td>
</tr>
<tr>
<td>51 - 60</td>
<td>40 - 50</td>
<td>50 - 65</td>
</tr>
<tr>
<td>61 - 70</td>
<td>45 - 55</td>
<td>55 - 70</td>
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<td>71 - 80</td>
<td>50 - 60</td>
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<td>81 - 90</td>
<td>55 - 65</td>
<td>65 - 80</td>
</tr>
<tr>
<td>91 - 100</td>
<td>60 - 70</td>
<td>70 - 85</td>
</tr>
</tbody>
</table>

### Table 2 – Density of water

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Density (t/m³)</th>
<th>Temperature (°C)</th>
<th>Density (t/m³)</th>
<th>Temperature (°C)</th>
<th>Density (t/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.9998</td>
<td>14</td>
<td>0.9992</td>
<td>28</td>
<td>0.9962</td>
</tr>
<tr>
<td>1</td>
<td>0.9999</td>
<td>15</td>
<td>0.9991</td>
<td>29</td>
<td>0.9959</td>
</tr>
<tr>
<td>2</td>
<td>0.9999</td>
<td>16</td>
<td>0.9989</td>
<td>30</td>
<td>0.9957</td>
</tr>
<tr>
<td>3</td>
<td>1.0000</td>
<td>17</td>
<td>0.9988</td>
<td>31</td>
<td>0.9953</td>
</tr>
<tr>
<td>4</td>
<td>1.0000</td>
<td>18</td>
<td>0.9986</td>
<td>32</td>
<td>0.9950</td>
</tr>
</tbody>
</table>

Superseded
<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Density (t/m³)</th>
<th>Temperature (°C)</th>
<th>Density (t/m³)</th>
<th>Temperature (°C)</th>
<th>Density (t/m³)</th>
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Test Method Q306D: Compacted density of asphalt - mensuration

This test shall be performed in accordance with AS 2891.9.3: Determination of bulk density of compacted asphalt – Mensuration method.
Test Method Q306E: Compacted density of asphalt - nuclear gauge

This test shall be performed in accordance with Test Method N04: Compacted Density of Asphalt contained within the department's Nuclear Gauge Testing Manual.
Test Method Q307A: Maximum density of asphalt – water displacement

This test shall be performed in accordance with AS 2891.7.1: Determination of maximum density of asphalt – Water displacement method.
Test Method Q308A: Binder content and aggregate grading of asphalt – reflux method

This test shall be performed in accordance with AS 2891.3.1: Binder content and aggregate grading – Reflux method.
Test Method Q308C: Binder content and aggregate grading of emulsion based cold mix

1 Source

This method applies the principles of AS 2891.3.1: Bitumen content and aggregate grading - Reflux method and the procedure for water content determination described in AS 2891.10: Water and volatile oils content.

2 Scope

This method describes the procedure for the determination of the binder content and aggregate grading of cold mix which has been prepared using bituminous emulsion and has negligible volatile oils content, for example, bituminous slurry surfacing. The method involves extraction of residual water in the mix and determination of the binder content by solvent extraction and the particle size distribution of the aggregate by sieve analysis.

3 Apparatus

Where appropriate, the working tolerances of particular apparatus are contained in Table 1.

The following apparatus is required:

3.1 Balances:

3.1.1 Balance of suitable capacity, with a resolution of at least 0.1 g and with a limit of performance within the range of ± 0.5 g.

3.1.2 Balance of suitable capacity, with a resolution of at least 0.001 g and with a limit of performance within the range of ± 0.005 g.

3.2 Centrifuge, an electric centrifuge capable of holding at least two 15 mL aliquots.

3.3 Hotplate, capable of maintaining a temperature of 305ºC (Note 10.1).

3.4 Fume cupboard.

3.5 Heating mantle, electric heating mantle of suitable size to heat the 1 L flask and contents.

3.6 Receiver, a standard Dean and Stark light entrainer of 25 mL capacity.

3.7 Adaptors, as required to connect the flask, receiver and condenser.

3.8 Pipette, 10 mL pipette graduated in 0.1 mL increments.

3.9 Flask, round bottom flask of 1 L capacity with a ground glass neck of at least 55 mm diameter and fitted with a stopper.

3.10 Condenser, double surface condenser to fit the neck of the flask.

3.11 Beaker, of at least 100 mL capacity.

3.12 Containers, two flat-bottomed aluminium containers of approximate dimensions 100 mm diameter and 75 mm depth and equipped with tightly fitting slip-on lids.

3.13 Metal tray, of sufficient capacity to contain the aggregate.

3.14 Sieves, 37.5 mm, 26.5 mm, 19.0 mm, 13.2 mm, 9.50 mm, 6.70 mm, 4.75 mm, 2.36 mm, 1.18 mm, 0.600 mm, 0.300 mm, 0.150 mm, 0.075 mm and reinforced 0.075 mm as required complying with AS 1152.

3.15 Sieve brush.

Superseded
3.16 Mechanical sieve shaker (optional).

4 Materials

The following materials are required:

4.1 Solvent, toluene commercial grade (Note 10.2).

4.2 Washing solvent such as kerosene, mineral turpentine or similar (optional) (Note 10.2).

5 Procedure – binder content

The following procedure shall be conducted on a single test portion for asphalt of nominal size less than 20 mm and on two test portions for asphalt of nominal size 20 mm or larger.

5.1 Determine the mass of the flask with stopper (m₁).

5.2 Obtain a representative sample of approximately 500 g by coning and quartering in accordance with Subsection 4.2 of Test Method Q301.

5.3 With the flask held at an angle of about 45 degrees, transfer the sample to the flask. Determine the mass of the flask, stopper and sample (m₂).

5.4 Add sufficient solvent to the flask so that the level of solvent is at least 25 mm above the level of the sample.

5.5 Place the flask in the heating mantle, fit the receiver and condenser to the flask and turn on the water supply to the condenser.

5.6 Apply heat to the flask, cautiously at first, and then regulated so that the condensate falls at a rate of 2 to 5 drops per second.

5.7 Continue heating until the volume of water in the receiver remains constant for 15 minutes (Note 10.3).

5.8 Discontinue heating and allow the water in the receiver to cool to room temperature.

5.9 Dislodge any droplets of water adhering to the inner surface of the receiver using a length of straight wire. Record the volume of water in the receiver to the nearest 0.1 mL (v) and measure the room temperature to the nearest 1ºC.

5.10 Remove the flask from the receiver, stopper the flask and allow the contents to cool to room temperature.

5.11 Examine the contents of the flask to ensure that all binder has been dissolved (Note 10.4), then determine the mass of the flask, mix and solvent (m₃).

5.12 Perform the following procedure on two aliquots:

5.12.1 Using the beaker, transfer an aliquot of at least 15 mL of the solution from the flask to the centrifuge tube(s). Stopper the tube(s) immediately and centrifuge to separate any suspended mineral matter.

5.12.2 Determine the mass of the container with lid to the nearest 0.001 g (m₄).

5.12.3 Pour the supernatant liquid from the centrifuge tube(s) into the container, taking care not to disturb the settled mineral matter, and fit the lid. Determine the mass of the container and supernatant liquid immediately to the nearest 0.001 g (m₅).
5.12.4 Remove the lid and place the container on the hotplate maintained at a temperature of 305 ± 10ºC in the fume cupboard to evaporate the solvent. Continue the heating for two minutes after fumes are first seen to rise from the binder (Note 10.5).

5.12.5 Remove the container from the hotplate, replace the lid and allow the container to cool to room temperature.

5.12.6 Determine the mass of the container, lid and binder to the nearest 0.001 g (m₆).

### 6 Calculations – binder content

#### 6.1
Calculate the binder content based on each aliquot to the nearest 0.01% as follows:

\[
B_a = \frac{(m_3 - m_2 + vD_w)(m_6 - m_4)100}{(m_2 - m_1 - vD_w)(m_5 - m_6)}
\]

where
- \(B_a\) = binder content based on one aliquot (%)
- \(m_3\) = mass of flask, mix and solvent (g)
- \(m_2\) = mass of flask and mix (g)
- \(v\) = volume of water in receiver (mL)
- \(D_w\) = density of water at room temperature (t/m³) (Table 2)
- \(m_6\) = mass of container, lid and binder (g)
- \(m_4\) = mass of container and lid (g)
- \(m_1\) = mass of flask (g)
- \(m_5\) = mass of container, lid and supernatant liquid (g)

#### 6.2 Asphalt of nominal size < 20 mm

Provided the difference between the binder contents based on the two aliquots is less than 0.06%, calculate the binder content of the mix (B) as the average of the two results to the nearest 0.01% (Note 10.5).

#### 6.3 Asphalt of nominal size ≥ 20 mm

6.3.1 Provided the difference between the binder contents based on the two aliquots from each portion is less than 0.06%, calculate the binder content of each portion as the average of the two results to the nearest 0.01% (Note 10.5).

6.3.2 Calculate the binder content of the mix (B) as the average binder content of the two portions to the nearest 0.01%.

### 7 Procedure – particle size distribution

#### 7.1
Pour the solution from the flask over the reinforced 0.075 mm sieve and discard the solvent and fines passing the sieve. Retain as much as is possible of the flask's contents in the flask for further washing.

#### 7.2
Add solvent or a washing solvent to the flask and shake the flask vigorously.

#### 7.3
Repeat Steps 7.1 and 7.2 until the sample is free from binder (Note 10.6).
7.4 Transfer the bulk of the contents in the flask to the tray, dry on the hotplate and allow to cool to room temperature.

7.5 Using solvent or washing solvent, transfer any aggregate remaining in the flask to the 0.075 mm reinforced sieve. Dry the aggregate retained on the sieve and transfer it to the tray using a sieve brush.

7.6 Pass the contents of the tray through the sieves appropriate to the asphalt type and nominal size (Notes 10.7 and 10.8).

7.7 Determine the mass of the aggregate retained on each sieve and record the mass retained \( m_i \) to the nearest 0.1 g (Note 10.9).

8 Calculations – particle size distribution

8.1 Asphalt of nominal size < 20 mm

8.1.1 Calculate the total mass of aggregate to the nearest 0.1 g as follows:

\[
m = \frac{(m_2 - m_1 - vD_w)(100 - B)}{100}
\]

where 
- \( m \) = total mass of aggregate (g)
- \( m_2 \) = mass of flask and mix (g)
- \( m_1 \) = mass of flask (g)
- \( v \) = volume of water in receiver (mL)
- \( D_w \) = density of water at room temperature (t/m³) (Table 2)
- \( B \) = binder content of mix (%)

8.2 Asphalt of nominal size ≥ 20 mm

8.2.1 Calculate the mass of each portion to the nearest 0.1 g as follows:

\[
m_d = m_2 - m_1 - vD_w
\]

where 
- \( m_d \) = mass of portion (g)
- \( m_2 \) = mass of flask and mix (g)
- \( m_1 \) = mass of flask (g)
- \( v \) = volume of water in receiver (mL)
- \( D_w \) = density of water at room temperature (t/m³) (Table 2)

8.2.2 Calculate the total mass of sample as the combined mass of the two portions to the nearest 0.1 g as follows:

\[
m_s = m_{d1} + m_{d2}
\]

where 
- \( m_s \) = total mass of sample (g)
- \( m_{d1} \) = mass of first portion (g)
8.2.3 Calculate the total mass of aggregate to the nearest 0.1 g as follows:

\[ m = \frac{m_s (100-B)}{100} \]

where

- \( m \) = total mass of aggregate (g)
- \( m_s \) = total mass of sample (g)
- \( B \) = binder content of mix (%)  

8.3 Calculate the cumulative mass retained on each sieve as follows:

\[ M = \sum m_r \]

where

- \( M \) = cumulative mass retained on a particular sieve (g)
- \( m_r \) = individual mass retained on each sieve (g)

8.4 Calculate the cumulative per cent passing each sieve as follows:

\[ p_p = 100 \cdot \frac{100M}{m} \]

where

- \( p_p \) = cumulative percent passing a particular sieve (%)
- \( M \) = cumulative mass retained on a particular sieve (g)
- \( m \) = total mass of aggregate (g)

9 Reporting

9.1 Binder content

Report the binder content of the sample to the nearest 0.05%.

9.2 Particle size distribution

Report the cumulative per cent passing all sieves to the nearest 1% for values \( \geq 10\% \), and to the nearest 0.1% for values <10%.

10 Notes on method

10.1 Depending on the type of binder within the sample and/or container size, it may be necessary to vary the temperature of the hotplate and time of fuming of the binder film. The appropriate hotplate temperature and fuming time can be determined by calibrating against solutions of known binder content.

10.2 Before handling toluene or other solvent, the operator must consult the relevant Safety Data Sheet (SDS).

10.3 Where the volume of water extracted from the sample exceeds the capacity of the receiver, a portion of the water may be drawn off using the pipette and the volume recorded to the nearest 0.1 mL. This value shall be added to that recorded in Step 5.9 to obtain the volume \( v \).

10.4 If the aggregate in the bottom of the flask is clean, then all the binder has been dissolved. If the aggregate retains a coating of binder then the refluxing should be continued until the
aggregate is clean. For mixes containing slag or other absorptive type aggregates, it may be necessary to heat the mixture for periods up to eight hours in order to extract all traces of absorbed or occluded binder.

10.5 Where the difference between the binder contents based on the two aliquots is 0.06 % or greater, Subsection 5.12 shall be repeated.

10.6 To enhance drying of the aggregate, acetone may be used in the final washing of the sample (Note 10.2).

10.7 Sieving may be conducted by hand or mechanical shaker. When hand sieving, a lateral and vertical motion shall be employed accompanied by a slight jarring action to keep the sample moving continuously over the sieve. Particles 19.0 mm or larger may be placed by hand to pass the sieves. Sieving shall be continued until the mass passing each sieve in one minute is less than 1% of the mass of material retained on that sieve. Mechanical sieving shall be carried out for such time as will give a comparable result with hand sieving, which is generally 15 minutes.

10.8 Overloading of sieves may affect the accuracy of results and damage the sieves. The recommended maximum loads on sieves at completion of sieving are given in Table 3.

10.9 For asphalt of nominal size ≥ 20 mm, the mass retained on each sieve for each of the two portions shall be summed and this combined mass recorded as the individual mass retained.

**Table 1 – Working tolerances for apparatus**

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Dimension</th>
<th>Tolerance</th>
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<td>Temperature distribution (C°)</td>
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<td>± 10</td>
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**Table 2 – Density of water**

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<th>Water density (t/m³)</th>
<th>Test temperature (°C)</th>
<th>Water density (t/m³)</th>
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<td>0.998</td>
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<tr>
<td>13</td>
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### Test Method Q308C: Binder content and aggregate grading of emulsion based cold mix

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<th>Water density (t/m³)</th>
<th>Test temperature (°C)</th>
<th>Water density (t/m³)</th>
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**Table 3 – Maximum sieve loading**

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Superseded
Test Method Q308D: Binder content and aggregate grading of asphalt – ignition 
oven

This test shall be performed in accordance with AUSTROADS test method AG:PT/T234: Asphalt 
binder content (ignition oven method).
Test Method Q309: Preparation and testing of asphalt mix

1 Source
This method was developed in-house using techniques evolved through internal departmental research investigations into laboratory mix preparation and evaluation.

2 Scope
This method describes the procedure for the laboratory preparation and testing of asphalt mix designs. It is applicable to both the design and assessment processes associated with asphalt mix design registration.

3 Apparatus
The following apparatus is required:

3.1 Mixer, a mechanical mixer comprising a mixing bowl of sufficient capacity to contain an asphalt mix, and an appropriate stirrer which will not cause excessive breakdown of the aggregates and filler. A Hobart dough mixer of 35 L capacity equipped with a heavy duty wire whip stirrer has been found suitable.

3.2 Balance of suitable capacity, with a resolution of at least 1 g and with a limit of performance within the range of ± 5 g.

3.3 Drying oven of suitable capacity, having a temperature of 105-110°C and complying with AS 1289.0.

3.4 Oven of suitable capacity and capable of heating a sample of binder to a temperature of 160 - 180°C.

3.5 Hotplate.

3.6 Heating container, metal container able to be heated to the required temperature (see Step 7.3) and of sufficient capacity to contain the aggregates and added filler.

3.7 Heat source, for heating the aggregates and filler to about 220°C where a bitumen binder is to be used, and to about 240°C where a polymer modified binder is to be used, for example gas burner.

3.8 Thermometer, a partial immersion thermometer or other suitable temperature measuring device having a temperature range of at least 150 - 250°C and graduated to 1°C or less with an uncertainty of no more than 0.5°C.

3.9 Quartering table, a heated metal tray of appropriate dimensions to contain an asphalt mix. A tray of dimensions 750 mm square has been found suitable.

3.10 Mixing tools, assorted metal scoops, trowels and spatulas.

3.11 Containers, metal or heavy duty plastic containers of sufficient capacity to contain the aggregate size fractions. Containers of length 420 mm, width 280 mm and height 150 mm have been found suitable.

3.12 Sample dividers, riffles with slot widths of approximately 50 mm, 25 mm, 13 mm and 7 mm.

3.13 Sieves, 37.5 mm, 26.5 mm, 19.0 mm, 13.2 mm, 9.50 mm, 6.70 mm, 4.75 mm, 2.36 mm, 1.18 mm, 0.600 mm, 0.300 mm, 0.150 mm, 0.075 mm and reinforced 0.075 mm as required complying with AS 1152.
3.14 Mechanical sieve shaker (optional).
3.15 A means for washing the aggregate size fractions.

4 Materials

The following materials are required:

4.1 Aggregate components: coarse aggregates, fine aggregates and sand (as appropriate) of the required quantities (see Step 5.6).

4.2 Added filler components: fly ash, hydrated lime, baghouse fines or other material of the required quantities (see Step 5.7) (Note 9.1).

4.3 Binder: bitumen complying with MRTS 17, polymer modified binder complying with MRTS 18 or other specified binder (Note 9.1).

4.4 Other components: fibres and additives (where appropriate) (Note 9.1).

5 Preparation of aggregates and added filler

5.1 Where necessary, dry the aggregate and added filler components comprising the mix design in the oven.

5.2 Determine the total quantity of aggregates and filler required for mix preparation (M).

5.3 Where RAP is a component of the mix design, determine the grading and binder content of a representative sample of the RAP material in accordance with Test Method Q308A.

5.4 Where RAP is a component of the mix design, calculate the quantity of aggregates and filler in the RAP material as follows:

\[
M_{RA} = \frac{MP_{R}(100 - BR)}{10^4}
\]

where

- \(M_{RA}\) = mass of RAP aggregates and filler (g)
- \(M\) = required mass of aggregates and filler (g)
- \(P_{R}\) = proportion of the RAP component in the mix design (%)
- \(B_{R}\) = binder content of the RAP component (%)

5.5 Calculate the quantity of aggregates and filler required, excluding that in any RAP component, as follows:

\[
M_T = M - M_{RA}
\]

where

- \(M_T\) = total mass of aggregates and added filler excluding RAP (g)
- \(M\) = required mass of aggregates and filler (g)
- \(M_{RA}\) = mass of RAP aggregates and filler (g)

5.6 Calculate the required mass of each aggregate component to the nearest 1 g as follows (Note 9.2):

\[
M_A = \frac{P_A M_T}{(100 - P_R)}
\]
where \( M_A \) = required mass of the aggregate component (g)
\( P_A \) = proportion of the aggregate component in the mix design (%)
\( M_T \) = total mass of aggregates and added filler excluding RAP (g)
\( P_R \) = proportion of the RAP component in the mix design (%)

5.7 Calculate the required mass of each added filler component to the nearest 1 g as follows (Note 9.2):

\[
M_F = \frac{P_F M_T}{(100 - P_R)}
\]

where \( M_F \) = required mass of the added filler component (g)
\( P_F \) = proportion of the added filler component in the mix design (%)
\( M_T \) = total mass of aggregates and added filler excluding RAP (g)
\( P_R \) = proportion of the RAP component in the mix design (%)

5.8 Obtain the required masses of the aggregate components calculated in Step 5.6 by riffling and then combine these masses into a single sample. Added filler components are not introduced at this stage.

5.9 Sieve the combined sample to obtain the size fractions of Table 1 or Table 2 as appropriate using the procedure of Test Method Q103B, and place each sieved size fraction into a separate labelled aggregate container.

5.10 Wash each size fraction, excepting the material passing 0.075 mm, over a nest of two sieves comprising a sieve corresponding to the retained size fraction and the reinforced 0.075 mm sieve. Wash each size fraction until the wash water is clear.

5.11 Wash, dry and resieve all material retained on the 0.075 mm sieve over the sieves used in Step 5.9 in accordance with Test Method Q103B. Combine and thoroughly mix the material retained on each sieve with the corresponding size fraction obtained in Step 5.10.

5.12 Dry each size fraction in the drying oven (Note 9.3).

5.13 Determine the particle size distribution of each added filler component in accordance with Test Method Q103B.

5.14 Sieve the required mass of each added filler component into the relevant size fractions of Table 1 or Table 2 as appropriate using the procedure of Test Method Q103B, and place each sieved size fraction into a separate labelled filler container.

6 Calculation of mix component masses

6.1 Aggregates and added filler components

6.1.1 Record the grading of the mix (Note 9.4).

6.1.2 Calculate the percentage in each of the relevant size fractions \( P_S \) of Table 1 or Table 2 as appropriate for the mix grading.
6.1.3 Calculate the required mass of each added filler component for each size fraction to the nearest 1 g as follows:

\[ M_{FS} = \frac{P_{FS} \cdot M_F}{100} \]

where

- \( M_{FS} \) = required mass of added filler size fraction (g)
- \( P_{FS} \) = proportion in the size fraction for the added filler determined from Step 5.13 (%)
- \( M_F \) = required mass of added filler calculated in Step 5.7 (g)

6.1.4 Calculate the total mass of added filler (\( M_{FST} \)) for each size fraction by summing the relevant \( M_{FS} \) values for all added filler components.

6.1.5 Calculate the required masses of each aggregate size fraction to the nearest 1 g as follows (Note 9.5):

\[ M_{AS} = \frac{P_s M_T}{100} - M_{FST} - \frac{M_{RA} P_{RS}}{100} \]

where

- \( M_{AS} \) = required mass of aggregate size fraction (g)
- \( P_s \) = proportion in the size fraction calculated in Step 6.1.2 (%)
- \( M_T \) = total mass of aggregate and added filler in the mix (g)
- \( M_{FST} \) = total mass of added filler for the size fraction (g)
- \( M_{RA} \) = mass of RAP aggregates and filler calculated in Step 5.4 (g)
- \( P_{RS} \) = proportion in the size fraction for the RAP material determined from Step 5.3 (%)

6.2 Binder

Record the design binder content of the mix. Where required for dense graded asphalt, calculate the high and low tolerance binder contents by applying the appropriate maximum permitted variations of Table 3 to the design binder content.

7 Preparation of mix

7.1 Prepare the mixing bowl as follows:

7.1.1 Following use of the bowl in mixing aggregate, filler and binder components, empty the bowl and scrape adhering fines from the mixing area within the bowl while allowing a thin coating of binder to remain on the inside surface of the bowl.

7.1.2 Preheat the mixing bowl on the hotplate or in the oven.

7.2 Weigh the required masses of each size fraction calculated in Steps 6.1.3 and 6.1.5 for a particular mix into the heating container.
7.3 Heat the container and contents to the appropriate temperature (Table 4). During the heating process, mix the contents periodically using the scoop to provide an even temperature distribution (Note 9.6).

7.4 Heat sufficient binder (and RAP material where applicable) for the mix in the oven to the appropriate temperature (Table 4).

7.5 Weigh the heated mixing bowl and record the mass ($m_1$) to the nearest 1 g.

7.6 Remove the container from the heat source and empty the contents carefully into the mixing bowl, ensuring that any fines adhering to the container are returned to the mix by brushing.

7.7 With the contents of the mixing bowl at the appropriate temperature (Table 4), weigh the mixing bowl and contents and record the mass ($m_2$) to the nearest 1 g.

7.8 Where RAP is a component of the mix design, calculate the required mass of RAP material for the mix to the nearest 1 g as follows:

$$M_R = \frac{P_R (m_2 - m_1)}{(100 - P_R)}$$

where

- $M_R$ = required mass of RAP material (g)
- $P_R$ = proportion of RAP in the mix (%)
- $m_2$ = mass of mixing bowl and contents (g)
- $m_1$ = mass of mixing bowl (g)

7.9 Remove the RAP material from the oven and add the required mass of representative RAP material ($M_R$) to the mixing bowl.

7.10 Using a scoop or trowel, thoroughly stir the contents of the mixing bowl and then form a crater in the centre of the contents of the mixing bowl.

7.11 Calculate the required mass of binder for the mix to the nearest 1 g as follows (Note 9.7):

$$M_B = \frac{P_B (m_2 - m_1) - B_R M_R}{100}$$

where

- $M_B$ = required mass of binder (g)
- $P_B$ = proportion of binder in the mix design (%)
- $m_2$ = mass of mixing bowl and contents (g)
- $m_1$ = mass of mixing bowl (g)
- $B_R$ = binder content of the RAP material (%)
- $M_R$ = required mass of RAP material (g)

7.12 Remove the binder from the oven, stir the binder and pour the required mass of binder ($M_B$) into the crater.

7.13 Mechanically mix the contents of the mixing bowl for 90 seconds at the slowest speed.
7.14 Stop the mixer and return any binder rich fines adhering to the stirrer and walls of the mixing bowl to the mix by scraping with the trowel or spatula.

7.15 Mechanically mix the contents of the mixing bowl for a further 90 seconds at the slowest speed.

7.16 Transfer the mix from the mixing bowl to the quartering table. Return any material adhering to the stirrer and mixing bowl to the mix by scraping with the trowel or spatula.

7.17 Obtain representative portions of the mix in accordance with Subsection 4.2 of Test Method Q301 and prepare test specimens in accordance with Section 5 of Test Method Q305, two for DG28 mix and four for all other mixes.

7.18 Remove any lip formed around the edges of each test specimen without damage to the test specimen.

7.19 Determine the compacted density of each test specimen in accordance with Test Method Q306C.

7.20 Where required, determine the stability, flow and stiffness of the test specimens in accordance with Test Method Q305.

7.21 Where required for open graded asphalt and stone mastic asphalt, prepare a 2 kg sample of mix in accordance with Steps 7.1 to 7.16 and test the mix for binder drainage in accordance with Test Method Q310.

7.22 Where required for open graded asphalt, test the four specimens for abrasion loss in accordance with Test Method Q313.

7.23 Prepare a 2 kg sample of mix in accordance with Steps 7.1 to 7.16 and determine the maximum density in accordance with Test Method Q307A.

7.24 Where required (excepting open graded asphalt), combine the mix from all test specimens, dry the mix, obtain a representative sample of the combined mix and determine the binder content and grading of the sample in accordance with Test Method Q308A.

7.25 Using the corresponding compacted density and maximum density values for each test specimen, determine the air voids for each test specimen in accordance with Test Method Q311.

7.26 Calculate the average air voids and average compacted density for the test specimens, and determine the remaining voids properties for the mix in accordance with Test Method Q311.

7.27 For tolerance mixes, if the test results for the mix meet the specified requirements within the maximum testing variation limits of Table 5, the mix shall be deemed to comply.

8 Reporting

Report all test results obtained for the mix.

9 Notes on method

9.1 Before handling fillers, binders, fibres and additives, the operator must consult the relevant Safety Data Sheet (SDS).

9.2 $M_T$ should normally be about 50 kg for asphalt nominal size < 20 mm and about 70 kg for asphalt nominal size ≥ 20 mm.
9.3 The time required to dry the size fractions in the 105-110°C oven will be dependent on the properties of the aggregate. Drying overnight will normally be sufficient, although longer drying periods may be required for aggregates having high water absorption values.

9.4 Where a tolerance mix is to be prepared for dense graded asphalt, calculate the coarse and/or fine gradings by applying the appropriate maximum permitted variations of Table 3 to the design grading.

9.5 Some breakdown of the aggregates in the mix may occur during the mixing process. Where this breakdown is significant for particular aggregates, an appropriate reduction in the calculated mass of aggregate for the percentage passing 0.075 mm may be necessary.

9.6 Mixing for 30 seconds following each 15 minute heating period has been found adequate.

9.7 For stone mastic asphalt, the fibre component of the mix shall be added to the heated contents of the mixing bowl immediately prior to addition of the binder. Where a bituminous pelletised fibre is used, the quantity of binder added to the mix shall be adjusted to allow for the binder contribution from the fibre.

Table 1 - Size fractions for dense graded asphalt

<table>
<thead>
<tr>
<th>Sieve size (mm)</th>
<th>DG7</th>
<th>DG10</th>
<th>DG14</th>
<th>DG20</th>
<th>DG28</th>
</tr>
</thead>
<tbody>
<tr>
<td>37.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>37.5 - 26.5</td>
</tr>
<tr>
<td>26.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>26.5 - 19.0</td>
<td>26.5 - 19.0</td>
</tr>
<tr>
<td>9.50</td>
<td>9.50 - 6.70</td>
<td>9.50 - 6.70</td>
<td>9.50 - 4.75</td>
<td>9.50 - 4.75</td>
<td>9.50 - 4.75</td>
</tr>
<tr>
<td>6.70</td>
<td>6.70 - 4.75</td>
<td>6.70 - 4.75</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4.75</td>
<td>4.75 - 2.36</td>
<td>4.75 - 2.36</td>
<td>4.75 - 2.36</td>
<td>4.75 - 2.36</td>
<td>4.75 - 2.36</td>
</tr>
<tr>
<td>2.36</td>
<td>2.36 - 1.18</td>
<td>2.36 - 1.18</td>
<td>2.36 - 1.18</td>
<td>2.36 - 1.18</td>
<td>2.36 - 1.18</td>
</tr>
<tr>
<td>1.18</td>
<td>1.18 - 0.600</td>
<td>1.18 - 0.600</td>
<td>1.18 - 0.600</td>
<td>1.18 - 0.600</td>
<td>1.18 - 0.600</td>
</tr>
<tr>
<td>0.600</td>
<td>0.600 - 0.300</td>
<td>0.600 - 0.300</td>
<td>0.600 - 0.300</td>
<td>0.600 - 0.300</td>
<td>0.600 - 0.300</td>
</tr>
<tr>
<td>0.300</td>
<td>0.300 - 0.150</td>
<td>0.300 - 0.150</td>
<td>0.300 - 0.150</td>
<td>0.300 - 0.150</td>
<td>0.300 - 0.150</td>
</tr>
<tr>
<td>0.150</td>
<td>0.150 - 0.075</td>
<td>0.150 - 0.075</td>
<td>0.150 - 0.075</td>
<td>0.150 - 0.075</td>
<td>0.150 - 0.075</td>
</tr>
<tr>
<td>0.075</td>
<td>&lt; 0.075</td>
<td>&lt; 0.075</td>
<td>&lt; 0.075</td>
<td>&lt; 0.075</td>
<td>&lt; 0.075</td>
</tr>
</tbody>
</table>

Table 2 – Size fractions for stone mastic and open graded asphalt

<table>
<thead>
<tr>
<th>Sieve size (mm)</th>
<th>SM10</th>
<th>SM14</th>
<th>OG10</th>
<th>OG14</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.50</td>
<td>9.50 - 6.70</td>
<td>9.50 - 6.70</td>
<td>9.50 - 6.70</td>
<td>9.50 - 6.70</td>
</tr>
<tr>
<td>6.70</td>
<td>6.70 - 4.75</td>
<td>6.70 - 4.75</td>
<td>6.70 - 4.75</td>
<td>6.70 - 4.75</td>
</tr>
</tbody>
</table>
### Sieve size (mm) vs. Size fraction (mm)

<table>
<thead>
<tr>
<th>Sieve size (mm)</th>
<th>SM10</th>
<th>SM14</th>
<th>OG10</th>
<th>OG14</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.75</td>
<td>4.75 - 2.36</td>
<td>4.75 - 2.36</td>
<td>4.75 - 2.36</td>
<td>4.75 - 2.36</td>
</tr>
<tr>
<td>2.36</td>
<td>2.36 - 1.18</td>
<td>2.36 - 1.18</td>
<td>2.36 - 1.18</td>
<td>2.36 - 1.18</td>
</tr>
<tr>
<td>1.18</td>
<td>1.18 - 0.600</td>
<td>1.18 - 0.600</td>
<td>1.18 - 0.300</td>
<td>1.18 - 0.300</td>
</tr>
<tr>
<td>0.600</td>
<td>0.600 - 0.300</td>
<td>0.600 - 0.300</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>0.300</td>
<td>0.300 - 0.150</td>
<td>0.300 - 0.150</td>
<td>0.300 - 0.075</td>
<td>0.300 - 0.075</td>
</tr>
<tr>
<td>0.150</td>
<td>0.150 - 0.075</td>
<td>0.150 - 0.075</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>0.075</td>
<td>&lt; 0.075</td>
<td>&lt; 0.075</td>
<td>&lt; 0.075</td>
<td>&lt; 0.075</td>
</tr>
</tbody>
</table>

**Table 3 - Maximum permitted variation for dense graded asphalt**

<table>
<thead>
<tr>
<th>Sieve size (mm)</th>
<th>Variation (% by mass)</th>
<th>Sieve size (mm)</th>
<th>Variation (% by mass)</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 9.50</td>
<td>± 7</td>
<td>0.600</td>
<td>± 4</td>
</tr>
<tr>
<td>6.70</td>
<td>± 6</td>
<td>0.300</td>
<td>± 3</td>
</tr>
<tr>
<td>4.75</td>
<td>± 6</td>
<td>0.150</td>
<td>± 2</td>
</tr>
<tr>
<td>2.36</td>
<td>± 5</td>
<td>0.075</td>
<td>± 1</td>
</tr>
<tr>
<td>1.18</td>
<td>± 4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Binder content (%) ± 0.3*  

* May be tightened to achieve specification compliance

**Table 4 - Temperatures for laboratory mix production**

<table>
<thead>
<tr>
<th>Component</th>
<th>Asphalt type</th>
<th>Temperature (°C)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 320 bitumen</td>
<td>Dense graded, stone mastic</td>
<td>Component 160 - 170 Mixing bowl 210 - 230</td>
</tr>
<tr>
<td>Class 320 bitumen</td>
<td>Open graded</td>
<td>160 - 170</td>
</tr>
<tr>
<td>Class 600 bitumen</td>
<td>Dense graded</td>
<td>160 - 170</td>
</tr>
<tr>
<td>Multigrade bitumen</td>
<td>Dense graded</td>
<td>160 - 170</td>
</tr>
<tr>
<td>A5S polymer modified binder</td>
<td>Dense graded, stone mastic</td>
<td>170 - 180</td>
</tr>
<tr>
<td>A5S polymer modified binder</td>
<td>Open graded</td>
<td>170 - 180</td>
</tr>
<tr>
<td>Reclaimed asphalt pavement</td>
<td>Dense graded</td>
<td>160 - 170</td>
</tr>
</tbody>
</table>

* For binders other than those listed, the appropriate temperatures may be interpolated/extrapolated based on binder viscosities
## Table 5 - Maximum testing variations for dense graded asphalt tolerance mixes

<table>
<thead>
<tr>
<th>Test method</th>
<th>Property</th>
<th>Maximum testing variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q305</td>
<td>Stability (kN)</td>
<td>± 0.3</td>
</tr>
<tr>
<td></td>
<td>Flow (mm)</td>
<td>± 0.1</td>
</tr>
<tr>
<td></td>
<td>Stiffness (kN/mm)</td>
<td>± 0.1</td>
</tr>
<tr>
<td>Q311</td>
<td>Air voids (%)</td>
<td>± 0.2</td>
</tr>
<tr>
<td></td>
<td>Voids in mineral aggregate (%)</td>
<td>± 0.3</td>
</tr>
<tr>
<td></td>
<td>Voids filled with binder (%)</td>
<td>± 0.9</td>
</tr>
</tbody>
</table>
Test Method Q310: Binder drainage of asphalt mix

1 Source
This method applies the principles of AUSTROADS Bituminous Mixtures Test AG:PT/T235: Asphalt binder drain-off.

2 Scope
This method determines the propensity of asphalt to lose binder by the draindown effect. It involves heating a sample of representative mix in an oven at a temperature close to that at which the mix will normally be handled and determining the weight of binder remaining when the mix is emptied from the sample container.

3 Apparatus
Where appropriate, the working tolerances of particular apparatus are contained in Table 1.
The following apparatus is required:
3.1 Oven of suitable capacity, capable of maintaining the test temperature (Note 8.1).
3.2 Balance of suitable capacity, having a resolution of at least 0.1 g and with a limit of performance within the range of ± 0.5 g.
3.3 Beaker, glass beaker of 1 litre capacity.
3.4 Beaker cover, a watchglass or can lid of suitable size.
3.5 Filter funnel, a glass filter funnel.
3.6 Metal tray, capable of holding at least 1 kg of mix.
3.7 Heat resistant gloves (Note 8.2).

4 Materials
The following materials are required:
4.1 Filter paper, Whatman No. 1 or equivalent.
4.2 Mineral turpentine (Note 8.3).

5 Procedure
The procedure shall be as follows:
5.1 Weigh a 1 litre beaker and record the mass to the nearest 0.1 g (m₁) (Note 8.2).
5.2 Prepare a representative sample of 1000 ± 100 g of mix in accordance with Subsection 4.2 of Test Method Q301 and place it in the beaker.
5.3 Weigh the beaker and mix and record the mass to the nearest 0.1 g (m₂).
5.4 Cover the beaker and place it in the oven for 60 ± 1 minutes.
5.5 Remove the beaker from the oven with minimal disturbance of the contents.
5.6 Remove the cover and immediately upend the beaker over the metal tray. Allow the mix to empty from the beaker without the use of any shaking or vibration for 10 ± 1 seconds and then return the beaker to the upright position.
5.7 Weigh the beaker and record the mass to the nearest 0.1 g ($m_3$).

5.8 Add sufficient mineral turpentine to the beaker to dissolve the binder.

5.9 Weigh a filter paper and record the mass to the nearest 0.1 g ($m_4$).

5.10 Filter the solution and transfer the entire contents of the beaker to the filter paper using additional mineral turpentine as required.

5.11 Wash the residue on the filter paper with mineral turpentine until it is free of binder.

5.12 Dry the filter paper ensuring no loss of residue.

5.13 Weigh the filter paper and residue and record the mass to the nearest 0.1 g ($m_5$).

6 Calculations

Calculate the binder drainage of the sample to the nearest 0.01% as follows:

$$BD = \frac{100(m_3 + m_4 - m_1 - m_5)}{(m_2 - m_1)}$$

where

- $BD$ = binder drainage (%)
- $m_3$ = mass of beaker, binder and residue (g)
- $m_4$ = mass of filter paper (g)
- $m_1$ = mass of beaker (g)
- $m_5$ = mass of filter paper and residue (g)
- $m_2$ = mass of beaker and mix (g)

7 Reporting

Report the binder drainage of the sample to the nearest 0.01%.

8 Notes on method

8.1 The test temperature is intended to approximate the expected average maximum handling temperature of the mix in the field. Test temperatures of 150°C and 175°C are appropriate for mixes containing bitumen binders and polymer modified binders respectively. If the expected average maximum handling temperature is known to vary significantly from these temperatures, then a different test temperature should be used.

8.2 All equipment including gloves used for holding hot apparatus must be very clean. The sensitivity of the test means that a smear of binder on the beaker can substantially affect the result.

8.3 Before handling mineral turpentine, the operator must consult the relevant Safety Data Sheet (SDS).
Table 1 – Working tolerances for apparatus

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Dimension</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oven</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test Temperature (°C)</td>
<td>Note 8.1</td>
<td>± 5</td>
</tr>
</tbody>
</table>
Test Method Q311: Voids properties for compacted asphalt

1 Source
This method applies the principles of AS/NZS 2891.8: Voids and volumetric properties of compacted asphalt mixes. It differs from this Australian Standard in that binder absorption is determined either directly or indirectly from water absorption as well as via calculation from values of aggregate particle density, binder density and asphalt maximum density.

2 Scope
This method describes the procedure for calculation of the voids relationships for a sample of compacted asphalt. It requires prior determination of the compacted density, maximum density and binder content of the sample, the density of the binder and the binder absorption of the aggregate.

3 Procedure
The procedure shall be as follows:

3.1 Determine the compacted density of the sample \( (D_C) \) in accordance with Test Method Q306A, Q306B, Q306C, Q306D or Q306E as appropriate, and record the value to the nearest 0.001 \( t/m^3 \).

3.2 Determine the maximum density of the sample \( (D_M) \) in accordance with Test Method Q307A and record the value to the nearest 0.001 \( t/m^3 \).

3.3 Determine the binder content of the sample \( (B) \) in accordance with Test Method Q308A or Q308D as appropriate and record the value to the nearest 0.01%.

3.4 Determine the density of the binder in the sample \( (D_B) \) in accordance with Test Method Q331 and record the value at 25ºC to the nearest 0.001 \( t/m^3 \) (Note 6.1).

3.5 Determine the binder absorption of the aggregate either in accordance with Test Method Q211 or Q316, or using an established binder absorption/water absorption relationship, and record the value to the nearest 0.01% (Notes 6.2, 6.3 and 6.4). Where binder absorption is determined using a binder absorption/water absorption relationship, determine the water absorption of the coarse fraction (retained 4.75 mm) \( (WA_c) \) and fine fraction (passing 4.75 mm and retained 0.075 mm) \( (WA_f) \) in accordance with Test Methods AS 1141.6.1 and AS 1141.5 respectively, and record these values to the nearest 0.01%.

4 Calculations
4.1 Calculate the percentage by volume of air voids in the sample to the nearest 0.1 as follows:

\[
AV = 100 \left( 1 - \frac{D_C}{D_M} \right)
\]

where

\( AV \) = air voids (\%)

\( D_C \) = compacted density of the sample \( (t/m^3) \)

\( D_M \) = maximum density of the sample \( (t/m^3) \)
4.2 Calculate the percentage by volume of effective binder in the sample to the nearest 0.1 using the appropriate calculation as follows (Note 6.4):

4.2.1 For binder absorption of the aggregate determined using Test Method Q211 or an established binder absorption/water absorption relationship:

\[
V_B = \frac{D_C}{D_B} \left( B - b_a + \frac{B b_a}{100} \right)
\]

where

- \( V_B \) = effective binder volume (%)
- \( D_C \) = compacted density of the sample (t/m³)
- \( D_B \) = density of the binder (t/m³)
- \( B \) = binder content of the sample (%)
- \( b_a \) = binder absorption of the aggregate (% by mass of aggregate)

4.2.2 For binder absorption of the aggregate determined using Test Method Q316:

\[
V_B = \frac{D_C}{D_B} (B - b_m)
\]

where

- \( V_B \) = effective binder volume (%)
- \( D_C \) = compacted density of the sample (t/m³)
- \( D_B \) = density of the binder (t/m³)
- \( B \) = binder content of the sample (%)
- \( b_m \) = binder absorption of the aggregate (% by mass of mix)

4.3 Calculate the percentage by volume of voids in the mineral aggregate in the sample to the nearest 0.1 as follows:

\[
V_{MA} = AV + V_B
\]

where

- \( V_{MA} \) = voids in the mineral aggregate (%)
- \( AV \) = air voids (%)
- \( V_B \) = effective binder volume (%)

4.4 Calculate the percentage by volume of voids filled with binder in the sample to the nearest 0.1 as follows:

\[
V_{FB} = \frac{100V_B}{V_{MA}}
\]

where

- \( V_{FB} \) = voids filled with binder (%)
- \( V_B \) = effective binder volume (%)
- \( V_{MA} \) = voids in the mineral aggregate (%)
4.5 Where a number of tests have been performed on a lot, calculate the maximum and minimum characteristic percentage by volume of air voids as detailed in Test Method Q020.

5 **Reporting**

Report the following values:

5.1 Air voids to the nearest 0.1%.

5.2 Voids in the mineral aggregate to the nearest 0.1%.

5.3 Voids filled with binder to the nearest 0.5%.

5.4 The minimum characteristic percentage by volume of air voids as detailed in Test Method Q020, if required.

5.5 The maximum characteristic percentage by volume of air voids as detailed in Test Method Q020, if required.

6 **Notes on method**

6.1 Where the density of the binder is unknown and circumstances do not allow its determination, a value of 1.040 t/m³ may be assumed.

6.2 Where the binder absorption of the aggregate in the sample is to be obtained using Test Method Q211 but is known from previous determination, further testing in accordance with Q211 is unnecessary.

6.3 Where the binder absorption of the aggregate in the sample is to be obtained using an established binder absorption/water absorption relationship, the following calculation may be used:

\[ b_a = 0.55 \times WA \]

where

- \( b_a \) = binder absorption of the aggregate (% by mass of aggregate)
- \( WA \) = water absorption of the aggregate (%)

WA may be calculated using either of the following which assume the filler component to have an absorption value equivalent to the average of the coarse and fine aggregate absorption values.

a) Where water absorption values are available for the coarse and fine fractions of the combined aggregate, calculate the water absorption of the aggregate as detailed in Test Method Q214.

\[ WA = \frac{P_c \times WA_c + P_f \times WA_f}{P_c + P_f} \]

where

- \( WA \) = water absorption of the aggregate (%)
- \( P_c \) = proportion of coarse aggregate (%)
- \( WA_c \) = water absorption of coarse aggregate (%)
- \( P_f \) = proportion of fine aggregate (%)
- \( WA_f \) = water absorption of fine aggregate (%)
b) Where water absorption values are available for the coarse and fine fractions of each individual aggregate component of the combined aggregate, calculate the water absorption as follows:

\[ WA = \sum_{i=1}^{N} p_i W_{Ai} \]

where

- \( WA \) = water absorption of the aggregate (%)
- \( p_i \) = proportion of the \( i^{th} \) aggregate component in the combined aggregate (%)
- \( W_{Ai} \) = water absorption of \( i^{th} \) aggregate component calculated using Test Method Q214 (%)
- \( n \) = number of aggregate components

6.4 Where binder absorption of the aggregate is determined using Test Method Q211 or an established binder absorption/water absorption relationship, it is expressed as a percentage by mass of aggregate. To convert from percentage by mass of aggregate to percentage by mass of mix, the following calculation may be used:

\[ b_m = b_a \cdot \frac{B_b}{100} \]

where

- \( b_m \) = binder absorption of the aggregate (% by mass of mix)
- \( b_a \) = binder absorption of the aggregate (% by mass of aggregate)
- \( B_b \) = binder content of the sample (%)

Superseded
Test Method Q312: Extraction of binder from road surfacings

1 Source

This method is based on a procedure developed from research performed by the Australian Road Research Board (Dickinson, E.I. "A Method of Following the Hardening of Paving Bitumens in Service", ARRB Research report ARR66, 1976).

2 Scope

This method describes the procedure for the extraction of binder from samples taken from sprayed seal or asphalt surfacings. The binder is prepared in a manner which allows measurement of its viscosity using suitable apparatus.

3 Apparatus

The following apparatus is required:

3.1 Test oven, as described in Test Method AS 2341.13.
3.1.1 Oven of suitable capacity, having a temperature of 105-110°C and complying with AS 1289.0.
3.2 Flowmeter, capable of measuring a gas flow rate of 4 L/min.
3.3 Sample bottles, as described in Test Method AS 2341.13.
3.4 Heating and mixing assembly, as described in Test Method AS 2341.13, and including the teflon dish.
3.5 Balance of suitable capacity, having a resolution of at least 0.1 g and with a limit of performance within the range of ± 0.5 g.
3.6 Centrifuge, capable of holding at least two 50 mL aliquots and achieving 3000 rpm rotation.
3.7 Freezer, of sufficient capacity to contain the teflon dish.
3.8 Measuring cylinders, two measuring cylinders of 25 mL and 100 mL capacity, graduated in 1 mL increments.
3.9 Filter funnel, a glass filter funnel.
3.10 Beakers, four beakers of 250 mL capacity.
3.11 Sieve, 0.075 mm complying with AS 1152.
3.12 Implements, for subsampling the test material, for example, knife or screwdriver for sprayed seal, metal trowel for asphalt, and for removing the binder from the sample bottles and teflon dish, for example, scalpel or spatula.

4 Materials

The following materials are required:

4.1 Toluene, AR grade (Note 6.1).
4.2 Aluminium foil.
4.3 Filter paper, Whatman No. 41 or equivalent.
4.4 Carbon dioxide supply, regulated to 4 ± 0.5 L/min.
5 Procedure

The procedure shall be as follows:

5.1 Preheat the test oven to 100°C.
5.2 Place the sample of road surfacing in the drying oven for approximately 15 minutes to soften the sample.
5.3 For a sprayed seal sample, prise a sufficient number of stone pieces from the seal to yield a representative subsample of about 100 g.
5.4 For an asphalt sample, obtain a representative subsample of about 50 g by coning and quartering.
5.5 Place the subsample into a 250 mL beaker and add about 100 mL of toluene by measuring cylinder (Note 6.2).
5.6 Cover the beaker with aluminium foil and allow it to stand for 1 hour.
5.7 Decant the contents of the beaker over the 0.075 mm sieve into a second 250 mL beaker.
5.8 Transfer the bitumen solution in the beaker to the centrifuge tubes and centrifuge the solution at approximately 3000 rpm for 15 minutes.
5.9 Pour the centrifuged solution in the centrifuge tubes into a third 250 mL beaker and filter this solution into the remaining 250 mL beaker.
5.10 Determine the mass of each of the four sample bottles.
5.11 Transfer 15 to 20 mL of the filtered solution to each sample bottle by measuring cylinder.
5.12 Turn the test oven off and place the sample bottles into the carriage of the test oven (Note 6.3).
5.13 Turn the test oven on and start the carriage rotation and carbon dioxide flow. Adjust the carbon dioxide flow to obtain a flow rate of 4 ± 0.5 L/min through the oven's outlet orifice.
5.14 After 45 minutes, turn the test oven off and remove the sample bottles.
5.15 Weigh each sample bottle and record the mass to the nearest 0.1 g (Note 6.4).
5.16 Scrape as much as possible of the binder film from the four sample bottles and transfer the scrapings to the teflon dish.
5.17 Bring the heating and mixing assembly to a temperature of 200 ± 5°C, and attach the carbon dioxide feed.
5.18 Place the teflon dish within the heating and mixing assembly and adjust the carbon dioxide flow rate to about 4 L/min.
5.19 After 5 minutes, remove the teflon dish from the heating and mixing assembly and immediately place it in the freezer.
5.20 Remove the teflon dish from the freezer and lever the homogenised binder from the dish using a warmed spatula (Note 6.5).

6 Notes on method

6.1 Before handling toluene, the operator must consult the relevant Safety Data Sheet (SDS).
6.2 Addition of toluene to dissolve the binder and extraction of binder from the toluene/bitumen solution must be performed on the same day.
6.3 While the test oven can accommodate up to eight sample bottles, only four sample bottles are used for each sample. When binder from one sample only is to be extracted, the remaining four spaces shall be filled with empty bottles.

6.4 The mass of binder in each of the four sample bottles shall be from 0.3 g to 0.8 g. A binder film of mass less than 0.3 g may have been oxidised during the extraction process, while a binder film of mass greater than 0.8 g may not have been evaporated for sufficient time to remove all of the toluene. Where the mass of binder recovered in each sample bottle falls outside this mass range, the procedure shall be repeated.

6.5 Where the viscosity of the homogenised binder is not to be determined on the same day as the extraction, the teflon dish containing the homogenised sample shall be covered with aluminium foil and stored in the freezer.
Test Method Q313: Abrasion loss of asphalt

This test shall be performed in accordance with Austroads Test Method AG:PT/T236 - Asphalt particle loss.
Test Method Q314: Relative compaction of asphalt

1 Source
This method is based on AS 2891.14.5: Field density tests – density ratio of compacted asphalt.

2 Scope
This method describes the procedure for determining the relative compaction of asphalt. It is determined as the ratio of the compacted density and the maximum density values for the asphalt expressed as a percentage.

3 Procedure
The procedure shall be as follows:

3.1 Determine the compacted density of the sample \(D_c\) in accordance with Test Method Q306A, Q306B, Q306C, Q306D or Q306E as appropriate, and record the value to the nearest 0.001 \(t/m^3\).

3.2 Determine the maximum density of the sample \(D_M\) in accordance with Test Method Q307A and record the value to the nearest 0.001 \(t/m^3\).

4 Calculations
4.1 Calculate the relative compaction to the nearest 0.1% as follows:
\[
RC = \frac{100D_c}{D_M}
\]
where
- \(RC\) = relative compaction (%)
- \(D_c\) = compacted density (\(t/m^3\))
- \(D_M\) = maximum density (\(t/m^3\))

4.2 Where a number of tests have been performed on a lot, calculate the minimum and/or maximum characteristic relative compaction as detailed in Test Method Q020.

5 Reporting
5.1 Report the relative compaction to the nearest 0.1%.

5.2 If required, report the minimum and/or maximum characteristic relative compaction as detailed in Test Method Q020.
Test Method Q315: Sensitivity of asphalt to water

1 Source

This method applies the principles of Austroads Test Method AG:PT/T232: Stripping potential of asphalt – Tensile strength ratio.

2 Scope

This method describes the procedure for the determination of the stripping potential of asphalt in the presence of water. The effect of water on the indirect tensile strength of moisture conditioned specimens is expressed as a ratio of the indirect tensile strength determined from dry specimens. It is applicable to asphalt having a nominal size no greater than 20 mm.

3 Apparatus

The following apparatus is required:

3.1 Mechanical mixer and accessories to prepare the asphalt in accordance with Test Method AS 2891.2.1.

3.2 Compaction equipment required to compact the asphalt specimens in accordance with either Test Method AS 2891.2.2 or Test Method Q305.

3.3 Marshall testing machine, breaking head and associated measurement system to load an asphalt specimen at 51 ± 3 mm per minute.

3.4 Loading blocks, as described in Test Method AS 2891.13.1.

3.5 Balance of suitable capacity, having a resolution of at least 0.1 g and with a limit of performance within the range of ± 0.5 g.

3.6 Freezer, maintained at a temperature of –18 ± 3°C and of sufficient capacity to contain three test specimens.

3.7 Constant temperature environment, a cabinet or room maintained at a temperature of 25 ± 1°C.

3.8 Water baths, two baths maintained at temperatures of 25 ± 1°C and 60 ± 1°C and of sufficient capacity to contain three test specimens.

3.9 Vacuum system, capable of applying a partial vacuum of 13 – 67 kPa absolute pressure.

3.10 Vacuum dessicator.

3.11 Thermometer, a partial or total immersion thermometer or other suitable temperature measuring device with a temperature range of at least 0 to 40°C and graduated to 1°C or less with an uncertainty of no more than 0.5°C.

3.12 Thermometer, a partial or total immersion thermometer or other suitable temperature measuring device with a temperature range of at least -20 to 0°C and graduated to 1°C or less with an uncertainty of no more than 0.5°C.

3.13 Callipers.

3.14 Measuring cylinder, of 10 mL capacity.
4 Materials

The following materials are required:

4.1 Plastic cling wrap, thick leak proof plastic bags and masking tape, suitable for sealing asphalt specimens.

4.2 Cloth, a damp cloth which has been soaked in water and then wrung out.

5 Procedure

The procedure shall be as follows:

5.1 Obtain an 8 kg sample of either plant production mix sampled as detailed in Test Method Q301, or laboratory manufactured mix prepared using the components and nominated binder content and grading for the mix design in accordance with the procedures described in Test Methods Q309 and AS 2891.2.1.

5.2 Prepare six 100 mm diameter compacted specimens to a height of 65 ± 1 mm and an air voids content of 8 ± 1% using the required mass of laboratory manufactured mix compacted in accordance with Test Method AS 2891.2.2 or Test Method Q305.

5.3 Determine the maximum density of the remainder of the laboratory manufactured mix in accordance with Test Method Q307A.

5.4 Measure the height (H) and diameter (D) of each specimen using the callipers and record the values to the nearest 1 mm.

5.5 Weigh each specimen and record the mass to the nearest 0.1 g (m₁).

5.6 Determine the compacted density of each specimen in accordance with Test Method Q306B or Q306C, and record the volume of the specimen (Vᵢ) (Note 8.1).

5.7 Determine the air voids of each specimen in accordance with Test Method Q311 (Note 8.2).

5.8 Divide the six specimens into two sets of three specimens such that each set has similar average air voids.

5.9 Select one set of three specimens, place the specimens on their sides under water in the vacuum desiccator and record the temperature of the water to the nearest 1°C.

5.10 Apply vacuum to partially saturate the specimens to between 55% and 80% saturation (Note 8.3).

5.11 Dry each of the three specimens to a surface-dry condition by quickly blotting the surface of the specimen with the damp cloth (Note 8.4).

5.12 Weigh each of three specimens and record the mass to the nearest 0.1 g (m₂).

5.13 Wrap each of the three specimens in several layers of plastic cling wrap.

5.14 Place each wrapped specimen into a separate plastic bag containing 10 mL water and seal the bag using masking tape.

5.15 Place the plastic bags containing the specimens in the freezer for 18 ± 1 hours, ensuring that the wrapped specimens are not in contact with each other.

5.16 Transfer the three specimens from the freezer to the 60°C water bath. As soon as possible after placement in the water bath, remove the plastic bag and wrapping from the specimens, and allow the specimens to soak in the bath for 24 ± 1 hours.
5.17 Transfer the three specimens to the 25°C water bath, ensuring they are not in contact and leave them in the bath for 120 ± 5 minutes (Note 8.5).

5.18 Remove a specimen from the water bath and immediately test it in accordance with the procedure described in Sections 5 and 6 of Test Method Q305, except that loading blocks shall be used instead of the breaking head. Record the maximum load for each specimen to the nearest 0.1 kN.

5.19 Repeat Step 5.18 for the two remaining moisture conditioned specimens.

5.20 Condition the remaining set of three dry specimens in the 25°C constant temperature environment for 120 ± 5 minutes (Note 8.6).

5.21 Remove a specimen from the constant temperature environment and immediately test it in accordance with the procedure described in Sections 5 and 6 of Test Method Q305, except that loading blocks shall be used instead of the breaking head. Record the maximum load for each specimen to the nearest 0.1 kN.

5.22 Repeat Step 5.21 for the two remaining dry specimens.

6 Calculations

Calculate as follows:

6.1 Calculate the degree of saturation for each of the three moisture conditioned specimens as follows:

\[ SP = \frac{10000(m_2 - m_1)}{AVD_w V_d} \]

where

- \( SP \) = degree of saturation of partially saturated specimens (%)
- \( m_2 \) = mass of partially saturated specimen (g)
- \( m_1 \) = mass of dry specimen (g)
- \( AV \) = air voids of specimen (%)
- \( D_w \) = density of water in the vacuum desiccator (t/m³) (Table 1)
- \( V_d \) = volume of specimen (cm³)

6.2 Calculate the tensile strength for each of the dry and moisture conditioned specimens using as follows:

\[ S = \frac{2P10^6}{\pi HD} \]

where

- \( S \) = tensile strength of specimen (kPa)
- \( P \) = maximum load for specimen (kN)
- \( H \) = height of specimen (mm)
- \( D \) = diameter of specimen (mm)
6.3 Calculate the average tensile strengths for the three soaked specimens ($S_w$) and for the three dry specimens ($S_d$) to the nearest 10 kPa.

6.4 Determine the tensile strength ratio as follows:

$$TSR = \frac{100S_w}{S_d}$$

where

- $TSR$ = tensile strength ratio (%)

- $S_w$ = average tensile strength of the moisture conditioned specimens (kPa)

- $S_d$ = average tensile strength of the dry specimens (kPa)

7 Reporting

Report the following:

7.1 The air voids of each specimen to the nearest 0.1%.

7.2 The degree of saturation of each partially saturated specimen to the nearest 0.1%.

7.3 The average tensile strengths for the moisture conditioned specimens and for the dry specimens to the nearest 10 kPa.

7.4 The tensile strength ratio to the nearest 1%.

8 Notes on method

8.1 If Test Method Q306B is used to determine compacted density, the following shall apply:

a) The period of immersion for each specimen shall be 3 to 5 minutes instead of a minimum of 5 minutes.

b) The three specimens to be tested dry (Step 5.8) shall be allowed to air dry to the original dry mass prior to conditioning in the 25°C constant temperature environment (Step 5.20).

8.2 If the air voids for the compacted specimens falls outside the range of 8 ± 1%, preparation of the mix shall be repeated and an adjusted number of gyratory cycles or Marshall blows shall be used to produce specimens within the required air voids range.

8.3 Partial saturation between 55% and 80% will normally require about 30 seconds under vacuum. A partial vacuum of 13 – 67 kPa absolute pressure is approximately equivalent to a -88 to -34 kPa reading on a vacuum gauge at sea level.

8.4 The purpose of blotting with the damp cloth is to remove excess water beaded on the surface. It is not intended that water is drawn from the void spaces so the blotting must be done lightly and as quickly as possible.

8.5 To ensure that the conditioning period does not exceed 125 minutes prior to testing (see Steps 5.18 to 5.19), it may be necessary to stagger transfer of the specimens to the water bath.

8.6 To ensure that the conditioning period does not exceed 125 minutes prior to testing (see Steps 5.21 to 5.22), it may be necessary to stagger transfer of the specimens to the constant temperature environment.
### Table 1 - Density of water

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<th>Temperature (°C)</th>
<th>Density (t/m³)</th>
<th>Temperature (°C)</th>
<th>Density (t/m³)</th>
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Test Method Q316: Binder absorption of asphalt mix components

1 Source
This method is based on the procedure for binder absorption calculation contained within AS/NZS 2981.8: Voids and volumetric properties of compacted asphalt mixes.

2 Scope
This method sets out a procedure for calculation of the binder absorption within a sample of asphalt mix. It requires prior determination of the binder content, aggregate grading and maximum density of sample, density of binder, particle density on a dry basis of the coarse aggregate and fine aggregate, apparent particle density of the filler and the proportions of coarse aggregate, fine aggregate and filler in the combined aggregate of the sample.

3 Procedure
3.1 Determine the total binder content \( B \) and aggregate grading of the sample of asphalt mix in accordance with Test Method Q308A or Q308D as appropriate and record the binder content value to the nearest 0.01%.

3.2 Determine the maximum density of the sample of asphalt mix \( D_{\text{mf}} \) in accordance with Test Method Q307A and record the value to the nearest 0.001 t/m³.

3.3 Determine the density of the binder in the sample \( BD \) in accordance with Test Method Q331 and record the value at 25°C to the nearest 0.001 t/m³ (Note 6.1).

3.4 Determine the particle density on a dry basis of the coarse aggregate (retained 4.75 mm) \( c \rho \) in accordance with Test Method AS 1141.6.1 and record the value to the nearest 0.001 t/m³.

3.5 Determine the particle density on a dry basis of the fine aggregate (passing 4.75 mm and retained 0.075 mm) \( f \rho \) in accordance with Test Method AS 1141.5 and record the value to the nearest 0.001 t/m³.

3.6 Determine the apparent particle density of the filler \( \text{fill} \rho \) in accordance with Test Method AS1141.7 and record the value to the nearest 0.001 t/m³.

3.7 Determine the proportions of coarse aggregate (retained 4.75 mm) \( cP \), fine aggregate (passing 4.75 mm and retained 0.075 mm) \( fP \) and filler \( \text{fillP} \) in the combined aggregate and record these values to the nearest 0.1%.

4 Calculations
4.1 Calculate the particle density of the combined mineral aggregate to the nearest 0.001 t/m³ as follows:

\[
\rho_s = \frac{100}{\frac{cP}{c \rho} + \frac{fP}{f \rho} + \frac{\text{fillP}}{\text{fill} \rho}}
\]
where  
\[
\begin{align*}
\rho_a &= \text{particle density of combined aggregate (t/m}^3) \\
\rho_c &= \text{proportion of coarse aggregate (\%)}
\end{align*}
\]
\[
\begin{align*}
\rho_c &= \text{particle density of coarse aggregate on a dry basis (t/m}^3) \\
p_c &= \text{proportion of fine aggregate (\%)}
\end{align*}
\]
\[
\begin{align*}
\rho_f &= \text{particle density of fine aggregate on a dry basis (t/m}^3) \\
p_f &= \text{proportion of filler (\%)}
\end{align*}
\]
\[
\begin{align*}
\rho_{\text{fill}} &= \text{apparent particle density of filler (t/m}^3) \\
p_{\text{fill}} &= \text{proportion of filler (\%)}
\end{align*}
\]

4.2 Calculate the binder absorption of the aggregate in the sample to the nearest 0.01% as follows:

\[
b_m = B - \frac{D_m}{D_B} \left( \frac{100}{100 - \left( \frac{100-B}{\rho_a} \right)} \right)
\]

where  
\[
\begin{align*}
b_m &= \text{binder absorption of the aggregate (\% by mass of mix)} \\
B &= \text{binder content of the sample (\%)}
\end{align*}
\]
\[
\begin{align*}
D_B &= \text{density of the binder (t/m}^3) \\
D_m &= \text{maximum density of the sample (t/m}^3)
\end{align*}
\]
\[
\begin{align*}
\rho_a &= \text{particle density of combined aggregate (t/m}^3)
\end{align*}
\]

5 Reporting

Report binder absorption to the nearest 0.05%.

6 Notes on method

6.1 Where the density of the binder is unknown and circumstances do not allow its determination, a value of 1.040 t/m³ may be assumed.
Test Method Q317: Binder film index of asphalt

This test shall be performed in accordance with either AS 2891.8: Voids and volumetric properties of compacted asphalt mixes or AUSTROADS test method AG:PT/T237: Binder film index.
Test Method Q318: Mix volume ratio of stone mastic asphalt

1 Source
This method was developed in-house using information contained within technical references.

2 Scope
This method describes the procedure for calculation of the mix volume ratio for SM14 and SM10 stone mastic asphalt. This ratio is defined as the volume of the components other than the coarse aggregate within a compacted mix expressed as a proportion of the volume of air voids contained within the coarse aggregate in a dry rodded condition. The coarse aggregate is defined as the fraction retained 4.75 mm for SM14 mix, and 2.36 mm for SM10 mix. The method requires determination of the binder content and grading of the mix, the particle density on a dry basis of the coarse aggregate, the compacted unit mass of the coarse aggregate and the compacted density of the mix.

3 Procedure
The procedure shall be as follows:

3.1 Determine the total binder content (B) and aggregate grading of the mix in accordance with Test Method Q308A or Q308D as appropriate. Record the proportion of coarse aggregate in the total aggregate (Pc) to the nearest 0.1%.

3.2 Determine the particle density on a dry basis of the coarse aggregate (Dρ) in accordance with Test Method Q214B and record this value to the nearest 0.001 t/m³.

3.3 Determine the average compacted unit mass of the coarse aggregate (Cρ) in accordance with Test Method Q221B with the exception that the test shall be performed in triplicate and the average compacted unit mass shall be recorded to the nearest 0.00 t/m³.

3.4 Determine the compacted density of the mix (CD) in accordance with Test Method Q306C and record the value to the nearest 0.001 t/m³.

4 Calculations
4.1 Calculate the volume of coarse aggregate in the mix to the nearest 0.1% using as follows:

$$V_c = \frac{P_c D_C (100-B)}{100 D_{\rho}}$$

where

- $V_c$ = volume of coarse aggregate in the mix (%)
- $P_c$ = proportion of coarse aggregate in the total aggregate (%)
- $D_C$ = compacted density of the mix (t/m³)
- $B$ = total binder content of the mix (%)
- $D_{\rho}$ = particle density on a dry basis of the coarse aggregate (t/m³)
4.2 Calculate the void volume in the compacted coarse aggregate to the nearest 0.1% using as follows:

\[ V_v = 100 \left( 1 - \frac{\rho_c}{\rho_D} \right) \]

where

- \( V_v \) = void volume in the compacted coarse aggregate in the dry rodded condition (%)
- \( \rho_c \) = average compacted unit mass of the coarse aggregate (t/m³)
- \( \rho_D \) = particle density on a dry basis of the coarse aggregate (t/m³)

4.3 Calculate the mix volume ratio for the mix to the nearest 0.01 as follows:

\[ MVR = \frac{100 - V_v}{V_v} \]

where

- \( MVR \) = mix volume ratio
- \( V_v \) = volume of coarse aggregate in the mix (%)
- \( V_v \) = void volume in the compacted coarse aggregate (%)

5 Reporting

Report the mix volume ratio to the nearest 0.01.
Test Method Q319: Manufacture of laboratory slab specimens for wheel tracker testing - segmental wheel compactor

1 Source
This method applies the principles of Austroads Asphalt Test AST 05: Sample preparation - Compaction of asphalt slabs suitable for characterisation.

2 Scope
This method describes the procedure for the laboratory manufacture of asphalt slab specimens using a segmental wheel compactor for wheel tracker testing. It may also be applied in part to the manufacture of asphalt slab specimens from plant mix. Three slab specimens are prepared for each mix.

3 Apparatus
The following apparatus is required:

3.1 Segmental wheel compactor, comprising the following (Note 8.1):

3.1.1 Compaction device, capable of applying a loading of 1000 to 30 000 N to within 500 N. The compaction device shall be in the form of a freely rotating wheel segment of diameter 1200 ± 200 mm. The foot of the compaction device shall have an arc length of 300 mm and a width of 300 mm. The compaction foot shall be able to be moved vertically and set to a specified height above the base of the compaction mould using a setting block. It shall have the option of vibratory compaction and shall be of sufficient rigidity that it will not deform under load over the operating range.

3.1.2 Compaction table, having an oscillating speed of 10 to 25 oscillations per minute adjustable to within 1 oscillation per minute, and a travel of 200 to 450 mm adjustable to within 5 mm. The table shall have provision to firmly attach the compaction mould.

3.1.3 Compaction moulds, three metal moulds of internal dimensions 300 mm length, 300 mm width and of sufficient depth to accommodate the slab specimen mix prior to compaction. Each mould shall be fitted with two removable end plates of dimensions 300 mm length and 125 mm height attached to the top of two opposite sides of the mould. The mould shall be equipped with electrical heating to allow it to be heated to the compaction temperature.

3.1.4 Lifting device, to move a compaction mould (with or without mix) to and from the compaction table.

3.2 Mixer, a mechanical mixer comprising a mixing bowl of sufficient capacity to contain the mix to be used in manufacture of three slab specimens, and an appropriate stirrer which will not cause excessive breakdown of the aggregates. A mixer of 35 L capacity has been found suitable.

3.3 Balance of suitable capacity, having a resolution of at least 1 g and with a limit of performance within the range of ± 5 g.

3.4 Container, fitted with an overflow and filled with clean water to the overflow. The container shall be of suitable dimensions to allow a slab specimen to be completely immersed without contacting any part of the container.

3.5 Suspension device, cable or wire frame to suspend a slab specimen on its side.

3.6 Oven, of suitable capacity and maintained at a temperature of 150°C.
3.7 Quartering table, metal tray (preferably heated) of appropriate dimensions to contain the mix for three slab specimens. A tray of dimensions 1 m square has been found suitable.

3.8 Oven or hotplate, capable of heating a sample of binder to a temperature of 150-180°C.

3.9 A means for heating the aggregates and added filler to about 210°C (for example, gas burner).

3.10 Heating container(s), metal container(s) able to be heated to at least 210°C and of sufficient capacity to contain the aggregates and added filler.

3.11 Transfer container, metal container of sufficient capacity to transfer the entire mix from the mixer to the quartering table.

3.12 Thermometer, a partial immersion thermometer or other suitable temperature measuring device having a temperature range of up to 250°C and with a resolution of 1°C or less with an uncertainty of no more than 2.0°C.

3.13 Fan, an electric fan to disperse vapours emanating from the sealant during the curing period.

3.14 Mixing tools (for example, metal scoops, trowels, spatulas).

3.15 Marking medium, to identify the slab specimen.

4 Materials

The following materials are required:

4.1 Sealant, acetic cure silicone sealant of known density to the nearest 0.001 t/m³ (Note 8.3)

4.2 Asphalt release agent (Note 8.2).

4.3 Aggregate components: coarse aggregates, fine aggregates and sand (as appropriate) of the required quantities (see Step 5.2).

4.4 Added filler components: fly ash, hydrated lime, baghouse fines or other material of the required quantities (see Step 5.2) (Note 8.2).

4.5 Binder: bitumen complying with MRTS 17, polymer modified binder complying with MRTS 18 or other specified binder (Note 8.2).

4.6 Other components: fibres and additives (where appropriate) (Note 8.2).

5 Preparation of mix

The procedure shall be as follows:

5.1 Dry sufficient quantities of the aggregate and added filler components of the mix design to provide the required total mass of aggregates and added filler (Note 8.2).

5.2 Calculate the required mass of each aggregate and added filler component as follows:

\[ M_R = \frac{P_R M_T}{100} \]

where

- \( M_R \) = mass of aggregate or added filler component (g)
- \( P_R \) = proportion of the aggregate or added filler in the mix design (%)
- \( M_T \) = total mass of aggregates and added filler (g)
5.3 Combine the required masses of the aggregates and added filler and then transfer representative portions of the combined materials into one or more heating containers (Note 8.4).

5.4 Heat the container(s) and contents to the appropriate temperature using the gas burner or other means (Table 1). During the heating process, mix the contents periodically using a metal scoop to provide an even temperature distribution (Note 8.5).

5.5 Heat the binder in the oven or on the hotplate to the appropriate temperature (Table 1).

5.6 Remove a container from the heating source, determine the mass of the container and contents \( m_{c1} \).

5.7 Empty the contents of the container carefully into the mixer, determine the mass of the container \( m_{c2} \).

5.8 Calculate the mass of the contents of the container as follows:

\[
C_m = m_{c2} - m_{c1}
\]

where

- \( C_m \) = mass of contents of heating container (g)
- \( m_{c2} \) = mass of heating container and contents (g)
- \( m_{c1} \) = mass of heating container (g)

5.9 Repeat Steps 5.6 to 5.8 for the remaining containers.

5.10 Calculate the total mass of the contents from all heating containers \( M_c \) by summing the individual masses calculated in Steps 5.8 and 5.9.

5.11 Where fibre is a component of the mix design, undertake the following:

5.11.1 Calculate the mass of fibre for the mix as follows:

\[
M_f = \frac{P_f M_c}{100}
\]

where

- \( M_f \) = mass of fibre (g)
- \( P_f \) = proportion of fibre in the mix (%)
- \( M_c \) = total mass of contents (g)

5.11.2 Add the required mass of fibre to the contents of the mixer, and distribute the fibre uniformly throughout the contents by mixing for about 15 seconds.

5.12 Calculate the mass of binder for the mix as follows:

\[
M_b = \frac{P_b M_c}{100-P_b}
\]

where

- \( M_b \) = required mass of binder (g)
- \( P_b \) = proportion of binder in the mix (%) (Note 8.6)
- \( M_c \) = total mass of contents (g)
5.13 Pour the required mass of binder \( M_b \) into a crater formed in the centre of the contents of the mixer.

5.14 Mix the contents of the mixer by hand for about 30 seconds using a trowel. Return any material adhering to the trowel to the mixer.

5.15 Mechanically mix the contents for 90 seconds at the slowest speed.

5.16 Stop the mixer and return any binder rich fines adhering to the walls of the mixer to the mix by scraping with a trowel or spatula.

5.17 Mechanically mix the contents for a further 90 seconds at the slowest speed.

5.18 Using the transfer container, transfer the entire mix from the mixer to the quartering table. Return any material adhering to the mixer or transfer container to the mix by scraping with the trowel or spatula.

5.19 Calculate the mass of mix required for each slab specimen as follows:

\[
M = \frac{D_M V (100 - AV)}{100}
\]

where

- \( M_b \) = mass of mix (g)
- \( P_b \) = maximum density of mix (t/m³) (Note 8.7)
- \( V \) = volume of specimen mould (cm³)
- \( AV \) = target air voids (%)

5.20 Prepare the mix in accordance with Clause 4.2 of Test Method Q301 to obtain representative portions for three slab specimens and for mix testing as detailed in Test Methods Q307A and Q308A/Q308D.

6 Preparation of slab specimen

Prepare each slab specimen portion as follows:

6.1 Condition the portion of mix allocated for the slab specimen in the oven for one hour at 150°C (Note 8.8).

6.2 Assemble the mould and fix one of the end plates to the mould.

6.3 Preheat the mould to the compaction temperature and preheat the compaction foot (Note 8.9).

6.4 Apply a thin layer of asphalt release agent to the inside surfaces of the mould and to the bottom of the compaction foot.

6.5 Insert the appropriate setting block into the slab compactor to set the thickness of the slab specimen and locate the compaction foot at a height corresponding to just below the top of the mould end plate.

6.6 Transfer the mix portion to the mould, screed it flat without segregation using a trowel and level the mix.

6.7 With the compaction table at the end of its forward cycle, transfer the mould and sample to the compaction table using the lifting device, inserting the side opposite the end plate first.

6.8 Fix the mould to the compaction table.

Superseded
6.9 Move the compaction table until the compaction foot just contacts the end plate.
6.10 Attach the second end plate to the mould.
6.11 Lower the compaction foot to rest on the mix in the mould.
6.12 Compact the sample in the mould using the manufacturer’s instructions to provide the following compaction sequence:
   a) 5 oscillations at a pressure of 25 kPa.
   b) 5 oscillations at a pressure of 50 kPa.
   c) 10 oscillations at a pressure of 100 kPa.
   d) 10 oscillations at each additional increment of 100 kPa until the target slab thickness is attained across the whole of the slab specimen (Note 8.10).
6.13 Raise the compaction foot, remove the mould end plates, move the compaction table to the end of its forward cycle and remove the mould from the segmental wheel compactor using the lifting device.
6.14 Mark the slab specimen with the direction of rolling and an identification number.
6.15 Allow the slab specimen to cool and then remove it from the mould.

7 Testing of mix and slab specimen

Test the mix and each slab specimen as follows:
7.1 Determine the mass of the slab specimen \( m_1 \).
7.2 Apply silicone sealant to approximately one half of the surface area of the slab specimen to achieve a smooth and even finish (Note 8.11).
7.3 Place the sample in front of a fan and allow the sealant to cure to a firm and tack-free state.
7.4 Apply silicone sealant to the remainder of the sample to achieve a smooth and even finish and allow the sealant to cure (Note 8.11).
7.5 Inspect the sealed slab specimen, apply silicone sealant to any unsealed areas and allow the sealant to cure.
7.6 Determine the mass of the sealed slab specimen \( m_2 \).
7.7 Fit the suspension device to the balance, allow the remainder of the suspension device to be immersed in the water container, and tare the balance.
7.8 Attach the sealed slab specimen to the suspension device and gently lower it into the water container on its side until completely immersed, taking care to ensure that the suspended specimen hangs free of the sides and bottom of the container.
7.9 Determine the mass of the suspended slab specimen \( m_3 \).
7.10 Measure the temperature of the water in the container to the nearest 1°C.
7.11 Calculate the compacted density of the slab specimen as follows:

\[
D_c = \frac{\frac{m_1}{D_w} - \frac{m_2}{m_1}}{\frac{m_3}{m_1} - \frac{m_2}{D_s}}
\]
where  \( D_C \) = compacted density of slab specimen (t/m³)
\( m_1 \) = mass of slab specimen (g)
\( m_2 \) = mass of sealed slab specimen (g)
\( m_3 \) = mass of immersed sealed slab specimen (g)
\( D_w \) = density of water at test temperature (t/m³) (Table 2)
\( D_S \) = density of silicone sealant (t/m³)

7.12 Repeat Steps 7.1 to 7.11 for the remaining slab specimens.

7.13 Determine the maximum density of the mix in accordance with Test Method Q307A using the designated test portion.

7.14 Determine the binder content and grading of the mix in accordance with Test Method Q308A or Q308D using the designated test portion.

7.15 Using the values for compacted density and maximum density obtained in Steps 7.11 and 7.13, calculate the air voids in the slab specimen in accordance with Test Method Q311.

7.16 Accept the slab specimen for further preparation and testing subject to the following:
   a) The air void content is within ± 0.5% of the target air voids.
   b) The binder content and grading of the mix agree with the target values within the tolerances specified in Table 3.

7.17 Store the slab specimen at a temperature not exceeding 30°C on a flat non-deforming surface of dimensions not less than those of the slab specimen.

8 Notes on method

8.1 The BP Slab Compactor satisfies the requirements of the segmental wheel compactor.

8.2 Before handling the silicone sealant, flyash, hydrated lime, fibre, the operator must consult the relevant Material Safety Data Sheet (MSDS).

8.3 The total mass of aggregates and added filler may be estimated from the quantity of mix required to prepare three slab specimens and perform testing for binder content, grading and maximum density. This quantity of mix will vary according to the required thickness of the slab specimen and the maximum density of the mix. A mix quantity of 35 to 50 kg will normally be required.

8.4 Some breakdown of the aggregates in the mix may occur during the mixing process. Where this breakdown is significant for particular aggregates, an appropriate adjustment to the calculated required masses of the aggregates and added filler may be necessary.

8.5 Mixing for 30 seconds following each 15 minute heating period has been found adequate.

8.6 Depending on the particular mix prepared and the nature of the mechanical mixer, it may be necessary to increase the proportion of binder in the mix by up to 0.15% to allow for binder losses on the stirrer and mixing bowl.

8.7 Where the maximum density of the mix is unknown, prior preparation and testing of a trial mix for maximum density measurement may be necessary. Otherwise, an estimate of the maximum density based on previous experience may be used.
8.8 Given that the three slab specimens are prepared consecutively, a longer curing time for the second and third slab specimens is permissible. However, this additional time should be minimised.

8.9 The compaction foot may be heated by allowing it to rest on the base of the compaction mould during the preheating of the mould.

8.10 Vibratory compaction may be used where it becomes apparent that compaction without vibration will not achieve the target slab thickness.

8.11 During the application of the silicone sealant, it is important that no air is trapped between the silicone sealant layer and the surface of the slab specimen.

**Table 1 - Temperatures for mix manufacture**

<table>
<thead>
<tr>
<th>Component</th>
<th>Asphalt type</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Binder</td>
</tr>
<tr>
<td>Class 170 bitumen</td>
<td>DG, SM</td>
<td>160 - 170</td>
</tr>
<tr>
<td>Class 320 bitumen</td>
<td>DG, SM</td>
<td>160 - 170</td>
</tr>
<tr>
<td>Class 600 bitumen</td>
<td>DG</td>
<td>160 - 170</td>
</tr>
<tr>
<td>Multigrade bitumen</td>
<td>DG</td>
<td>160 - 170</td>
</tr>
<tr>
<td>Polymer modified binder</td>
<td>DG, SM</td>
<td>170 - 180</td>
</tr>
</tbody>
</table>

Note: DG – Dense graded, SM – Stone mastic

**Table 2 - Density of water**

<table>
<thead>
<tr>
<th>Test temperature (°C)</th>
<th>Water density (t/m³)</th>
<th>Test temperature (°C)</th>
<th>Water density (t/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.000</td>
<td>21</td>
<td>0.998</td>
</tr>
<tr>
<td>2</td>
<td>1.000</td>
<td>22</td>
<td>0.998</td>
</tr>
<tr>
<td>3</td>
<td>1.000</td>
<td>23</td>
<td>0.998</td>
</tr>
<tr>
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<td>8</td>
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<td>33</td>
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<tr>
<td>14</td>
<td>0.999</td>
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<tr>
<td>15</td>
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<td>0.994</td>
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</tbody>
</table>
### Test temperature

<table>
<thead>
<tr>
<th>Test temperature (°C)</th>
<th>Water density (t/m³)</th>
<th>Test temperature (°C)</th>
<th>Water density (t/m³)</th>
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</thead>
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<tr>
<td>16</td>
<td>0.999</td>
<td>36</td>
<td>0.994</td>
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<tr>
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<tr>
<td>19</td>
<td>0.998</td>
<td>39</td>
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</tr>
<tr>
<td>20</td>
<td>0.998</td>
<td>40</td>
<td>0.992</td>
</tr>
</tbody>
</table>

**Table 3 - Maximum compositional variation**

<table>
<thead>
<tr>
<th>Sieve size (mm)</th>
<th>Maximum compositional variation (% passing)</th>
<th>DG20, DG28</th>
<th>All other mixes</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 4.75</td>
<td>-2 to +4</td>
<td>-3 to +3</td>
<td></td>
</tr>
<tr>
<td>2.36</td>
<td>-2 to +3</td>
<td>-2 to +2</td>
<td></td>
</tr>
<tr>
<td>1.18</td>
<td>-2 to +3</td>
<td>-2 to +2</td>
<td></td>
</tr>
<tr>
<td>0.600</td>
<td>-1 to +2</td>
<td>-1 to +2</td>
<td></td>
</tr>
<tr>
<td>0.300</td>
<td>-1 to +2</td>
<td>-1 to +2</td>
<td></td>
</tr>
<tr>
<td>0.150</td>
<td>-1 to +2</td>
<td>-1 to +2</td>
<td></td>
</tr>
<tr>
<td>0.075</td>
<td>0 to +2</td>
<td>-0.5 to +1</td>
<td></td>
</tr>
</tbody>
</table>

Binder content (%): ± 0.010 ± 0.015

**Superseded**
Test Method Q320: Deformation of asphalt - wheel tracker

1 Source

This method applies the principles of Austroads Asphalt Test AG PT/T231 - Deformation Resistance of Asphalt Mixtures by the Wheel Tracking Test.

2 Scope

This method describes the procedure for determining the susceptibility of asphalt to deform under load. It involves monitoring the deformation that occurs in an asphalt sample undergoing to and fro motion when a loaded wheel is brought to bear on its surface. The method is applicable to asphalt mix either manufactured in the laboratory or sampled from an existing asphalt pavement.

3 Apparatus

The following apparatus is required:

3.1 Wheel tracker apparatus comprising the following:

3.1.1 Loaded wheel mechanism, consisting of a steel wheel of diameter 200 to 205 mm and width 50 ± 1 mm fitted with a smooth solid rubber tread of thickness 10 to 13 mm and hardness 80 ± 10 IRHD units. The mechanism shall include a means of loading the wheel so that a force of 700 ± 20 N is applied centrally and normal to the top surface of the test specimen. Vertical play in the loaded wheel mechanism shall be less than 0.25 mm.

3.1.2 Wheel tracker table, capable of moving in simple harmonic motion at a frequency of 42 ± 0.5 passes per minute over a travel distance of 230 ± 10 mm (Note 9.1). It shall be fitted with a means for fixing a prismatic test specimen of dimensions up to 305 mm length, 305 mm width or cylindrical specimen of at least 200 mm in diameter centrally in a horizontal plane below the load wheel. There should be sufficient adjustment to cater for samples from 35 mm to 110 mm in thickness.

3.1.3 Rut depth measurement device, an electronic displacement measuring device having a minimum travel of 20 mm and a limit of performance within the range of ± 0.1 mm.

3.1.4 A means for continuously recording rut depth measurements at progressive numbers of wheel tracker cycles.

3.1.5 A means for controlling the test specimen temperature to within ± 1°C of the test temperature throughout the test.

3.2 Wheel tracker mould, a steel mould comprising detachable sides and baseplate and having dimensions of 305 mm length and 305 mm width and a depth of between 50 mm and 100 mm depending on the thickness of the test specimen.

3.3 Oven, maintained at the test temperature to within ± 1°C.

3.4 Balance of suitable capacity, with a resolution of at least 1 g and with a limit of performance within the range of ± 5 g and capable of below balance weighing.

3.5 Water container, filled with water at ambient temperature, fitted with an overflow device and of sufficient capacity to contain a test specimen.

3.6 Suspension device, cable or wire frame to suspend the test specimen on its side.

3.7 Suspension bridge, to support the balance and suspension device over the water container.
3.8 Thermometer, a partial immersion thermometer or other suitable temperature measuring device having a temperature range including ambient and graduated to 1°C or less with an uncertainty of no more than 0.5°C.

3.9 Saw, diamond tipped masonry saw.

3.10 Mixing utensils, for preparing the regulation course material

3.11 Dummy specimen, an asphalt specimen with a mass of at least 25% of the test specimen and instrumented with thermocouples to monitor its temperature.

3.12 Ruler, a steel ruler to measure the dimensions of test specimens to the nearest 1 mm.

3.13 Straight edge.

3.14 Marking medium to identify specimens.

4 Materials

The following materials are required:

4.1 Silicone grease (Note 9.2).

4.2 Regulation course material, a mixture of Plaster of Paris and fine sand (Notes 9.2, 9.3).

4.3 Potable water.

5 Preparation

The test specimens shall be prepared as follows:

5.1 Prepare the test specimens from triplicate slab specimens either manufactured in the laboratory or sampled from a pavement as follows:

5.1.1 Slab specimens manufactured in the laboratory shall be prepared in accordance with Test Method Q319. Laboratory manufactured test specimens shall have a thickness of 50 or 75 mm +/- 5 mm and be between 4 and 30 days old at the time of testing.

5.1.2 Slab specimens sampled from the pavement shall have minimum dimensions of 300 mm length, 300 mm width and 35 mm thickness and a maximum thickness of 110 mm. The specimens shall consist of a single layer of material and have no discontinuities. Slab specimens shall be examined for any defects caused through sampling and shall be rejected if cracks are visible to the naked eye or if the geometry of the specimen is compromised through spalling of corners and edges. The rolling or traffic direction shall be clearly indicated on the upper surface.

5.2 For slab specimens having dimensions greater than 305 mm length and 305 mm width, cut a test specimen of about 300 mm square from the central portion of the slab specimen using the masonry saw, and discard the remainder.

5.3 Air dry the test specimen to constant mass and determine its mass ($m_1$).

5.4 Immerse the test specimen in the water container for at least 5 minutes.

5.5 Position the water container directly beneath the balance on the suspension bridge and attach the suspension device to the balance.

5.6 Transfer the soaked test specimen to the suspension device so that the specimen remains completely immersed on its side in the water container but clear of the walls and bottom of the container.
5.7 Determine the mass of the soaked test specimen in water ($m_2$).

5.8 Remove the soaked test specimen from the suspension device and allow it to drain for 5 seconds.

5.9 Determine the mass of the soaked test specimen in air ($m_3$).

5.10 Measure the temperature of the water in the water container to the nearest 1°C.

5.11 Air dry the test specimen and measure its thickness to the nearest 1 mm.

5.12 Coat the wheel tracker mould components with silicone grease and assemble the wheel tracking mould without the baseplate.

5.13 Invert the test specimen and place it centrally within the raised mould.

5.14 Prepare the regulation course material and pour it over the inverted test specimen to fill the mould. Strike off any excess material using the straight edge so that the regulation course material provides a smooth and even surface level with the upper edges of the mould.

5.15 Attach the base plate invert the mould and allow the regulation course material to set.

5.16 If the dimensions of the asphalt specimen and mould differ by more than 0.5 mm fill the gap with regulation course material.

5.17 Remove any regulation course material from the top surface of the test specimen.

6 Procedure

The procedure shall be performed on each of the test specimens prepared in triplicate as follows:

6.1 Condition the test specimen in the wheel tracker mould at the test temperature for a minimum of 8 hours but no more than 24 hours, either in the wheel tracker apparatus or in the oven (Note 9.4).

6.2 Fix the test specimen to the wheel tracker table ensuring that the indicated rolling or traffic direction is aligned with the direction of travel of the loaded wheel.

6.3 Place the dummy specimen within 300 mm of the test specimen and within the same temperature controlled environment.

6.4 Allow a minimum period of 1 hour for the test specimen and dummy specimen to reach equilibrium temperature.

6.5 Check the temperature of the dummy specimen and proceed with the test provided that the temperature of the dummy specimen is within ± 1°C of the test temperature.

6.6 Lower the loaded wheel to the surface of the test specimen. Allow 5 cycles/10 passes of the wheel then commence wheel tracking in accordance with the operating instructions for the wheel tracker apparatus.

6.7 Obtain a continuous record of the rut depth corresponding to different numbers of wheel tracker cycles (Note 9.5).

6.8 Continue wheel tracking for a minimum of 5000 cycles or until the rut depth is in excess of 15 mm (Note 9.1).

6.9 Determine the maximum density of the mix as detailed in Test Method Q307A.
7 Calculations

The calculations shall be as follows:

7.1 For each test specimen calculate the compacted density as follows:

\[ D_c = \frac{m_1 D_w}{m_3 - m_2} \]

where

- \( D_c \) = compacted density of sample (t/m³)
- \( m_1 \) = mass of test specimen in air (g)
- \( D_w \) = density of water at test temperature (t/m³) (Table 1)
- \( m_3 \) = mass of soaked test specimen in air (g)
- \( m_2 \) = mass of soaked test specimen in water (g)

7.2 Using the values for maximum density and compacted density obtained in Steps 6.9 and 7.1, calculate the air voids in each test specimen as detailed in Test Method Q311.

7.3 For each test specimen, calculate the tracking rate over the range of cycles specified for the test as follows (Notes 9.6, 9.7):

\[ T_R = \frac{R_H - R_L}{N_H - N_L} \]

where

- \( T_R \) = specimen tracking rate (mm/kCycle)
- \( R_H \) = rut depth at higher number of specified cycles (mm)
- \( R_L \) = rut depth at lower number of specified cycles (mm)
- \( N_H \) = higher number of specified cycles (kCycles)
- \( N_L \) = lower number of specified cycles (kCycles)

7.4 Calculate the average value for the three test specimens for each of the following properties:

a) Tracking rate to the nearest 0.01 mm/kCycle
b) Rut depth at the completion of the test to the nearest 0.01 mm
c) Air voids to the nearest 0.1%
d) Layer thickness to the nearest 1 mm.

8 Reporting

Report the following values and general information:

8.1 Tracking rate to the nearest 0.01 mm/kCycle.
8.2 Range of wheel tracker cycles over which the tracking rate was calculated.
8.3 Rut depth at the completion of the test to the nearest 0.01 mm.
8.4 Air voids to the nearest 0.1%.
8.5 Layer thickness to the nearest 1 mm.
8.6 Number of loading cycles.
8.7 Test temperature to the nearest 1°C.
8.8 Age of the test specimen.

9 Notes on method

9.1 One cycle represents the outward and return passes of the loaded wheel (that is, two passes).
9.2 Before handling silicone grease or Plaster of Paris, the operator must consult the relevant Safety Data Sheet (SDS).
9.3 The regulation course material shall comprise the following:
   a) For application to the base of the test specimen, a homogeneous mixture by volume of mix 5 parts of Plaster of Paris, 5 parts fine sand and 3.5 parts water.
   b) To fill the gap between the test specimen and the sides of the mould, a homogeneous mixture by volume of mix 5 parts of Plaster of Paris, 5 parts fine sand and 7 parts water.
9.4 The test temperature will normally be 60°C.
9.5 Record the tracking depth in the centre of the wheel travel, at +/-7.5 mm, +/-22.5 mm and at 37.5 mm from the centre of wheel travel to within 2.5 mm. Readings shall be taken, as a minimum, at the following intervals: 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 150, 200, 250, 300, 400, 500, 1000, 2000, 3000, 4000, 5000, 6000, 7000, 8000, 9000 and 10,000.
9.6 Where no range of cycles is specified for the test, a range of 2000 to 5000 cycles may be used.
9.7 Alternatively, the data over the specified range of wheel tracker cycles may be analysed using linear regression analysis of rut depth against number of cycles to determine the tracking rate.

Table 1 – Density of water

<table>
<thead>
<tr>
<th>Test temperature (°C)</th>
<th>Water density (t/m³)</th>
<th>Test temperature (°C)</th>
<th>Water density (t/m³)</th>
</tr>
</thead>
<tbody>
<tr>
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Test Method Q321: Fixed and free binder in asphalt

1 Source
This method was developed in-house using measures evolved through internal departmental research investigations.

2 Scope
This method sets out a procedure for calculation of the fixed and free binder in a sample of asphalt. Fixed binder represents that portion of the binder which is immobilised by the filler. Free binder represents that portion of the binder which is neither absorbed by the aggregate nor immobilised by the filler. Prior determination is required of the binder content and compacted density of the sample, density of the binder, binder absorption of the aggregate, apparent particle density and voids of the combined filler, and the proportion of combined filler in the sample.

3 Procedure
The procedure shall be as follows:

3.1 Determine the binder content of the sample (B) in accordance with Test Method Q308A or Q308D as appropriate and record the value to the nearest 0.01%.

3.2 Determine the binder absorption of the aggregate either in accordance with Test Method Q211 or Q316, or using an established binder absorption/water absorption relationship, and record the value to the nearest 0.01% (Notes 6.1, 6.2 and 6.3). Where binder absorption is determined using a binder absorption/water absorption relationship, determine the water absorption of the coarse fraction (retained 4.75 mm) (WA_c) and fine fraction (passing 4.75 mm and retained 0.075 mm) (WA_f) in accordance with Test Methods AS 1141.6.1 and AS 1141.5 respectively, and record these values to the nearest 0.01%.

3.3 Determine the density of the binder in the sample (BD) in accordance with Test Method Q331 and record the value at 25°C to the nearest 0.001 t/m³ (Note 6.4).

3.4 Determine the compacted density of the sample (CD) in accordance with Test Method Q306A, Q306B or Q306C as appropriate and record the value to the nearest 0.001 t/m³.

3.5 Determine the proportion of the combined filler (P_fill) as a percentage of the total aggregate and filler in the sample and record the value to the nearest 0.1%.

3.6 Determine the apparent particle density of the combined filler (ρ_fill) in accordance with Test Method AS 1141.7 and record the value to the nearest 0.001 t/m³.

3.7 Determine the voids in dry compacted filler for the combined filler (V) in accordance with Test Method AS 1141.17 and record the value to the nearest 0.1%.

4 Calculations
4.1 Calculate the effective binder volume in the sample to the nearest 0.1% as follows:

\[ V_B = \frac{D_C}{D_B} (B-b_m) \]
Test Method Q321: Fixed and free binder in asphalt

where

\[ V_B = \text{effective binder volume (\% by volume of mix)} \]

\[ D_C = \text{compacted density (t/m}^3\text{)} \]

\[ D_B = \text{density of the binder (t/m}^3\text{)} \]

\[ B = \text{binder content (\% by mass of mix)} \]

\[ b_m = \text{binder absorption of the aggregate (\% by mass of mix) (Note 6.3)} \]

4.2 Calculate the fixed binder volume in the sample to the nearest 0.1\% as follows:

\[ V_f = \frac{P_{\text{fill}} V D_C}{\rho_{\text{fill}} (100-V) 100} (100-B) \]

where

\[ V_f = \text{fixed binder volume (\% by volume of mix)} \]

\[ P_{\text{fill}} = \text{proportion of the combined filler (\% by mass of aggregate and filler)} \]

\[ V = \text{voids in dry compacted filler (\%)} \]

\[ D_C = \text{compacted density (t/m}^3\text{)} \]

\[ \rho_{\text{fill}} = \text{apparent particle density of the combined filler (t/m}^3\text{)} \]

\[ B = \text{binder content (\% by mass of mix)} \]

4.3 Calculate the fixed binder fraction in the sample to the nearest 0.01 as follows:

\[ f_B = \frac{V_f}{V_B} \]

where

\[ f_B = \text{fixed binder fraction} \]

\[ V_f = \text{fixed binder volume (\% by volume of mix)} \]

\[ V_B = \text{effective binder volume (\% by volume of mix)} \]

4.4 Calculate the free binder volume in the sample to the nearest 0.1\% as follows:

\[ V_f = V_B - V_f \]

where

\[ V_f = \text{free binder volume (\% by volume of mix)} \]

\[ V_B = \text{effective binder volume (\% by volume of mix)} \]

\[ V_f = \text{fixed binder volume (\% by volume of mix)} \]

4.5 Calculate the free binder fraction in the sample to the nearest 0.01 as follows:

\[ f_B = \frac{V_f}{V_B} \]

where

\[ f_B = \text{free binder fraction} \]
Test Method Q321: Fixed and free binder in asphalt

\[ V_F = \text{free binder volume (\% by volume of mix)} \]
\[ V_a = \text{effective binder volume (\% by volume of mix)} \]

5 Reporting

Report the following values:

5.1 Effective binder volume to the nearest 0.1%.
5.2 Free binder volume to the nearest 0.1%.
5.3 Fixed binder fraction to the nearest 0.01.
5.4 Fixed binder volume to the nearest 0.1% (where required).
5.5 Free binder fraction to the nearest 0.01 (where required).

6 Notes on method

6.1 Where the binder absorption of the aggregate in the sample is to be obtained using Test Method Q211 but is known from previous determination, further testing in accordance with Q211 is unnecessary.

6.2 Where the binder absorption of the aggregate in the sample is to be obtained using an established binder absorption/water absorption relationship, the following calculation may be used:

\[ b_a = 0.55 W_A \]

where

\[ b_a = \text{binder absorption of the aggregate (\% by mass of aggregate)} \]
\[ W_A = \text{water absorption of the aggregate (\%)} \]

WA may be calculated using either of the following which assume the filler component to have an absorption value equivalent to the average of the coarse and fine aggregate absorption values.

a) Where water absorption values are available for the coarse and fine fractions of the combined aggregate, calculate the water absorption of the aggregate as detailed in Test Method Q214.

\[ W_A = \frac{P_c W_{A_c} + P_f W_{A_f}}{P_c + P_f} \]

where

\[ W_A = \text{water absorption of the aggregate (\%)} \]
\[ P_c = \text{proportion of coarse aggregate (\%)} \]
\[ W_{A_c} = \text{water absorption of coarse aggregate (\%)} \]
\[ P_f = \text{proportion of fine aggregate (\%)} \]
\[ W_{A_f} = \text{water absorption of fine aggregate (\%)} \]
b) Where water absorption values are available for the coarse and fine fractions of each individual aggregate component of the combined aggregate, calculate the water absorption as follows:

\[ WA = \sum_{i=1}^{N} P_i WA_i \]

where

- \( WA \) = water absorption of the aggregate (%)
- \( P_i \) = proportion of the \( i^{th} \) aggregate component in the combined aggregate (%)
- \( WA_i \) = water absorption of \( i^{th} \) aggregate component calculated using Test Method Q214(%) 
- \( n \) = number of aggregate components

6.3 Where binder absorption of the aggregate is determined using Test Method Q211 or an established binder absorption/water absorption relationship, it is expressed as a percentage by mass of aggregate. To convert from percentage by mass of aggregate to percentage by mass of mix, the following calculation may be used:

\[ b_m = b_a - \frac{Bb}{100} \]

where

- \( b_m \) = binder absorption of the aggregate (% by mass of mix)
- \( b_a \) = binder absorption of the aggregate (% by mass of aggregate)
- \( B \) = binder content of the sample (%) 

6.4 Where the density of the binder is unknown and circumstances do not allow its determination, a value of 1.040 t/m³ may be assumed.
Test Method Q322: Gyratory compaction curve of asphalt

1 Source

This method is based on AS 2891.2.2: Sample preparation - Compaction of asphalt test specimens using a gyratory compactor. It differs from this Australian Standard in that it specifies a set number of compaction cycles and includes some apparatus and procedural variations.

2 Scope

This method sets out the procedure for determining the compaction curve relating specimen height and number of compaction cycles for mixes compacted with a gyratory compactor. It is applicable to asphalt mixes not exceeding 20 mm nominal size.

3 Apparatus

Where appropriate, the working tolerances of particular apparatus are contained in Table 1.

The following apparatus is required:

3.1 Gyratory compactor, capable of applying a vertical loading stress of 240 kPa to a test specimen in a mould at a rate of 60 rpm and at a fixed angle of 2º measured at the centre of the height of the mould. The compactor shall be fitted with the means for providing a continuous readout of test specimen height with the number of compaction cycles.

3.2 Specimen mould assembly, as described in AS 2891.2.2 for 100 mm diameter test specimens.

3.3 Wearing discs, steel discs of diameter 99.8 mm and thickness of 0.9 mm.

3.4 Specimen extractor, of suitable design to enable the test specimen to be removed intact from the mould.

3.5 Oven, thermostatically controlled at a temperature of 150°C.

3.6 Balance of a suitable capacity, having a resolution of at least 0.1 g and with a limit of performance within the range of ± 0.5 g.

3.7 Thermometer, a partial immersion thermometer or other suitable temperature measuring device having a temperature range which includes 150°C, and graduated to 1°C or less with an uncertainty of no more than 0.5°C.

3.8 Assorted mixing and handling apparatus, such as steel trays, trowels, spatulas and scoops.

4 Materials

4.1 Paper discs, having a diameter of about 100 mm.

4.2 Lubricant, suitable light oil for lubricating the paper discs (Note 8.1).

5 Compaction procedure

The procedure shall be as follows:

5.1 Place the specimen mould assembly in the oven for a period of at least 1 hour.

5.2 Remove the mould assembly from the oven and position a lubricated paper disc on the lower wearing disc in the mould.

5.3 Transfer about 1250 g mix into the mould and return the mould assembly to the oven for 60 ± 10 minutes.
5.4 Remove the mould assembly from the oven, place a thermometer in the mix and measure the temperature. Provided that the temperature is within 150 ± 3°C, level the mix in the mould and place a lubricated paper disc on the mix surface (Note 8.2).

5.5 Place the upper wearing disc and top platen on the mix in the mould, position the mould assembly in the gyratory compactor and lock the mould assembly in place.

5.6 Compact the mix in the mould assembly with 350 cycles of gyratory compaction, providing a continuous plot of specimen height against number of cycles.

5.7 Remove the mould assembly from the gyratory compactor and take off the upper platen.

5.8 Allow the mould to cool sufficiently in air and then remove the test specimen from the mould using the specimen extractor, while ensuring the test specimen remains intact and shows no deformation.

5.9 Prepare a further three test specimens using the procedure of Steps 5.1 to 5.8.

5.10 Where the air voids of the mix at 350 cycles is required, determine the following:

5.10.1 The compacted density of each of the test specimens compacted to 350 cycles in accordance with Test Method Q306C.

5.10.2 The maximum density of the mix in accordance with Test Method Q307A.

6 Calculations

Where required, calculate the following:

6.1 The air voids at 350 cycles for each test specimen to the nearest 0.01% in accordance with Test Method Q311 using the compacted density and maximum density values determined in Step 5.10.

6.2 The compacted density at a specified number of cycles for each test specimen to the nearest 0.001 t/m$^3$ as follows:

$$D_{CN} = \frac{D_{C350}H_{S350}}{H_N}$$

where

$D_{CN}$ = compacted density of the test specimen at the specified number of cycles (t/m$^3$)

$D_{C350}$ = compacted density of the test specimen at 350 cycles (t/m$^3$)

$H_{350}$ = height of the test specimen at 350 cycles (mm)

$H_N$ = height of the test specimen at the specified number of cycles (mm)

6.3 The air voids at the specified number of cycles for each test specimen to the nearest 0.01% in accordance with Test Method Q311, using the compacted density determined in Step 6.2 and the maximum density determined in Step 5.10.2.

6.4 The air voids at 350 cycles for the mix to the nearest 0.1% as the average of the air voids results determined in Step 6.1.

6.5 The air voids at the specified number of cycles for the mix to the nearest 0.1% as the average of the air voids results determined in Step 6.3.
7 Reporting

Report the following:

7.1 The compaction curves of the four test specimens showing the relationship between test specimen height and the number of compaction cycles.

7.2 Where required, the air voids at 350 cycles for the mix to the nearest 0.1%.

7.3 Where required, the air voids at the specified number of cycles for the mix to the nearest 0.1%.

8 Notes on method

8.1 Before handling the oil, the operator must consult the relevant Safety Data Sheet (SDS).

8.2 If the temperature of the mix falls below the compaction temperature range, the mix may be reheated. This will involve returning the mould assembly containing the mix to the oven until it reaches oven temperature and then repeating Step 5.4.

Table 1 – Specifications and working tolerances of apparatus

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<th>Item</th>
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Test Method Q323: Equivalent compaction temperature for warm mix asphalt

1 Source
This method is based on the procedure outlined in *Warm mix asphalts: tips and tricks developed by professionals for professionals* (German Asphalt Paving Association (DAV) 2009). It also makes reference to Australian Standard Test Methods AS/NZS 2891.2.2 and AS/NZS 2891.9.2, and Transport and Main Roads Test Methods Q305, Q306B and Q306C.

2 Scope
This method sets out the procedure for determining the equivalent compaction temperature for warm mix asphalt (WMA), by means of comparing and matching the compacted densities of hot mix asphalt (HMA) mix prepared with and without the WMA technology. The method requires prior preparation of sufficient quantities of WMA mix (HMA with the WMA technology) and HMA mix (reference mix). It allows test specimens to be compacted using either gyratory or Marshall compaction.

3 Apparatus
The equipment required for this test method is listed in the following references:

3.1 Q305 Stability, flow and stiffness of asphalt - Marshall
3.2 Q306B Compacted density of dense graded asphalt - presaturation
3.3 Q306C Compacted density of asphalt - silicone sealed
3.4 AS/NZS 2891.2.2 Methods of sampling and testing asphalt - Sample preparation - Compaction of asphalt test specimens using a gyratory compactor
3.5 AS/NZS 2891.9.2 Methods of sampling and testing asphalt - Determination of bulk density of compacted asphalt - Presaturation method

4 Procedure
The procedure shall be as follows:

4.1 Compaction method
Select either the gyratory compaction method (AS/NZS 2891.2.2) or the Marshall compaction method (Q305) as appropriate.

4.2 Specimen preparation
4.2.1 Reference mix specimens
From the sample of HMA mix, compact at least three reference mix specimens in accordance with the relevant method (AS/NZS 2891.2.2 or Q305) at the standard compaction temperature appropriate for the HMA mix design (for example, 150 ± 3°C for mix containing C320 bitumen).

4.2.2 WMA specimens
From the sample of WMA mix, compact at least three WMA specimens at each of several compaction temperatures (for example, 110, 120, 130, 140 and 150 ± 3°C) in accordance with the relevant method (AS/NZS 2891.2.2 or Q305).
4.3 Compacted density measurement of specimens

4.3.1 Reference mix specimens:
    a) Determine the compacted density to the nearest 0.001 t/m³ of each specimen prepared in Subsection 4.2.1, in accordance with Test Method AS/NZS 2891.9.2, Q306B or Q306C.
    b) Calculate the average compacted density for the reference mix specimens to the nearest 0.001 t/m³ and record this as the mix reference density.

4.3.2 WMA specimens
    a) Determine the compacted density to the nearest 0.001 t/m³ of each specimen prepared in Subsection 4.2.2, in accordance with Test Method AS/NZS 2891.9.2, Q306B or Q306C.
    b) For each set of WMA specimens prepared at each compaction temperature, calculate the average compacted density to the nearest 0.001 t/m³.

4.4 Equivalent compaction temperature for WMA

4.4.1 Plot the average compacted density results of the WMA specimens determined in Subsection 4.3.2(b) against the corresponding compaction temperatures to create a compacted density-temperature curve for WMA, similar to that shown in Figure 1.

4.4.2 Add the average compacted density of reference mix specimens data point determined in Subsection 4.3.1 (b) to the same graph.

4.4.3 As illustrated in Figure 1, determine the temperature corresponding to this reference mix density on the density-temperature curve for WMA. Record this temperature as the calculated equivalent compaction temperature for WMA.

4.5 Validation of calculated equivalent compaction temperature

4.5.1 Compact at least three WMA specimens at the calculated equivalent compaction temperature in accordance with the relevant method (AS/NZS 2891.2.2 or Q305).

4.5.2 Determine the compacted density to the nearest 0.001 t/m³ of each of the validation specimens in accordance with Test Method AS/NZS 2891.9.2, Q306B or Q306C.

4.5.3 Calculate the average compacted density for the validation specimens to the nearest 0.001 t/m³ and record this as the mix validation density.

4.5.4 If the difference between the mix validation density and the mix reference density is ≤ 0.3% of the mix reference density, accept the calculated equivalent compaction temperature as being validated.

4.5.5 If the difference between the mix validation density and the mix reference density is > 0.3% of the mix reference density, repeat the procedure.

5 Reporting

Report the validated equivalent compaction temperature for the WMA to the nearest 5°C.
Figure 1 - Compacted density versus compaction temperature
Test Method Q324: Rapid drying of compacted asphalt specimens - vacuum

1 Source
This method is based on ASTM D7227: Standard practice for rapid drying of compacted asphalt specimens using vacuum drying apparatus.

2 Scope
This method describes a procedure for drying compacted asphalt specimens using a vacuum drying apparatus. It is applicable to a range of laboratory compacted and field specimens including cylindrical, slab and prism specimens.

3 Apparatus
The following apparatus is required:

3.1 Absorptive cloth for drying the surface of the specimens.

3.2 Vacuum apparatus meeting the following requirements:

3.2.1 Chamber of suitable capacity for asphalt specimens. With a vacuum pump capable of evacuating the chamber and maintaining a pressure of 6 Torr or less. The chamber shall have automatic vacuum, airflow and temperature control features to ensure drying of the specimens at close to room temperatures (Note 5.1).

3.2.2 Water removable plate, used for removing free water from the bottom of the vacuum chamber.

3.2.3 Electronic cold trap with an airflow divider, used for trapping water before it enters the vacuum pump.

3.3 Balance, a top pan balance of suitable capacity, with a resolution of at least 0.1 g and with a limit of performance within the range of ±0.5 g.

3.4 Thermometer, an infra-red having a temperature range which includes the range of 15-30 ºC and graduated to 1ºC or less with an uncertainty of no more than 0.5ºC.

4 Procedure
The procedure shall be as follows:

4.1 Checking vacuum apparatus

4.1.1 Follow the manufacturer’s recommendations for warm-up and self-test procedures.

4.1.2 Using an absorptive cloth dry the cold trap and specimen chamber.

4.1.3 Operate the unit without any specimens and check the pressure reading on the display is 6 Torr or less. If the indicated pressure is higher than 6 Torr, check the system for oil level and quality, seals or water in the chamber.

4.2 Drying specimens

4.2.1 Using the infra-red thermometer check the specimen temperature is in the range of 15-30 ºC. If not place the specimens in a room temperature environment until the surface temperature lies within the range of 15-30 ºC.

4.2.2 Using an absorptive cloth remove any excess water from the surface of the specimen.

4.2.3 Determine the wet mass of the specimen \( (m_1) \).
4.2.4 Place the specimen on top of a specimen support plate, or on a mesh shelf within the chamber.

4.2.5 Close the vacuum chamber and using the controls start the drying process.

4.2.6 Remove the specimen from the vacuum chamber and determine the dry mass of the specimen (m₂).

4.2.7 Return the specimen to the vacuum chamber and dry for at least another 15 minutes.

4.2.8 Repeat Steps 4.2.5 to 4.2.7 until such time that the specimen has reached constant mass (Notes 5.2 and 5.3).

4.2.9 At the completion of the drying process, remove the cold trap lid and the airflow divider plate and wipe out any free standing water in the cold trap.

5 Notes on method

5.1 Since the specimen cools during the evaporation process, making water harder to evaporate at low temperature, it is important to have suitable temperature controls in the chamber to ensure the specimen remains at close to room temperature. Automatic controls within the unit allow the specimen to remain at close to room temperature by periodically allowing a flow of warm air to enter the vacuum chamber. Cycling between vacuum and airflow conditions allows the specimen to dry in a short period of time. Completely saturated specimens can be dried in about 30 minutes. The typical cycling times are 30 to 180 seconds of vacuum operation followed by 30 to 120 seconds of airflow.

5.2 A sample is considered to have reached a constant mass when the difference between successive weighings, after a further 15 minutes vacuum drying, is not more than 0.03 percent.

5.3 Some vacuum apparatus are factory calibrated to sense a "dry specimen condition". For these apparatus Steps 4.2.7 and 4.2.8 may be omitted provided the manufacturers procedure for determining and checking the dry specimen condition is followed.
Test Method Q325: Stability of asphalt – Hamburg wheel tracking device (HWTD)

1 Source
This method applies the principles of AASHTO T324 – Hamburg Wheel-Track Testing of Compacted Hot Mix Asphalt (HMA).

2 Scope
This method describes the procedure for determining the stability of asphalt mixes under loading while submerged in water. It involves monitoring the deformation (rutting) that occurs in an asphalt sample undergoing wheel tracking motion with loaded steel wheels. The method is applicable to asphalt mix either manufactured in the laboratory or sampled from an existing asphalt pavement, and can be performed using asphalt slabs, cores or Laboratory manufactured specimens.

The test is used to determine the susceptibility to failure by means of moisture damage, poor binder properties or structural weakness of the sample in the presence of high temperatures and/or water.

3 Apparatus
The following apparatus is required:

3.1 Wheel Tracker, Hamburg Wheel Tracking Device comprising the following:

3.1.1 Loaded wheel mechanism, consisting of a single or dual steel wheel of diameter 203 mm and width 47 mm. The mechanism shall include a means of loading the wheel so that a force of 705 ± 4.5 N is applied centrally and normal to the top surface of the test specimen.

3.1.2 The wheel shall make 52 ± 2 passes (26 ± 1 cycles) across the specimen per minute, travelling across at least the central 230 mm of the sample.

3.1.3 Test base which should accommodate the fitting of mounting systems up to 400 mm in length and 300 mm in width. There should be (at least) the capabilities to cater for samples from 50 mm to 100 mm in thickness.

3.1.4 Rut depth measurement device, an electronic displacement measuring device, preferably a linear variable displacement transducer (LVDT) having a minimum travel of 20 mm and a limit of performance within the range of ± 0.15 mm.

3.1.5 A means for continuously recording rut depth measurements at progressive numbers of wheel tracker cycles – at least every 100 cycles with more regular readings in the first 100 cycles (e.g. at 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 200, 300 etc. cycles).

3.1.6 Water bath, a water bath able to be controlled to within +/- 1°C of the test temperature. It should be fitted with an overflow device and of sufficient capacity to contain a test specimen with the water level a minimum of 20 mm above it.

3.1.7 A mounting system that allows either moulds containing asphalt slabs, Laboratory prepared specimens or cores to be rigidly fixed to the device.

3.1.8 Core test moulds (Figure 1) consist of the following, metal moulds with internal dimensions of 360 mm by 300 mm. In addition to the metal mould are moulds that consist of a high-density polymer or plastic material that snugly fits into the metal mould does not allow for shifting of the specimen during testing. The mould should be able to accommodate two core or Servopac specimens of 150 mm diameter and thickness of 50 – 100 mm, with the edge of each specimen cut such that the moulds are flush against each other.
3.2 Segmental wheel compactor, capable of applying a loading of 1000 to 30 000 N to within 500 N. The compaction device shall be in the form of a freely rotating wheel segment of diameter 1200 ± 200 mm. The foot of the compaction device shall have an arc length of 400 mm and a width of 300 mm. The compaction foot shall be able to be moved vertically and set to a specified height above the base of the compaction mould. It shall have the option of vibratory compaction and shall be of sufficient rigidity that it will not deform under load over the operating range (Note 9.1).

3.2.1 Compaction table, having an oscillating speed of between 10 and 25 oscillations per minute, and sufficient travel to ensure even compaction of the asphalt in the mould. The table shall have provision to firmly attach the compaction mould.

3.2.2 Compaction moulds, metal moulds of internal dimensions 400 mm length, 300 mm width and of sufficient depth to accommodate the slab specimen mix prior to compaction. To achieve sufficient depth it is allowable to fix a collar to the top of the mould during compaction.

3.3 Lifting device, to move a compaction mould (with or without mix) to and from the compaction table or Wheel Tracking Device.

3.4 Ovens, for heating asphalt and binder, maintained to within ± 3°C of the design mix temperature to allow for attainment of target compaction density.

3.5 Balance of suitable capacity, with a resolution of at least 1 g and with a limit of performance of ± 5 g and capable of below balance weighing for slab specimens.

3.6 Balance of suitable capacity, with a resolution of at least 1 g and with a limit of performance of ± 1 g and capable of below balance weighing for core or Servopac specimens.

3.7 Servopac gyratory compactor, capable of compacting cylindrical pat specimens of 150 mm diameter to a pre-determined thickness and density.

3.8 Saw, diamond tipped masonry saw for cutting samples to size (if required).

3.9 Laboratory tools for specimen preparation, a ruler to measure specimens, a marking medium to identify specimens and a digital camera to document samples before and after testing.

3.10 Straight edge for striking off plaster.

4 Materials

The following materials are required:

4.1 Sealant, acetic cure silicone sealant of known density to the nearest 0.001 t/m³ (Note 9.2).

4.2 Silicone grease (Note 9.2).

4.3 Regulation course material, a mixture of Plaster of Paris and fine sand (Note 9.2).

a) for application to the base of the test specimen, a homogeneous mixture by volume of 5 parts of Plaster of Paris, 5 parts fine sand and 3.5 parts potable water

b) to fill the gap between the test specimen and the sides of the mould, a homogeneous mixture by volume of 5 parts of Plaster of Paris, 5 parts fine sand and 7 parts potable water.

4.4 Potable water.
5 Preparation

The test specimens shall be prepared as follows:

5.1 Each test with a dual-wheel Hamburg device requires two slab specimens or four core/pat specimens (arranged in two sets of two cores in core mould). Samples can either be manufactured in the laboratory or sampled from a pavement. For each sample:

5.1.1 Determine the bulk density of the specimens as detailed in Test Method AS/NZS 2891.9.2.

5.1.2 For laboratory manufactured specimens determine the maximum density of the asphalt mix as detailed in Test method AS 2891.7.1 (Note 9.2)

5.1.3 Determine the air void content of the specimens as detailed in Test method AS 2891.8.1.

5.2 Laboratory manufactured slab specimens

5.2.1 Slab specimens manufactured in the laboratory shall be prepared as detailed in Test Method Q319. Laboratory manufactured test specimens shall have a thickness of 50 – 100 mm and be between 4 and 30 days old at the time of testing.

5.2.2 Secure the asphalt slab in the Hamburg test mould.

5.3 Laboratory manufactured pat specimens

5.3.1 Prepare laboratory manufactured pat specimens using the Servopac compactor device as detailed in Test Method AS/NZS 2891.2.2 to a thickness of 40 - 100 mm, with the specimen thickness to be at least twice the nominal aggregate size. Allow compacted specimens to cool at room temperature on a clean, flat surface for 24 hours.

5.3.2 Cut the pat specimens, with the saw, along a secant or chord line (see Figure 3) so that when joined together in the moulds there is minimal gap between the cut faces of each specimen.

5.3.3 If required, invert the specimens and place them face down in the high density polyethylene moulds.

5.3.4 Prepare the regulation course material and pour it over the inverted cores to fill the moulds. Strike off any excess material using the straight edge so that the regulation course material provides a smooth and even surface level with the edges of the moulds. Allow to cure for 24 hours.

5.3.5 Secure the high density polyethylene mould and specimens in the Hamburg mould prior to testing.

5.4 Field sampled slab specimens

5.4.1 Slab specimens sampled from the pavement shall have minimum dimensions of 300 mm length, 300 mm width and a minimum thickness of 40 mm for DG14 or 50 mm for DG20 and a maximum thickness of 90 mm. The specimens shall consist of a single layer of material and have no discontinuities. Slab specimens shall be examined for any defects caused through sampling and shall be rejected if cracks are visible to the naked eye or if the geometry of the specimen is compromised through spalling of corners and edges. The rolling or traffic direction shall be clearly indicated on the upper surface.

5.4.2 For slab specimens having dimensions greater than 400 mm length and 300 mm width, cut a test specimen measuring about 400 by 300 mm from the central portion of the slab specimen using the masonry saw, and discard the remainder.

5.4.3 Remove the base of the compaction mould.
5.4.4 Invert the test specimen and place it centrally within the raised test mould.

5.4.5 Prepare the regulation course material and pour it over the inverted test specimen to fill the test mould. Strike off any excess material using the straight edge so that the regulation course material provides a smooth and even surface level with the upper edges of the test mould.

5.4.6 Allow the regulation course material to set.

5.4.7 If the dimensions of the asphalt specimen and mould differ by more than 0.5 mm fill the gap with regulation course material.

5.4.8 Remove any regulation course material from the top surface of the test specimen.

5.4.9 Carefully remove the test specimen from the compaction mould and secure it in the test mould.

5.5 Field sampled core specimens

5.5.1 Core specimens shall have a minimum diameter of 140 mm and a minimum depth of 40 mm for DG14 and 50 mm for DG20 Asphalt.

5.5.2 If required, cut the core specimen to give a height equal to the height of the high density polyethylene moulds. Otherwise prepare the core specimen as per test method Q303A.

5.5.3 Cut the core specimens, with the saw, along a secant or chord line (see Figure 3) so that when joined together in the moulds there is minimal gap between the cut faces of each specimen.

5.5.4 If the core heights are less than the thickness of the mould, invert the specimens and place them face down in the mould.

5.5.5 Prepare the regulation course material and pour it over the inverted cores to fill the mould. Strike off any excess material using the straight edge so that the regulation course material provides a smooth and even surface level with the edges of the mould. Allow to cure for 24 hours.

5.5.6 Secure the high density polyethylene mould and specimens in the Hamburg mould prior to testing.

5.6 Identify each sample with a marker and if required photograph each sample before and after testing.

6 Procedure

The procedure shall be performed on each of the test specimens as follows:

6.1 Fit the mould and specimen into the wheel tracking device.

6.2 Turn on the wheel tracking device and enter the project information.

6.3 Set the test temperature, maximum rut depth and termination cycles.

6.4 Condition the test specimen at the test temperature for a minimum of 120 minutes but no more than 12 hours.

6.5 At the commencement of testing but prior to the cycles starting ensure the LVDT is zeroed.

6.6 Begin the automated testing program and monitor the rut depth progression over the first 50 – 100 cycles.

6.7 Allow the wheel tracker to run until the predetermined number of cycles or maximum rut depth have been achieved.
6.8 Remove the sample and base frame from the device and remove the specimen from the frame by loosening the bolts.

6.9 Clear the water bath of any loose material and drain if required.

6.10 Take photos of each whole sample after testing. Cut the sample into quarters and take photographs of all internal faces of the specimen.

7 Calculations

7.1 Plot the rut depth vs cycles for each test and identify the creep and stripping sections (if any) of the curve (Figure 2).

7.2 Calculate the following:

7.2.1 Calculate the slope ($m_c$) and intercept ($C_c$) of the creep section of the curve.

7.2.2 Calculate the slope ($m_s$) and intercept of the stripping ($C_s$) section of the curve.

7.2.3 Calculate the stripping inflection point as follows:

$$SIP = \frac{C_s - C_c}{m_c - m_s}$$

where:
- $SIP$ = stripping inflection point (cycles)
- $C_s$ = intercept of stripping section of curve (mm)
- $C_c$ = intercept of creep section of curve (mm)
- $m_c$ = slope of creep section of curve (mm/cycle)
- $m_s$ = slope of stripping section of curve (mm/cycle)

8 Reporting

Report the following values and general information:

8.1 Specimen source and form (laboratory or field; slab, pat or core).

8.2 Age of the specimen.

8.3 Number of cycles completed.

8.4 Rut depth (mm) at termination cycles.

8.5 Test temperature.

8.6 Air voids of specimen (%).

8.7 Number of cycles at stripping inflection point.

9 Notes on method

9.1 The Controls Slab Compactor satisfies the requirements of the segmental wheel compactor.

9.2 Before handling the sealant, silicon grease or plaster of paris, the operator must consult the relevant Safety Data Sheet (SDS).
**Figure 1 – Core test mould**

![Core test mould diagram]

**Figure 2 – Example of rut depth v cycles plot**

![Rut depth v cycles plot diagram]
Figure 3 – Diagram showing the chord or secant line
Materials Testing Manual

Part 8: Bituminous Materials
Test Method Q331: Density of bitumen

This test shall be performed in accordance with AS 2341.7: Determination of density using a density bottle, except as follows:

a) A balance having a resolution of at least 0.0001 g and a limit of performance within the range of ± 0.0005 g may be used.

b) The density at 25°C may also be reported.

c) The density may also be reported in kg/L or t/m³ to the nearest 0.0001 as follows:

\[
\rho \text{ (kg/L)} = \frac{\rho \text{ (kg/m}^3\text{)}}{1,000} \quad \text{and} \quad \rho \text{ (t/m}^3\text{)} = \frac{\rho \text{ (kg/m}^3\text{)}}{1,000}
\]
Test Method Q334: Softening point of bituminous binder

For bitumens, this test shall be performed in accordance with AS 2341.18: Determination of softening point (ring and ball method). For modified binders, this test shall be performed in accordance with Austroads AG:PT/T131: Softening point of polymer modified binders. These referenced methods are identical in their procedural operations.

Within AS 2341.18, replacement of the manual testing apparatus and associated procedural steps with an approved automatic testing system is permitted, provided that automatic measurement is performed in accordance with the manufacturer's instructions. The ISL Automatic Softening Point Instrument (Model RB36) has been approved for this purpose.
Test Method Q336: Kinematic viscosity of petroleum products

This test shall be performed in accordance with AS 2341.3: Determination of kinematic viscosity by flow through a capillary tube.
Test Method Q350: SBS content of polymer modified binder

1 Source
This method was developed in-house using the principles of Attenuated Total Reflection-Fourier Transform Infrared (ATR-FTIR) Spectroscopy.

2 Scope
This method sets out a procedure using ATR-FTIR analysis for determining the poly-styrene-butadiene-styrene (SBS) content of polymer modified binder (PMB). The method applies a calibration based on Kraton® 1101 cs SBS polymer and Class 320 bitumen. The method is applicable to polymer modified binder samples and to bound samples such as asphalt which contain a polymer modified binder component. For bound samples containing a polymer modified binder component, extraction of the binder from the sample is required prior to ATR-FTIR testing.

3 Apparatus
The following apparatus is required:

3.1 ATR-FTIR instrument and a peak area integration software package.
3.2 Balance of suitable capacity, having a resolution of at least 0.1 g with a limit of performance within the range of ± 0.5 g.
3.3 Shaker, a mechanical shaker fitted with automatic timing.
3.4 Drying oven of suitable capacity, having a temperature of about 40°C.
3.5 Vials, glass vials fitted with an airtight cap and of sufficient capacity to contain the sample (Note 10.1).
3.6 Glass plates, having minimum dimensions of 15 mm length, 15 mm width and 5 mm thickness.
3.7 Pipette, of 10 mL capacity.
3.8 Pasteur pipettes.
3.9 Fume hood.

4 Materials
The following materials are required:

4.1 Solvent resistant gloves.
4.2 Soft tissue paper.

5 Reagents
The following reagents are required (Note 10.2):

5.1 Carbon disulphide (AR grade).
5.2 Isopropanol (AR grade).
5.3 Mineral turpentine.
6 Sample preparation

Prepare the sample for ATR-FTIR analysis using the procedure described in Subsections 6.1 or 6.2 as appropriate.

6.1 Binder samples

6.1.1 Place a glass vial on the balance and tare the balance.

6.1.2 Obtain a representative sample of approximately 2 g of the binder.

6.1.3 Transfer the sample to the glass vial and record the mass to the nearest 0.1 g.

6.1.4 Pipette 10 mL carbon disulphide into the vial and fit the cap.

6.1.5 Dissolve the binder by shaking the vial for at least one hour at room temperature on a mechanical shaker.

6.1.6 Using a pasteur pipette in a fume hood, extract a portion of the solution from the top half of the vial and transfer two drops of the extract to the centre of a glass plate, restricting the spread of the extract to as small a diameter as possible.

6.1.7 Allow the solution on the glass plate to dry (Note 10.3).

6.1.8 Repeat Steps 6.1.6 to 6.1.7 until an adequate thickness of binder on the glass plate has been achieved (Note 10.4).

6.1.9 Heat the glass plate and binder in the 40°C oven for one hour.

6.1.10 Repeat Steps 6.1.6 to 6.1.9 to prepare a duplicate binder sample for ATR-FTIR analysis.

6.2 Bound samples

6.2.1 Place a glass vial on the balance and tare the balance.

6.2.2 Obtain a representative sample of approximately 20 g of the bound material (Note 10.5).

6.2.3 Transfer the sample to the glass vial and record the mass to the nearest 0.1 g.

6.2.4 Pipette 10 mL carbon disulphide into the vial and fit the cap.

6.2.5 Dissolve the binder by shaking the vial for at least one hour at room temperature on a mechanical shaker.

6.2.6 Transfer the vial to a fume hood and allow it to stand undisturbed for at least one hour.

6.2.7 Using a pasteur pipette, extract a portion of the solution from the top half of the vial and transfer two drops of the extract to the centre of a glass plate, restricting the spread of the extract to as small a diameter as possible.

6.2.8 Allow the solution on the glass plate to dry (Note 10.3).

6.2.9 Repeat Steps 6.2.7 to 6.2.8 until an adequate thickness of binder on the glass plate has been achieved (Note 10.4).

6.2.10 Heat the glass plate and binder in the 40°C oven for one hour.

6.2.11 Repeat Steps 6.2.7 to 6.2.10 to prepare a duplicate binder sample for ATR-FTIR analysis.
7 Procedure

The procedure shall be as follows:

7.1 Instrument set-up

Set up the ATR-FTIR spectrophotometer as appropriate using the general requirements as detailed in Table 1.

7.2 ATR-FTIR measurement

Perform the following with reference to the instrument’s operating instructions.

7.2.1 Check the instrument energy level to confirm it is within specification.

7.2.2 Check the surface of the diamond window to confirm that it is clean and then obtain a background spectrum, that is, no sample applied.

7.2.3 Select one of the glass plates containing the binder sample and place it centrally over the diamond window on the instrument, ensuring complete contact between the window and the binder (Note 10.6).

7.2.4 Obtain a spectrum of the binder sample and carefully remove the glass plate and binder from the instrument.

7.2.5 Remove all residual binder from the diamond window and sample platform by thorough cleaning using mineral turpentine and then soft tissue paper.

7.2.6 Repeat Steps 7.2.3 to 7.2.5 for the remaining glass plate and binder.

8 Calculations

8.1 Using a relevant peak area integration software package and the “both ends” option, determine the areas of the peaks at 966 cm⁻¹, 911 cm⁻¹, 808 cm⁻¹ and 697 cm⁻¹ for each of the two spectra.

8.2 Calculate the SBS content corresponding to the peak area data for each of the two spectra as follows:

\[
S = \frac{28.42P_{697}}{P_{966} + P_{911} + P_{808} + P_{697}}
\]

where

\[
\begin{align*}
S & = \text{SBS content (\%)} \\
\text{P}_{697} & = \text{peak area at 697 cm}^{-1} \\
\text{P}_{966} & = \text{peak area at 966 cm}^{-1} \\
\text{P}_{911} & = \text{peak area at 911 cm}^{-1} \\
\text{P}_{808} & = \text{peak area at 808 cm}^{-1}
\end{align*}
\]

8.3 Calculate the SBS content of the sample as the average of the SBS contents determined for the two spectra.

9 Reporting

Report the SBS content to the nearest 0.1%.
10 Notes on method

10.1 Cylindrical glass vials of 16 mm internal diameter and 55 mm height (25 mL) have been found suitable for binder samples (Step 6.1.2) and for bound samples (Step 6.2.2) having a nominal size up to 14 mm. For bound samples of larger nominal size, glass vials of larger internal diameter may be required.

10.2 Before handling reagents, the operator must consult the relevant Safety Data Sheet (SDS).

10.3 It is only necessary to allow the binder film to dry to a condition that allows more extract to be dropped onto the glass plate.

10.4 The aim is to provide a spot of binder on the glass plate which is just sufficient to completely cover the diamond window of the ATR-FTIR. A spot of about 5 mm in diameter and of sufficient thickness to prevent the passage of light will be required.

10.5 For asphalt core samples, a representative sample should be obtained in accordance with Test Method Q303B.

10.6 To reduce the amount of binder adhering to the sample platform on the instrument, a thin paper or aluminium foil spacer may be used to separate much of the binder from the sample platform. The spacer shall have dimensions no smaller than the glass plate and shall contain a hole in the centre slightly larger than the diamond window. This will allow complete contact between the binder and diamond window while limiting contact between the binder and sample platform.

<table>
<thead>
<tr>
<th>Table 1 – Set-up of ATR-FTIR spectrophotometer</th>
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<tbody>
<tr>
<td>Component/condition</td>
</tr>
<tr>
<td>----------------------</td>
</tr>
<tr>
<td>Detector</td>
</tr>
<tr>
<td>Source</td>
</tr>
<tr>
<td>Window</td>
</tr>
<tr>
<td>Aperture</td>
</tr>
<tr>
<td>Scan range</td>
</tr>
</tbody>
</table>

* A full range scan of 4000-525 cm⁻¹ may also be used
Test Method Q358: Setting time of bituminous emulsion

1 Source

This method is performed in accordance with AS 2341.29: Determination of breaking behaviour by setting time, but incorporating the procedural details from Note 5 of Table 2 of AS 1160: Bituminous emulsions for the construction and maintenance of pavements.

2 Scope

This method determines the setting time category of a mixture of standard aggregate and bituminous emulsion and subsequent classification of the emulsion after mixing in the prescribed manner and observing the onset of breaking through change in the physical characteristics of the mixture. The method is not applicable to mixing grade emulsions.

3 Apparatus

Where appropriate, the working tolerances of particular apparatus are contained in Table 1.

The following apparatus is required:

3.1 Balance of a suitable capacity, having a resolution of at least 0.1 g and with a limit of performance within the range of \( \pm 0.5 \) g.

3.2 Test environment:

3.2.1 Test room, free from strong draughts and with atmospheric conditions maintained at a temperature of 23ºC, with relative humidity not less than 40%, or

3.2.2 Cabinet, free from strong draughts and with atmospheric conditions maintained at a temperature of 23ºC, with relative humidity not less than 40% (Note 8.1).

3.3 Beaker, a glass beaker of 100 mL capacity, with lip and glass stirring rod.

3.4 Spatula, of ebonite or similar material, with a blade approximately 19 mm wide, rounded at both ends.

3.5 Porcelain evaporating dish, approximately 230 mm in diameter.

3.6 Sieves, 9.50 mm and 4.75 mm complying with AS 1152.

3.7 Stopwatch or clock, with a sweep seconds display.

4 Materials

4.1 Standard aggregate:

Three types of crushed aggregate are required. Each aggregate, sieved to pass a 9.50 mm sieve and retained on a 4.75 mm sieve, shall be washed, dried and stored in the laboratory in which it is to be used. Batches of 500 g each shall be prepared as follows:

4.1.1 400 g dolerite from Prospect Quarry, NSW.

4.1.2 50 g white quartz (indicator) from Tenterfield, NSW.

4.1.3 50 g limestone (indicator) from Cow's Flat, NSW.

4.2 Distilled or demineralised water.
5 Preparation of test emulsion

5.1 Perform the setting time test on a sample of emulsion diluted to a nominal residual binder content of 60% mass. Calculate the quantity of water required as follows:

\[ w = \frac{m (R-60)}{60} \]

where

- \( w \) = the quantity of water to be added to \( m \) grams of bituminous emulsion (g)
- \( m \) = the quantity of bituminous emulsion which is to be diluted (g)
- \( R \) = residue from evaporation of the bituminous emulsion as determined by AS/NZS 2341.23 (%)

5.2 Dilute at least 50 g of emulsion with distilled or demineralised water and mix until homogenous.

5.3 Conduct the setting time test on the diluted emulsion as detailed in Section 6 within 30 minutes of dilution.

6 Procedure

The procedure shall be as follows:

6.1 Allow the apparatus and materials to reach equilibrium conditions in the test environment.

6.2 Place a 500 g batch of the standard aggregates in the porcelain dish and spread flat.

6.3 Stir the test emulsion until thoroughly mixed. Weigh into the 100 mL beaker a sufficient amount of the sample so that \( 35 \pm 2 \) g is delivered on pouring.

6.4 Pour \( 35 \pm 2 \) g of the test emulsion as uniformly as possible over the standard aggregate and, without delay, start the stopwatch and commence mixing in the following manner:

6.4.1 Turn the aggregates in from the edge to the centre at about two strokes of the spatula per second.

6.4.2 In the course of each stroke, push the spatula lengthwise into the aggregates in the dish to the full depth of the material and at an angle of about 30º to the horizontal.

6.4.3 Move the material towards the centre of the dish on each stroke by lifting and rotating the spatula.

6.4.4 Between strokes, rotate the dish about 45º in a constant direction.

6.5 Continue mixing for up to 3 minutes in the case of rapid setting emulsions, for 4 minutes to 7 minutes in the case of medium setting emulsions, and for a minimum of 8 minutes in the case of slow setting emulsions (Notes 8.2 and 8.3).

6.6 Push the spatula against the stones for about 2 seconds, then withdraw and inspect stones which remain stuck to it and will not fall off. The end point is reached when stones on the spatula stick to each other in more than one layer (Notes 8.4 and 8.5).

7 Reporting

Report the setting time in minutes to the nearest 0.25 and classify the emulsion as follows:

7.1 Rapid-setting type – if breaking is apparent within 3 minutes of mixing.
7.2 Medium-setting type – if breaking is apparent when mixing has proceeded for at least 4 minutes but not more than 7 minutes.

7.3 Slow-setting type – if all pieces of aggregate are smoothly and uniformly coated with emulsion, and no free bitumen is evident after mixing for 8 minutes.

8 Notes on method

8.1 An air cabinet can be used in place of an air-conditioned test room. Openings should be provided to allow access for the operator's arms to perform the mixing process.

8.2 Severe frothing sometimes develops during mixing, tending to mask the breaking of the emulsion.

8.3 Usually, the onset of breaking of the emulsion is quite evident during mixing, as is the absence of breaking at the end of mixing. Rapid setting grades of emulsion usually break after about 2 minutes.

8.4 The test is not designed to set a lower limit for the rate of break but abnormally rapid breaking, say within 0.5 minutes, may indicate an unstable emulsion, further evidence of which should be looked for in the form of partial breaking during the sieve test (AS/NZS 2341.26) or viscosity determination (AS 2341.25). A sedimentation test (Q361) should also be conducted in such circumstances.

8.5 Other indications of the emulsion breaking are as follows:

8.5.1 Balling up of the aggregate by free bitumen.

8.5.2 The presence of a thin coating of bitumen, allowing the white indicator stone to show through.

8.5.3 A watery appearance of the stone and a streakiness in the emulsion film on the side of the dish.

Table 1 – Test environment requirements

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Dimension</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test room or cabinet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>23</td>
<td>± 2</td>
</tr>
<tr>
<td>Relative humidity (%)</td>
<td>40</td>
<td>minimum</td>
</tr>
</tbody>
</table>

Superseded
Test Method Q361: Sedimentation of bituminous emulsion

1 Source
This method is based on AS/NZS 2341.27 – 1996: Method for Determination of Sedimentation. It differs from this Australian Standard in that it uses the difference between values of residue from evaporation to determine the sedimentation value. It also includes a defined sample mixing procedure prior to testing, as detailed in Main Roads Internal Report R2504, to ensure the sample when tested replicates a "fresh" emulsion condition.

2 Scope
This method sets out a procedure for determining the degree of sedimentation of bituminous emulsion on standing undisturbed. It provides a means of evaluating the tendency for the two phases of emulsion to separate with time.

3 Apparatus
The following apparatus is required:

3.1 Mixing container, a 5 L plastic pail having approximate dimensions of diameter 200 mm at the top and 180 mm at the bottom, and height 190 mm.

3.2 Mechanical stirrer, fitted with a helix shaped paddle having approximate dimensions of 140 mm in diameter and 140 mm depth, and capable of stirring the sample at 125 rpm (Figure 1).

3.3 Balance of suitable capacity, having a resolution of at least 0.001 g and with a limit of performance within the range of ± 0.005 g.

3.4 Measuring cylinders, two glass measuring cylinders of 500 mL capacity and 50 ± 5 mm outside diameter, graduated at 5 mL intervals. Each cylinder shall be fitted with a stopper and two glass stopcocks at the 50 mL and 450 mL graduation marks.

3.5 Beaker, of 2 L capacity.

3.6 Bitumen content containers, four flat-bottomed cylindrical metal containers of 500 mL capacity.

3.7 Stirring rods, four glass stirring rods.

4 Procedure
The procedure shall be as follows:

4.1 Obtain a representative sample of the bituminous emulsion of about 3 L and transfer it to the mixing container (Note 7.1).

4.2 Position the mechanical stirrer over the sample so that the paddle is placed centrally within the sample with a gap of about 1 cm between the bottom of the paddle and the bottom of the pail.

4.3 Stir the sample at 125 rpm for 10 minutes.

4.4 Immediately transfer about 1200 mL of the sample to the 2 L beaker and then fill the two measuring cylinders to the 500 mL mark.

4.5 Stopper the cylinders and allow them to stand undisturbed at room temperature for three days.

4.6 Place a stirring rod into each of two bitumen content containers, weigh each container and record the mass to the nearest 0.001 g.
4.7 Open the top stopcock on one of the measuring cylinders and collect the top 50 mL portion of the sample in one of the two bitumen content containers, taking care not to disturb the remainder of the sample.

4.8 Open the bottom stopcock and discard the next 400 mL of sample, taking care not to disturb the remainder of the sample.

4.9 Thoroughly stir the portion remaining in the measuring cylinder and pour it into the second bitumen content container.

4.10 Repeat Steps 4.6 to 4.9 for the sample in the second measuring cylinder.

4.11 Determine the residue from evaporation of the portion in each bitumen content container in accordance with AS/NZS 2341.23.

5 Calculations

Calculate the sedimentation of the sample as follows:

\[ S = \frac{B_1 + B_2 - A_1 - A_2}{2} \]

where

- \( S \) = sedimentation (%)
- \( B_1, B_2 \) = residue from evaporation for the two bottom layer portions (%)
- \( A_1, A_2 \) = residue from evaporation for the two top layer portions (%)

6 Reporting

Report the sedimentation of the sample to the nearest 0.1%.

7 Notes on method

7.1 It is preferable that the container used for sampling is the mixing container described in Step 3.1 which is then fitted with a lid. Where this is not possible, the sample must be thoroughly stirred and mixed to a homogeneous condition prior to transfer to the mixing container.
Figure 1 – Mechanical stirrer paddle
Test Method Q364: Recovery of polymer modified binder from polymer modified emulsion

1 Source
This method is based on outcomes from internal laboratory investigations as reported in the Transport and Main Roads Internal Report R2523: Investigation of Test Methods for Recovering Polymer Modified Binder from Polymer Modified Bituminous Emulsion.

2 Scope
This method describes the recovery of polymer modified binder from polymer modified emulsion. It involves separation of the binder by ethanol precipitation, and removal of the aqueous phase by draining and subsequent evaporation in an oxygen free environment using either a vacuum oven or a nitrogen purged oven. The recovery process is not expected to impact on the properties of the polymer modified binder. The method includes determination of the polymer modified binder content of the emulsion.

3 Apparatus
3.1 Mixing container, a 5 L plastic pail having approximate dimensions of diameter 200 mm at the top and 180 mm at the bottom, and height 190 mm.
3.2 Mechanical stirrer, fitted with a helix shaped paddle having approximate dimensions of diameter 140 mm and height 140 mm, and capable of stirring the sample at 125 rpm (Figure 1).
3.3 Balance of suitable capacity, with a resolution of at least 0.01 g and with a limit of performance within the range of ± 0.05 g.
3.4 Vacuum oven (optional – Subsection 5.2 only), fitted with a vacuum measuring device and thermostatically controlled over a temperature range including 100°C.
3.5 Vacuum system (optional – Subsection 5.2 only), comprising a vacuum tube connected to a vacuum pump capable of producing an absolute pressure of about 4 kPa. The system shall include a suitable ice water trap located between the vacuum pump and vacuum oven.
3.6 Nitrogen purged oven (optional – Subsection 5.3 only), thermostatically controlled over a temperature range including 100 to 130°C, and fitted with a nitrogen gas supply and circulation system. The purging outlet of the oven should be fed into a fume extraction system, for example, fume cupboard.
3.7 Trays, silicon rubber trays having approximate dimensions of 200 mm length, 200 mm width and 50 mm depth.
3.8 Spatula, stainless steel spatula having approximate dimensions of length 150 mm and width 15 mm.
3.9 Beakers, glass beakers of 500 mL capacity.
3.10 Measuring cylinder, a glass measuring cylinder of 250 mL capacity.
3.11 Container, metal container fitted with a lid and of sufficient capacity to store the recovered binder.
3.12 Gloves, rubber gloves suitable for handling the recovered binder.
4 Materials
Breaking agent, methylated spirits (industrial grade) or ethanol (LR grade).

5 Procedure
The procedure shall be as follows:

5.1 Sample preparation
5.1.1 Determine the total mass of binder to be recovered for testing.
5.1.2 Calculate the mass of emulsion required for binder recovery as follows (Note 8.1):

\[
M = \frac{1.5M_B}{0.75}
\]

where
- \( M \) = mass of emulsion required (g)
- \( M_B \) = moisture content of soil

5.1.3 Transfer the emulsion sample to the mixing container (Note 8.2).
5.1.4 Position the mechanical stirrer within the mixing container so that the paddle is located centrally with a gap of about 10 mm between the bottom of the paddle and the bottom of the container.
5.1.5 Stir the sample in the mixing container using the mechanical stirrer at 125 rpm for at least 10 minutes.
5.1.6 At the completion of stirring, immediately pour a quantity of emulsion not less than that calculated in Step 5.1.2 into a tared beaker(s).
5.1.7 Record the mass of emulsion in the beaker(s) to the nearest 0.01 g (me).
5.1.8 Transfer a portion of the emulsion from the beaker into a tared silicon rubber tray. This portion shall be about 120 g for the vacuum oven method (Subsection 5.2) and about 80 g for the nitrogen purged oven method (Subsection 5.3).
5.1.9 Repeat Step 5.1.7 until all of the emulsion in the beaker(s) has been transferred to the trays.
5.1.10 Add breaking agent to the residual emulsion in the beaker to separate the binder and aqueous phases.
5.1.11 Add a volume of breaking agent to the measuring cylinder approximating the volume of emulsion in each tray.
5.1.12 While stirring the emulsion in one of the trays with the spatula, slowly add the breaking agent from the measuring cylinder to separate the binder and aqueous phases.
5.1.13 Repeat Step 5.1.11 for each of the remaining trays.
5.1.14 Using the spatula, decant the aqueous phase from each of the trays, taking care to ensure none of the binder phase is included.
5.1.15 Transfer the binder phase from the beaker and spatula to one of the trays, rinsing with water as required.
5.1.16 Remove the binder phase from each tray and hand wash it by kneading and flushing with tap water until foaming ceases.
5.1.17 Transfer the binder phase back to each tray and form it into a thin layer to match the size of the tray.

5.1.18 Dry the binder phase on each tray using the procedure described in Subsection 5.2 or 5.3 as appropriate.

5.2 Vacuum oven method

5.2.1 Place each tray in the vacuum oven at 100ºC.

5.2.2 Gradually increase the vacuum to maximum, taking care to avoid excessive foaming, and allow the sample to be dried at maximum vacuum for two hours.

5.2.3 Remove the trays from the vacuum oven and allow them to cool.

5.2.4 Invert the samples in the trays then dry them in the vacuum oven at 100ºC under maximum vacuum for one hour.

5.2.5 Remove the trays from the vacuum oven and allow them to cool to room temperature.

5.2.6 Remove the recovered binder from each tray and place it in a tared metal container.

5.2.7 Weigh the recovered binder and record the mass to the nearest 0.01 g (mb).

5.3 Nitrogen purged oven method

5.3.1 Place each tray in the oven set at a temperature of 120ºC under nitrogen purging for two hours (Note 8.3).

5.3.2 Remove the trays from the oven and allow them to cool.

5.3.3 Invert the samples in the trays then dry them in the oven at 120ºC under nitrogen purging for one hour.

5.3.4 Remove the trays from the oven and allow them to cool to room temperature.

5.3.5 Remove the recovered binder from each tray and place it in a tared metal container.

5.3.6 Weigh the recovered binder and record the mass to the nearest 0.01 g (mb).

6 Calculation

Calculate the polymer modified binder content of the emulsion as follows:

\[ \text{PMB} = \frac{m_b}{m_e} \times 100 \]

where

- \( \text{PMB} \) = polymer modified binder content (%)
- \( m_e \) = mass of emulsion (g)
- \( m_b \) = mass of recovered binder (g)

7 Reporting

Report the polymer modified binder content of the emulsion to the nearest 0.1%.

8 Notes on method

8.1 This calculation assumes a polymer modified binder content of 75% for the emulsion. A factor of 1.5 is applied to account for variation between the assumed and actual binder contents, as
well as for potential binder losses during the recovery process and in the preparation of binder samples for testing.

8.2 To achieve efficient mixing without spillage under the stirring conditions of Step 5.1.5, sample sizes of 3 to 4 L can be accommodated in the mixing container. For larger sample sizes, representative sub-sampling or mixing with the mechanical stirrer directly in the sample container should be used. For smaller sample sizes, a longer mixing period in conjunction with manual stirring may be required.

8.3 At a temperature of 120°C, the sample should flow to uniformly cover the tray. If this does not occur, the oven temperature may be increased to as high as 130°C provided that it is returned to 120°C as soon as sufficient flow is achieved.

*Figure 1 – Mechanical stirrer paddle*
Test Method Q372: Cutter content of bituminous materials - modified Dean and Stark

1 Source
This method was developed in-house using techniques evolved through internal investigations, based on information and conditions implemented around the particular apparatus used.

2 Scope
This method sets out the procedure for the determination of the cutter content of bituminous materials using a modification to the Dean and Stark method of water extraction.

Internal investigations have indicated that the recovery of cutter from bituminous materials is not affected by cutter concentration. However, the extractive efficiency of this method is reduced for cutter products from the heavier fraction of the distillation range. The recovery efficiencies of this method for different cutter products are detailed in Table 1.

3 Apparatus
The following apparatus is required:

3.1 A balance of suitable capacity, with a resolution of 0.1 g and with a limit of performance within the range of ± 0.5 g.

3.2 A balance of suitable capacity, with a resolution of 0.01 g and with a limit of performance within the range of ± 0.05 g.

3.3 Round bottomed flask, of suitable capacity fitted with a ground glass neck (Table 2).

3.4 Boiling chips.

3.5 Heating mantle, thermostatically controlled.

3.6 Dean and Stark heavy entrainer of suitable size (Table 2).

3.7 Reflux condenser, Liebig type, with an effective cooling length of 400 mm.

3.8 Ground glass joint adaptors.

3.9 Wire, of approximately 500 mm in length and approximately 2 mm in diameter.

4 Materials
The following material is required:

4.1 Cutter, a sample of the cutter product used in the bituminous emulsion or asphalt material under test (if available) (Note 9.1).

4.2 Binder, a sample of the binder used in the cutback bitumen or asphalt material under test (if available).

4.3 Distilled water or equivalent (for example, reverse osmosis water).

5 Sample preparation
5.1 Cutback bitumen

5.1.1 Thoroughly mix the sample of cutback bitumen.
5.1.2 Using a portion of the sample, determine its density \( D_C \) in accordance with either Test Method Q374 or AS 2341.7 (Note 9.2).

5.2 **Asphalt**

5.2.1 Obtain a representative sample of suitable size (Table 2) by coning and quartering in accordance with Subsection 4.2 of Test Method Q301.

5.2.2 Determine the density of the cutter product used in the material at 25°C in accordance with Test Method Q374, using 0.997 kg/L as the density of water at 25°C (Note 9.3).

5.3 **Bituminous emulsion**

5.3.1 Thoroughly mix the sample of bituminous emulsion.

5.3.2 Determine the density of the cutter product used in the material at 25°C in accordance with Test Method Q374, using 0.997 kg/L as the density of water at 25°C (Note 9.3).

6 **Procedure**

The procedure shall be as follows:

6.1 Weigh a sample of suitable size (Table 2) into a tared flask (Note 9.4). Record the mass of the sample \( m \) to the nearest 0.1 g for asphalt samples and to the nearest 0.01 g for all other sample types.

6.2 Add distilled water (or equivalent) to the flask in accordance with the guidelines in Table 2.

6.3 Add boiling chips to the flask.

6.4 Transfer the flask and contents to the heating mantle and use the appropriate adaptors to connect the Dean and Stark apparatus to the flask and the Liebig reflux condenser to the Dean and Stark apparatus. Ensure that all joints and connections are airtight.

6.5 Adjust the water flow through the condenser tube to a slow uniform rate.

6.6 Heat the flask to raise the temperature to the boiling point of the mixture.

6.7 Adjust the heating so that the distillate collects in the entrainer at a rate of 2 to 5 drops per second.

6.8 Continue distillation until the volume of cutter collected in the entrainer remains constant for 60 minutes (Note 9.5). Dislodge any cutter adhering to the condenser or entrainer walls using the length of wire.

6.9 Allow the contents of the entrainer to cool to room temperature and record the volume of cutter collected to the nearest scale division \( V \) (Note 9.6).

7 **Calculations**

Calculate the cutter content of the sample of cutback bitumen, asphalt or bituminous emulsion using the appropriate calculation, as follows:

7.1 **Cutback bitumen**

7.1.1 No blank determination

Where no blank determination has been made on the original uncut bitumen, calculate the cutter content as follows:
a) Calculate the volume of cutter per mL of cutback bitumen as follows:

\[ V_c = \frac{D_c V}{m} \]

where
- \( V_c \) = volume of cutter per mL of cutback bitumen (mL)
- \( D_c \) = density of cutback bitumen (kg/L)
- \( V \) = volume of cutter recovered from cutback bitumen sample (mL)
- \( m \) = mass of cutback bitumen sample (g)

b) Calculate the cutter content as follows:

\[ C_v = \frac{V_c - 100}{1 - V_c} \]

where
- \( C_v \) = cutter content of the cutback bitumen expressed as the volume of cutter per 100 volumes of binder
- \( V_c \) = volume of cutter per mL of cutback bitumen (mL)

7.1.2 With blank determination

Where a blank determination has been made (Note 9.6), calculate the cutter content as follows:

a) Calculate the volume of cutter per mL of cutback bitumen as described in Step 7.1.1 a).

b) Calculate the volume of cutter per mL of the binder blank sample as follows:

\[ V_B = \frac{D_B V_O}{m_B} \]

where
- \( V_B \) = volume of cutter per mL of binder blank sample (mL)
- \( D_B \) = density of binder (kg/L)
- \( V_O \) = volume of cutter recovered from blank sample (mL)
- \( m_B \) = mass of binder sample (g)

c) Calculate the cutter content as follows:

\[ C_v = \frac{V_c - V_B}{1 - V_c + V_B} - 100 \]

where
- \( C_v \) = cutter content of the cutback bitumen expressed as the volume of cutter per 100 volumes of binder
- \( V_c \) = volume of cutter per mL of cutback bitumen (mL)
- \( V_B \) = volume of cutter per mL of binder blank sample (mL)
7.2 **Asphalt and bituminous emulsion**

7.2.1 **Cutter content by mass**

Calculate the cutter content as follows:

\[
C_m = \frac{VD}{m} \times 100
\]

where  
- \( C_m \) = cutter content of sample expressed as the percentage by mass of sample (\%)
- \( V \) = volume of cutter recovered from sample (mL)
- \( D \) = density of cutter (kg/L)
- \( m \) = mass of sample (g)

7.2.2 **Cutter content by volume**

For asphalt, the cutter content may also be calculated as volume of cutter per 100 volumes of the binder in the asphalt as follows:

a) Calculate the volume of the binder in the asphalt sample as follows:

\[
V_a = \frac{mB_a}{D_B (100-C_m)}
\]

where  
- \( V_a \) = volume of binder in asphalt sample (mL)
- \( m \) = mass of asphalt sample (g)
- \( B_a \) = binder content of the asphalt (\%) (Note 9.7)
- \( D_B \) = density of binder (kg/L) (Note 9.8)
- \( C_m \) = cutter content of sample expressed as the percentage by mass of sample (\%), as derived in Step 7.2.1

b) Calculate the cutter content as follows:

\[
C_V = \frac{V}{V_a} \times 100
\]

where  
- \( C_V \) = cutter content of the asphalt expressed as the volume of cutter per 100 volumes of the binder in the asphalt
- \( V \) = volume of cutter recovered from sample (mL)
- \( V_a \) = volume of binder in asphalt sample (mL)

8 **Reporting**

Report the following as appropriate:

8.1 For cutback bitumen and for asphalt (where required), report the cutter content as volumes of cutter per 100 volumes of binder to the nearest 0.1.
8.2 For asphalt and bituminous emulsion, report the cutter content as a percentage by mass to the nearest 0.1%.

9 Notes on method

9.1 Before handling any cutter oil product, the operator must consult the relevant Safety Data Sheet (SDS).

9.2 The choice of method for determining the density of the cutback bitumen depends upon the nature of the material. Highly cutback bitumen is better tested by Q374, since its density is likely to be lower than that of water, making AS 2341.7 difficult to perform.

9.3 If a sample of the cutter product used is not available, it may be necessary to repeat Steps 6.1 to 6.8 several times in order to extract sufficient of the cutter to determine its density. Alternatively, a value for cutter density may be assumed, provided that the degree of uncertainty that this introduces to the cutter content is acceptable. For kerosene cutters, a value of 0.78 kg/L may usually be used in the absence of any other data, alternatively the operator could consult the Material Safety Data Sheet for the relevant cutter to obtain a value for density.

9.4 The operator should exercise care when transferring the sample to the flask to ensure that no sample comes into contact with the ground glass neck of the flask.

9.5 In the case of high cutter content cutback bitumens, if the volume of cutter exceeds the capacity of the entrainer, the sample should be cooled and a quantity of cutter removed by pipette before reheating to complete the analysis. The quantity removed must be added to the final result.

9.6 Some bitumens contain volatile materials which will increase the volume of cutter extracted during this test. For the accurate determination of cutter content in a cutback made from such bitumens, a blank cutter content determination should be conducted on the bitumen only, if that is available.

9.7 Binder content of the asphalt should be determined in accordance with Test Method Q308A on a representative sample of the same asphalt. No attempt should be made to drive off the cutter before determining the binder content. The additional mass of any cutter originally present in the sample has been accounted for in the calculation in Step 7.2.2 (a).

9.8 In the absence of any other evidence, the density of the binder can be assumed to be 1.04 kg/L for bitumen binders and 1.03 kg/L for polymer modified binders.

9.9 To be able to reliably ascertain the concentration of a cutter in a cutback bitumen, the identity of the cutter should be known and adjustment factors should be developed for each cutter type to reflect its specific recovery efficiency.

9.10 When a mixture of cutters and fluxes of differing volatilities is used in a cutback bitumen, the recovery efficiency can be estimated from a weighted average of the individual cutter efficiencies.

Table 1 - Recovery efficiencies for different cutter products (Notes 9.9 and 9.10)

<table>
<thead>
<tr>
<th>Cutter material</th>
<th>Recovery (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BP Coralite</td>
<td>93 – 95</td>
</tr>
<tr>
<td>Shell high flash point cutter</td>
<td>93 – 95</td>
</tr>
<tr>
<td>Dieseline</td>
<td>68</td>
</tr>
</tbody>
</table>
### Cutter material and Recovery (%)

<table>
<thead>
<tr>
<th>Cutter material</th>
<th>Recovery (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coralite/dieselene blend</td>
<td>84</td>
</tr>
<tr>
<td>Furnace oil</td>
<td>8</td>
</tr>
</tbody>
</table>

### Table 2 - Recommended sample sizes, distilled water volumes, flask and entrainer sizes

<table>
<thead>
<tr>
<th>Bituminous material</th>
<th>Sample size (g)</th>
<th>Entrainer size (mL)</th>
<th>Distilled water (mL)</th>
<th>Flask size (mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cutback bitumen</td>
<td>50</td>
<td>12.5</td>
<td>500</td>
<td>1,000</td>
</tr>
<tr>
<td>Bituminous emulsion</td>
<td>100</td>
<td>12.5</td>
<td>500</td>
<td>1,000</td>
</tr>
<tr>
<td>Bitumen</td>
<td>100</td>
<td>3</td>
<td>500</td>
<td>1,000</td>
</tr>
<tr>
<td>Asphalt:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DG7, DG10, DG14</td>
<td>1,000</td>
<td>12.5</td>
<td>*</td>
<td>1,000</td>
</tr>
<tr>
<td>DG20, DG28</td>
<td>1,500</td>
<td>12.5</td>
<td>*</td>
<td>2,000</td>
</tr>
</tbody>
</table>

* Samples to be covered with distilled water (or equivalent) to a depth of 25 mm.
Test Method Q374: Density of petroleum products

1 Source
This method was developed in-house using information contained within technical references.

2 Scope
This method describes the procedure for the determination of the density of liquid petroleum products including cutter oils, flux oils and cutback bitumens. The test is performed at 25°C but provision is also made for the reporting of the corresponding density result at 15°C.

3 Apparatus
The following apparatus is required:

3.1 Balance, of suitable capacity, with a resolution of at least 0.001 g and a limit of performance within the range of ± 0.005 g.
3.2 Volumetric flasks, of 100 mL capacity.
3.3 Beakers, of 250 mL capacity.
3.4 Filter funnel, a long-stem glass funnel.
3.5 Water bath, maintained at a temperature of 25 ± 0.1°C.
3.6 Pasteur pipette.
3.7 Glass rod.

4 Materials
4.1 Distilled water or equivalent (for example, reverse osmosis water).

5 Procedure
Perform the following procedure in duplicate (Note 9.1).

5.1 Weigh the stoppered flask and record the mass to the nearest 0.001 g (m₁).
5.2 Fill the flask to about one centimetre below the calibration mark with distilled water (or equivalent) and stopper.
5.3 Place the stoppered flask in the water bath so that the water level is above the calibration mark. Leave the flask in the water bath for at least 45 minutes to allow the flask and contents to attain temperature equilibrium.
5.4 Using a pasteur pipette, add distilled water (or equivalent) dropwise to the flask until its level almost reaches the calibration mark. Stopper the flask and leave in the water bath for at least 15 minutes.
5.5 Using a pasteur pipette, fill the flask to the calibration mark with distilled water (or equivalent). Stopper the flask, remove from the water bath and dry thoroughly.
5.6 Weigh the stoppered flask and contents and record the mass to the nearest 0.001 g (m₂).
5.7 Empty the flask and dry thoroughly.
5.8 Stir the sample thoroughly and decant a portion into the beaker.
5.9 Using the filter funnel, transfer sufficient of the sample portion from the beaker to the flask to fill it to about one centimetre below the calibration mark (Note 9.2).

5.10 Stopper the flask and then place in the water bath so that the water level is above the calibration mark. Leave the flask in the water bath for at least 45 minutes to allow the flask and contents to attain temperature equilibrium.

5.11 Using a pasteur pipette or glass rod as appropriate, add sample to the flask until its level almost reaches the calibration mark (Note 9.2). Stopper the flask and leave in the water bath for at least 15 minutes.

5.12 Using a pasteur pipette or glass rod as appropriate, fill the flask to the calibration mark with the sample (Note 9.2). Stopper the flask, remove from the water bath and dry thoroughly.

5.13 Weigh the stoppered flask and contents and record the mass to the nearest 0.001 g ($m_1$).

6 Calculations

6.1 Calculate the density of each test portion of the sample as follows:

$$D = \frac{(m_3 - m_1) 0.997}{(m_2 - m_1)}$$

where

- $D$ = density of test portion (kg/L)
- $m_1$ = mass of stoppered flask (g)
- $m_2$ = mass of stoppered flask filled with distilled water (or equivalent) (g)
- $m_3$ = mass of stoppered flask filled with sample (g)

6.2 Provided that the difference between the density results from the two test portions is no greater than 0.0016 kg/L, calculate the density of the sample as the average of the two results to the nearest 0.001 kg/L.

6.3 When the density of the sample at 15ºC is required, record to the nearest 0.001 kg/L using Table 1.

7 Reporting

7.1 Report the density of the sample at 25ºC and/or 15ºC as appropriate, to the nearest 0.001 kg/L.

8 Precision

8.1 Repeatability

8.1.1 The results of duplicate tests by the same operator are acceptable if they do not differ by more than 0.0012 kg/L.

9 Notes on method

9.1 Steps 5.1 to 5.7 of the procedure determine the volume of the flask. Checks on this value may only be required periodically.

9.2 It is essential during flask filling that the sample makes no contact with that part of the neck of the flask above the calibration mark. If this is not achieved, it will be necessary to repeat the procedure.
### Table 1 - Comparison of density values of petroleum products at 25°C and 15°C

<table>
<thead>
<tr>
<th>Density (kg/L)</th>
<th>Density (kg/L)</th>
<th>Density (kg/L)</th>
<th>Density (kg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.7500</td>
<td>0.7588</td>
<td>0.8000</td>
<td>0.8072</td>
</tr>
<tr>
<td>0.7550</td>
<td>0.7638</td>
<td>0.8050</td>
<td>0.8122</td>
</tr>
<tr>
<td>0.7600</td>
<td>0.7688</td>
<td>0.8060</td>
<td>0.8132</td>
</tr>
<tr>
<td>0.7620</td>
<td>0.7706</td>
<td>0.8070</td>
<td>0.8141</td>
</tr>
<tr>
<td>0.7640</td>
<td>0.7728</td>
<td>0.8100</td>
<td>0.8171</td>
</tr>
<tr>
<td>0.7650</td>
<td>0.7735</td>
<td>0.8150</td>
<td>0.8221</td>
</tr>
<tr>
<td>0.7680</td>
<td>0.7762</td>
<td>0.8160</td>
<td>0.8230</td>
</tr>
<tr>
<td>0.7690</td>
<td>0.7772</td>
<td>0.8200</td>
<td>0.8270</td>
</tr>
<tr>
<td>0.7700</td>
<td>0.7781</td>
<td>0.8250</td>
<td>0.8320</td>
</tr>
<tr>
<td>0.7710</td>
<td>0.7790</td>
<td>0.8280</td>
<td>0.8350</td>
</tr>
<tr>
<td>0.7720</td>
<td>0.7800</td>
<td>0.8290</td>
<td>0.8359</td>
</tr>
<tr>
<td>0.7740</td>
<td>0.7818</td>
<td>0.8300</td>
<td>0.8369</td>
</tr>
<tr>
<td>0.7750</td>
<td>0.7828</td>
<td>0.8350</td>
<td>0.8419</td>
</tr>
<tr>
<td>0.7770</td>
<td>0.7846</td>
<td>0.8400</td>
<td>0.8469</td>
</tr>
<tr>
<td>0.7780</td>
<td>0.7856</td>
<td>0.8450</td>
<td>0.8519</td>
</tr>
<tr>
<td>0.7800</td>
<td>0.7874</td>
<td>0.8500</td>
<td>0.8569</td>
</tr>
<tr>
<td>0.7840</td>
<td>0.7914</td>
<td>0.8530</td>
<td>0.8599</td>
</tr>
<tr>
<td>0.7850</td>
<td>0.7923</td>
<td>0.8540</td>
<td>0.8608</td>
</tr>
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<td>0.7900</td>
<td>0.7973</td>
<td>0.8550</td>
<td>0.8618</td>
</tr>
<tr>
<td>0.7950</td>
<td>0.8023</td>
<td>0.8600</td>
<td>0.8668</td>
</tr>
<tr>
<td>0.7960</td>
<td>0.8032</td>
<td>0.8650</td>
<td>0.8718</td>
</tr>
</tbody>
</table>

Note: Values falling between those listed in Table 1 may be determined by linear interpolation.
Materials Testing Manual

Part 9: Concrete
Test Method Q456: Sulfate content of hardened concrete

1 Source
This method was developed in-house with reference to the procedures described in *A Text-Book of Quantitative Inorganic Analysis including Elementary Instrumental Analysis (3rd Edition)* – Arthur I. Vogel: Section V, 6 – Determination of Sulphate as Barium Sulphate.

2 Scope
This method describes the procedure for determining the sulfate content of hardened concrete. Sulfate content of finely ground hardened concrete is determined gravimetrically as barium sulfate following hydrochloric acid extraction and precipitation of the sulfate with barium chloride solution.

3 Apparatus
The following apparatus is required:

3.1 Balance of suitable capacity, with a resolution of at least 0.0001 g and with a limit of performance within the range of 0.0005 g.

3.2 Drying oven of suitable capacity, having a temperature of 105 to 110°C and complying with AS 1289.0.

3.3 Furnace, capable of maintaining temperature up to 800°C.

3.4 Hotplate, capable of maintaining a temperature of 150-200°C.

3.5 Steam bath.

3.6 Volumetric flasks, of 100 mL capacity.

3.7 Measuring cylinders of 25 mL, 50 mL and 100 mL capacity.

3.8 Pipettes, of 10 mL capacity, graduated in 0.1 mL divisions.

3.9 Pasteur pipettes.

3.10 Pipette filler.

3.11 Glass filter funnels.

3.12 Beakers, of 400 mL and 600 mL capacity.

3.13 Watch glasses of approximately 100 mm in diameter.

3.14 Desiccator, containing silica gel desiccant or equivalent.

3.15 Crucibles, silica or platinum crucibles with lids.

3.16 Crucible tongs.

3.17 Container, approximately 350 mL capacity, plastic and sealed with an airtight lid.

3.18 Storage bottles (amber glass), of 250 mL capacity.
4 Reagents

All reagents are analytical reagent grade and the following are required (Notes 10.1 and 10.2):

4.1 Ammonia solution, dilute:
- Dilute 25 mL of concentrated ammonia solution with distilled water (or equivalent) and make up to the mark in a 50 mL measuring cylinder.

4.2 Hydrochloric acid, concentrated (31-32% w/w).

4.3 Hydrochloric acid, dilute:
- Using a graduated pipette, add 1 mL of concentrated hydrochloric acid to 90 mL of distilled water (or equivalent) in a 100 mL measuring cylinder and make up to 100 mL with distilled water (or equivalent).

4.4 Methyl red indicator solution:
- Dissolve 0.1 g of methyl red indicator in distilled water (or equivalent) and make up to 100 mL with distilled water (or equivalent).

4.5 Barium chloride solution:
- Dissolve 10 g of barium chloride in distilled water (or equivalent).
- Transfer the solution to a 100 mL volumetric flask and make up to the mark with distilled water (or equivalent).

4.6 Silver nitrate solution (Note 10.3):
- Dissolve 1 g of silver nitrate in distilled water (or equivalent).
- Transfer the solution to a 100 mL volumetric flask and make up to the mark with distilled water (or equivalent).
- Transfer the solution to a 250 mL amber glass storage bottle and store in a dark cupboard.

5 Materials

5.1 Distilled water or equivalent (for example, reverse osmosis water).

5.2 Filter papers, Whatman No. 1, 40 and 542 or equivalent.

6 Sample preparation

6.1 Crush the sample to obtain a representative subsample passing 0.150 mm fine screening sieve as detailed in Test Method Q101F.

6.2 Dry the subsample in an oven maintained at 105-110°C and allow to cool to room temperature.

6.3 Store the oven dried subsample in a sealed container.

7 Procedure

Perform the following procedure in duplicate:

7.1 Weigh a sample portion expected to be equivalent to about 1 g of cement into a 400 mL beaker and record the mass to the nearest 0.0001 g $m_1$ (Note 10.4).
7.2 Disperse the sample by adding 25 mL of distilled water (or equivalent) and 10 mL of concentrated hydrochloric acid. If effervescence is evident, a watch glass may be placed over the top of the beaker.

7.3 Add 50 mL of hot distilled water (or equivalent) to the beaker, cover with the watch glass and boil the contents for 5 to 10 minutes on the hotplate.

7.4 Filter the solution through a Whatman No. 40 (or equivalent) filter paper, collecting the filtrate in a 600 mL beaker.

7.5 Wash the insoluble residue on the filter paper with 3 or 4 portions of 20 mL of hot dilute hydrochloric acid. Collect the washings in the 600 mL beaker containing the filtrate. Discard the remaining insoluble residue.

7.6 Heat the filtrate and the washings to boiling and add 5 drops of methyl red indicator solution using a pasteur pipette. Neutralise the solution by adding dropwise dilute ammonia solution until a colour change of from pink to yellow is observed.

7.7 Filter the solution through a Whatman No. 1 (or equivalent) filter paper, collecting the filtrate in a 400 mL beaker.

7.8 Wash the precipitate with 3 or 4 portions of 10 to 15 mL of hot distilled water (or equivalent). Collect the washings in the 400 mL beaker containing the filtrate. Discard this precipitate.

7.9 Add 1 mL of concentrated hydrochloric acid using a graduated pipette and pipette filler.

7.10 Place the beaker and contents on the hotplate and heat to boiling.

7.11 Remove the beaker from the hotplate and place on the steam bath to maintain gentle boiling of the contents.

7.12 Add barium chloride solution dropwise to the contents, ensuring that no interruption to the boiling occurs and until precipitation appears complete.

7.13 Remove the beaker from the steam bath and allow the precipitate to settle. Add a few drops of barium chloride solution to the clear supernatant liquid to ensure complete precipitation of barium sulfate has occurred.

7.14 If precipitation is incomplete, add additional barium chloride solution and return the beaker to the steam bath for 1 hour. Repeat Steps 7.12 to 7.14.

7.15 Once precipitation is complete, allow the beaker and contents to cool to room temperature and filter the contents carefully through a Whatman No. 542 (or equivalent) filter paper, ensuring that all of the precipitate is transferred from the beaker to the filter paper.

7.16 Wash the precipitate several times with portions of approximately 30 mL of boiling distilled water (or equivalent) until the washings are chloride free (Note 10.5). Discard the filtered solution.

7.17 Heat a crucible for approximately 30 minutes in the furnace at 600-800°C, cool to room temperature in a desiccator and weigh, recording the mass to the nearest 0.0001 g.

7.18 Repeat Step 7.17 until constant mass is attained (Note 10.6). Record the mass of the final weighing to the nearest 0.0001 g (m2).

7.19 Carefully transfer the filter paper containing the precipitate to the crucible and dry at approximately 100°C in the furnace.
7.20 Place the lid onto the crucible and gradually increase the temperature of the furnace to about 250°C over approximately 1 hour. Increase the temperature of the furnace further to 600 - 800°C and hold at this temperature for 1 hour.

7.21 Remove the crucible from the furnace, cool to room temperature in the desiccator and weigh to the nearest 0.0001 g.

7.22 Heat the crucible at 600 - 800°C for 15 to 20 minutes and repeat Step 7.20.

7.23 Repeat Step 7.22 until constant mass is attained (Note 10.6). Record the mass of the final weighing to the nearest 0.0001 g (m₃).

8 Calculations

8.1 Calculate the sulfate content for each run of the procedure, to the nearest 0.1% using the relevant calculation as follows:

\[ \text{SO}_4^{2-} = \frac{41.2(m₃-m₂)}{m₁} \]

where

- \( \text{SO}_4^{2-} \) = sulfate content expressed as \( \text{SO}_4^{2-} \) (%)
- \( m₁ \) = mass of sample (g)
- \( m₂ \) = mass of crucible (g)
- \( m₃ \) = mass of crucible and residue (g)

\[ \text{SO}_3 = \frac{34.3(m₃-m₂)}{m₁} \]

where

- \( \text{SO}_3 \) = sulfate content expressed as \( \text{SO}_3 \) (%)
- \( m₁ \) = mass of sample (g)
- \( m₂ \) = mass of crucible (g)
- \( m₃ \) = mass of crucible and residue (g)

8.2 Calculate the average of the two results and record as the sulfate content of the sample to the nearest 0.1%.

9 Reporting

Report the sulfate content expressed as \( \text{SO}_4^{2-} \) or \( \text{SO}_3 \) to the nearest 0.1%.

10 Notes on method

10.1 Before handling chemicals and preparing reagents, the operator must consult the relevant Safety Data Sheet (SDS).

10.2 Unless otherwise indicated, all reagents are to conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.
10.3 Silver nitrate should be handled carefully to avoid any spillage of the solution which readily leaves black stains on bench tops and so on. Should staining occur, it can be removed using a reagent prepared by dissolving 75 g of each of thiourea and citric acid in 1 L of distilled water (or equivalent). This reagent is stable indefinitely.

10.4 Generally for hardened concrete, a 5 g sample approximates 1 g of cement.

10.5 To ensure the washings are free from chlorides, approximately 10 mL of the washings are acidified with 3 drops of concentrated nitric acid and silver nitrate is added dropwise. If a white precipitate or cloudiness forms, further washing of the precipitate with boiling distilled water are carried out until the addition of silver nitrate produces no white discolouration.

10.6 Constant mass is achieved when subsequent weighings of the crucible do not vary by more than ± 0.0002 g.
Test Method Q457B: Chloride content of hardened concrete - Mohr titration

1  Source
This method was developed in-house and is based on the procedures described in A Text-Book of Quantitative Inorganic Analysis including Elementary Instrumental Analysis (3rd Ed.) - Arthur Vogel: Section III, 23 - Standardisation of the Silver Nitrate Solution: Part A - with Potassium Chromate as Indicator. The Mohr Titration (contained within page 259 of this edition).

2  Scope
This method describes the procedure for determining the chloride content of hardened concrete. Chloride content is determined by acid extraction and titrimetric analysis of the extract for chloride ions using standardised silver nitrate.

3  Apparatus
The following apparatus is required:

3.1  Balances:
3.1.1  Balance of suitable capacity, readable to 0.1 g and with a limit of performance within the range of ± 0.5 g.
3.1.2  Balance of suitable capacity, readable to 0.01 g and with a limit of performance within the range of ± 0.05 g.
3.1.3  Balance of suitable capacity, readable to 0.0001 g and with a limit of performance within the range of ± 0.0005 g.
3.2  Drying oven of suitable capacity, having a temperature of 105-110°C and complying with AS 1289.0.
3.3  Furnace, capable of maintaining a temperature of 250°C.
3.4  Steam bath.
3.5  Volumetric flasks, of 100 mL, 250 mL and 1000 mL capacity.
3.6  Measuring cylinder (graduated) of 250 mL capacity.
3.7  Pipettes:
3.7.1  Bulb type of 10 mL, 25 mL and 50 mL capacity.
3.7.2  Graduated type of 1 mL capacity (graduated in 0.1 mL divisions).
3.7.3  Pasteur pipettes.
3.8  Pipette filler.
3.9  Burette, of 50 mL capacity graduated in 0.1 mL divisions.
3.10  Filter funnels (glass).
3.11  Beakers, of 250 mL, 400 mL and 600 mL capacity.
3.12  Magnetic stirrer and stirring bar.
3.13  Desiccator, containing silica gel desiccant (or equivalent).
3.14  Storage bottles, of 100 mL and 250 mL, and one of 1000 mL capacity (amber glass).
3.15 pH meter or pH indicator paper.
3.16 Conical flasks, of 125 mL capacity.

4 Reagents

All reagents are analytical reagent grade and the following are required (Notes 11.1 and 11.2).

4.1 Standard sodium chloride solution.
- Heat sodium chloride in a furnace maintained at 250°C for 2 hours and then cool in a desiccator.
- Dissolve 1.6485 ± 0.0001 g of dry sodium chloride in distilled water (or equivalent).
- Transfer the solution to a 1000 mL volumetric flask and make up to the mark with distilled water (or equivalent) (1 mL of this solution equals 1 mg of chloride).

4.2 Silver nitrate solution.
- Dissolve 4.8 g of silver nitrate in distilled water (or equivalent).
- Transfer the solution to a 1000 mL volumetric flask and make up to the mark with distilled water (or equivalent).
- Transfer the solution to a 1000 mL amber glass storage bottle and store in a dark cupboard (Note 11.3).

4.3 Potassium chromate indicator solution.
- Dissolve 5 g of potassium chromate in 80 mL of distilled water (or equivalent).
- While stirring, add dropwise the silver nitrate solution until a permanent red precipitate is produced.
- Filter the solution and dilute the filtrate by making up to the mark in a 100 mL volumetric flask with distilled water (or equivalent). Transfer the indicator solution to a 100 mL storage bottle.

4.4 Sulfuric acid solution.
- Add 0.5 mL of concentrated sulfuric acid by means of a 1 mL graduated pipette to 180 mL of distilled water (or equivalent) in a measuring cylinder.
- Transfer the solution to a 250 mL storage bottle.

4.5 Sodium carbonate solution.
- Dissolve 1.1 g of sodium carbonate in 200 mL of distilled water (or equivalent) and transfer to a 250 mL storage bottle.

4.6 Phenolphthalein indicator solution.
- Dissolve 0.5 g of phenolphthalein in 50 mL of 95% ethanol and then slowly add 50 mL of distilled water (or equivalent) with constant stirring.
- Filter the solution and transfer to a 100 mL storage bottle.

4.7 Sodium hydroxide solution.
- Dissolve 5.1 g of sodium hydroxide in distilled water (or equivalent).
- Transfer the solution to a 250 mL volumetric flask and make up to the mark with distilled water (or equivalent).
4.8 Nitric acid, concentrated.

5 Materials

5.1 Distilled water or equivalent (for example, reverse osmosis water).

5.2 Filter paper, Whatman No 1 or equivalent.

6 Standardisation of silver nitrate solution

Perform Steps 6.1 to 6.4 in triplicate.

6.1 Pipette a 25 mL aliquot of standard sodium chloride solution into a 125 mL conical flask.

6.2 Add 1 mL of potassium chromate indicator solution to the flask by pasteur pipette.

6.3 Stir the solution using a magnetic stirring bar and titrate with silver nitrate solution to the first permanent red-brown colour change.

6.4 Record the titre value to the nearest 0.1 mL.

6.5 Calculate the average of the three titre determinations and record it as the molarity of the silver nitrate solution to the nearest 0.01.

7 Sample preparation

7.1 Crush the sample of hardened concrete to obtain a representative subsample of 750 g passing 0.150 mm sieve as detailed in Test Method Q101F.

7.2 Dry the subsample at 105 to 110°C and then allow to cool to room temperature.

7.3 Store the oven dried sample in a sealed container.

8 Procedure

Perform the following procedure in duplicate.

8.1 Weigh a portion of the sample to be equivalent to about 2 g of cement into a 250 mL beaker and record the mass to the nearest 0.0001 g (m) (Note 11.4).

8.2 Disperse the sample with 25 mL of distilled water (or equivalent) and 10 mL of concentrated nitric acid. Add 50 mL of hot distilled water (or equivalent) and place the beaker on a steam bath for 10 to 15 minutes.

8.3 Filter the solution and transfer all the material to the filter paper using a minimum quantity of distilled water (or equivalent). Wash the material retained on the filter paper with three 50 mL portions of distilled water (or equivalent). Collect the filtrate and washings in a 600 mL beaker. Discard the insoluble residue.

8.4 Adjust the pH of the filtrate to a value of 8.2 using the sodium hydroxide solution (Note 11.5).

8.5 If necessary, place the beaker on a steam bath and reduce the volume to approximately 250 mL.

8.6 Filter the solution into a 400 mL beaker. Transfer all of the precipitate to the filter paper from the 600 mL beaker using distilled water (or equivalent).

8.7 Wash the precipitate with three 10 mL portions of distilled water (or equivalent) and collect the washings in the 400 mL beaker containing the filtrate. Discard the insoluble residue.

8.8 Cool the filtrate to room temperature and add 2 mL of potassium chromate indicator.
8.9 Stir the solution using a magnetic stirring bar and titrate with silver nitrate solution to the first permanent red-brown colour change. For lengthy titrations, add additional 1 mL increments of potassium chromate indicator for every 10-15 mL of silver nitrate solution used.

8.10 Record the volume of the silver nitrate solution to the nearest 0.1 mL ($V_t$).

8.11 Carry out a blank determination using approximately 250 mL of distilled water (or equivalent).

8.12 Record the volume of silver nitrate solution to the nearest 0.1 mL ($V_b$).

9 **Calculations**

9.1 Calculate the chloride content for each run of the procedure to the nearest 1 part per million (ppm) as follows:

$$C = \frac{25000(V_t - V_b)}{V_m}$$

where

- $C$ = chloride content of sample (ppm)
- $V_t$ = volume of silver nitrate solution titrated against the sample extract (mL)
- $V_b$ = volume of silver nitrate solution titrated against the blank (mL)
- $V$ = average volume of silver nitrate solution titrated during standardisation (mL)
- $m$ = mass of sample portion (g)

9.2 Calculate and record the average of the two results as the chloride content of the sample to the nearest 1 ppm.

10 **Reporting**

Report the chloride content of the sample to the nearest 10 ppm.

11 **Notes on method**

11.1 Before handling chemicals and preparing reagents, the operator must consult the relevant Safety Data Sheet (SDS).

11.2 Unless otherwise indicated, all reagents are to conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.

11.3 Silver nitrate should be handled carefully to avoid any spillage of the solution which readily leaves black stains on bench tops and so on. Should staining occur, it can be removed using a reagent prepared by dissolving 75 g of each of thiourea and citric acid in 1 L of distilled water. This reagent is stable indefinitely.

11.4 Generally for hardened concrete, approximately 10 g of sample is equivalent to approximately 2 g of cement.

11.5 Sulfuric acid solution may be used if the pH of the solution goes above 8.2.
Test Method Q460A: Compressive stress and recovery of preformed joint filler

1 Source
This method is based on ASTM D545-84: Preformed expansion joint fillers for concrete construction (non-extruding and resilient types) Section 7.2: Recovery and compression, with only minor variations.

2 Scope
This method describes the procedure for determining, under specified conditions, both the stress required to compress preformed joint filler to a set strain level, and then the recovery of the filler material once the compressive force has been removed.

3 Apparatus
The following apparatus is required:

3.1 Compression testing machine, at least Class A as defined in AS 2193, with a moveable lower platen which travels at a uniform vertical rate of 1.3 mm/minute when measured loaded.

3.2 Compression platens, having machined parallel bearing surfaces at least 12.5 mm thick and of sufficient area to provide at least 10 mm clearance between the edge of the specimen and any edge of the platen.

3.3 Vertical displacement measuring system, to allow the measurement of the vertical displacement at the centre of the specimen. The system can use a dial gauge complying with the requirements of AS 2103, which has a scale interval of 0.01 mm and a minimum range of 30 mm, or a displacement transducer or any equivalent system of at least equal performance.

3.4 Force application assembly, incorporating a spherical seat.

3.5 Glass beaker, or similar heat resistant container having a capacity of approximately 5 L (Note 7.1).

3.6 Hotplate, with temperature control capable of maintaining a temperature of at least 110°C (Note 7.1).

4 Procedure
The procedure shall be as follows:

4.1 Sample Preparation
4.1.1 For self-expanding cork joint fillers only, boil a 120 mm x 120 mm sample for 1 hour (using the glass beaker and hot plate) and air dry for 24 hours.

4.1.2 Cut a test specimen, 100 mm square (tolerance ± 0.5 mm), from the preformed joint filler such that each edge is freshly cut.

4.2 Testing
4.2.1 Locate the lower and upper compression platens centrally on the lower platen of the testing machine. Place the displacement measuring system above the centre of the upper platen and record the dial gauge reading (d₁).

4.2.2 Raise the upper platen by hand and locate the test specimen centrally between the platens. Record the dial gauge reading (d₂).
4.2.3 Using the force application assembly, apply and record the maximum force \( F \) necessary to compress the specimen to 50 per cent of its original thickness (Note 7.2).

4.2.4 Immediately remove the force from the specimen and allow it to recover for 30 minutes with the upper platen, the displacement measuring system and the load application assembly in place.

4.2.5 Repeat Steps 4.2.3 and 4.2.4 applying sufficient force to again achieve a compression of 50 per cent of the original thickness.

4.2.6 Compress the test specimen a third time by repeating Step 4.2.5.

4.2.7 Immediately remove the force, disassemble the testing apparatus and allow the specimen to recover unrestrained for 24 hours.

4.2.8 At the end of the recovery period, locate the lower and upper compression platens on a flat surface such as the lower platen of the testing machine. Place the displacement measuring system above the centre of the upper platen and record the dial gauge reading \( d_1 \).

4.2.9 Raise the upper platen by hand and locate the recovered test specimen centrally between the platens. Record the dial gauge reading \( d_4 \).

5 Calculations

Calculate as follows:

5.1 Calculate the applied stress \( S \) as follows:

\[
S = \frac{F}{A}
\]

where

- \( S \) = applied stress (MPa)
- \( F \) = force required to achieve 50% thickness (N)
- \( A \) = area of test specimen (mm²) (taken as 10,000 mm²)

5.2 Calculate the percentage recovery \( R \) as follows:

\[
R = \frac{100(d_4 - d_3)}{d_2 - d_1}
\]

where

- \( R \) = recovery (%)
- \( d_4 \) = dial gauge reading for upper platen with recovered specimen (mm)
- \( d_3 \) = dial gauge reading for upper platen after testing (mm)
- \( d_2 \) = dial gauge reading for upper platen with untested specimen (mm)
- \( d_1 \) = dial gauge reading for upper platen before testing (mm)

6 Reporting

Report the following:

6.1 Applied stress to the nearest 0.1 MPa.

6.2 Percentage recovery to the nearest 0.5%.
Notes on method

7.1 The glass beaker and hotplate are only required when a self-expanding cork joint filler is to be tested.

7.2 The dial gauge reading corresponding to 50 per cent compression is calculated as follows:

\[ d_{50} = d_1 + \frac{(d_2 - d_1)}{2} \]

where

- \( d_{50} \) = dial gauge or transducer reading corresponding to 50% compression (mm)
- \( d_1 \) = dial gauge reading for upper platen before testing (mm)
- \( d_2 \) = dial gauge reading for upper platen with untested specimen (mm)
Test Method Q460B: Extrusion of preformed joint filler

1 Source
This method is based on ASTM D545-84: Preformed expansion joint fillers for concrete construction (non-extruding and resilient types), Section 7.3: Extrusion, with only minor variations.

2 Scope
This method describes the procedure for determining the extrusion of preformed joint filler when subjected to a compressive force under specified conditions.

3 Apparatus
Where appropriate, the working tolerances of particular apparatus are contained in Table 1.

The following apparatus is required:

3.1 Compression testing machine, at least Class A as defined in AS 2193, with a moveable lower platen which travels at a uniform vertical rate of 1.3 mm/minute when measured loaded.

3.2 Metal mould with a base of 100 mm x 100 mm, a thickness of 11 mm, and three sides which are at least 50 mm high and 5 mm thick (Note 7.1).

3.3 Compression platen, having machined parallel bearing surfaces 100 mm x 100 mm and at least 5 mm thick (Note 7.1).

3.4 Vertical displacement measuring system, to allow the measurement of the vertical displacement at the centre of the specimen. The system can use a dial gauge complying with the requirements of AS 2103, which has a scale interval of 0.01 mm and a minimum range of 30 mm, or a displacement transducer of at least equal performance.

3.5 Force application assembly, incorporating a spherical seat.

3.6 Horizontal displacement measuring system, to allow the measurement of the horizontal displacement of the specimen. The system can use a dial gauge complying with the requirements of AS 2103, which has a scale interval of 0.01 mm and a minimum range of 10 mm, and is fitted with a disk shaped contact and mounted on a stand, or other suitable assembly to allow the horizontal displacement of the specimen to be measured.

3.7 Glass beaker, or similar heat resistant container having a capacity of approximately 5 L (Note 7.2).

3.8 Hotplate, with temperature control capable of maintaining a temperature of at least 110ºC (Note 7.2).

4 Procedure
The procedure shall be as follows:

4.1 Sample preparation
4.1.1 For self-expanding cork joint fillers only, boil a 120 mm x 120 mm sample for 1 hour (using the glass beaker and hot plate) and air dry for 24 hours.

4.1.2 Cut a test specimen, 100 mm square (tolerance ± 0.5 mm), from the preformed joint filler such that each edge is freshly cut.
4.2 Testing

4.2.1 Locate the mould and compression platen centrally on the lower platen of the testing machine. Place the vertical measuring system above the centre of the compression platen and record the dial gauge reading \( d_1 \).

4.2.2 Remove the compression platen and place the specimen in the mould. Replace the platen and align it such that it is flush with the open side of the mould and is centrally located between the adjacent sides. Record the dial gauge reading \( d_2 \).

4.2.3 Locate the horizontal measuring system such that the contact is touching the free edge of the specimen. Record the dial gauge reading \( d_3 \).

4.2.4 Using the load application assembly, apply and record the force necessary to compress the specimen to 50 per cent of its original thickness (Note 7.3).

4.2.5 Immediately read and record the reading \( d_4 \) of the dial gauge in the horizontal system being used to measure extrusion of the specimen.

5 Calculations

Calculate the extrusion as follows:

\[
E = d_3 - d_4
\]

where

- \( E \) = extrusion (mm)
- \( d_3 \) = dial gauge reading before compression (mm)
- \( d_4 \) = dial gauge reading after compression (mm)

6 Reporting

Report the extrusion to the nearest 0.01 mm.

7 Notes on method

7.1 The compression platen must fit firmly into the mould without binding with any side.

7.2 The glass beaker and hotplate are only required when a self-expanding cork joint filler is to be tested.

7.3 The dial gauge reading corresponding to 50 per cent compression is calculated as follows:

\[
d_{50} = d_1 + \frac{(d_2 - d_1)}{2}
\]

where

- \( d_{50} \) = dial gauge or transducer reading corresponding to 50% compression (mm)
- \( d_1 \) = dial gauge reading for upper platen before testing (mm)
- \( d_2 \) = dial gauge reading for upper platen with untested specimen (mm)
Table 1 – Working tolerances for apparatus

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<tr>
<th>Apparatus</th>
<th>Value</th>
<th>Tolerance</th>
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<td><strong>Mould – base</strong></td>
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</tr>
<tr>
<td>Width (mm)</td>
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<td>+ 0.4, - 0.0</td>
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<tr>
<td>Length (mm)</td>
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<td><strong>Mould – sides</strong></td>
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<tr>
<td>Thickness (mm)</td>
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<tr>
<td><strong>Compression platen</strong></td>
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<tr>
<td>Width (mm)</td>
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<td>Length (mm)</td>
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Test Method Q460C: Expansion of preformed self-expanding joint filler

1 Source
This method is based on ASTM D545-84: Preformed expansion joint fillers for concrete construction (non-extruding and resilient types), Section 7.1: Expansion in boiling water, with only minor variations.

2 Scope
This method describes the procedure for determining the expansion of self-expanding joint filler in boiling water.

3 Apparatus
The following apparatus is required:

3.1 Glass beaker, or similar heat resistant container having a capacity of approximately 5 L.
3.2 Hotplate, with temperature control capable of maintaining a temperature of at least 110°C.
3.3 Digital calliper, with a resolution of at least 0.1 mm and complying with AS 1984.

4 Procedure
The procedure shall be as follows:

4.1 Sample preparation
Cut two test specimens, 114 mm square (tolerance ± 2.5 mm), from the self-expanding joint filler such that each edge is freshly cut.

4.2 Testing
4.2.1 Measure and record the average initial thickness of each test specimen to the nearest 0.1 mm ($t_1$).
4.2.2 Half fill the beaker with water and bring to the boil.
4.2.3 Immerse one of the specimens in the boiling water for 1 hour.
4.2.4 At the end of this period, remove the specimen and allow it to cool at room temperature for 15 minutes.
4.2.5 Measure and record the average thickness of the specimen to the nearest 0.1 mm ($t_2$).
4.2.6 Repeat Steps 4.2.2 to 4.2.5 for the second specimen.

5 Calculations
5.1 Calculate the percentage expansion for each specimen as follows:

$$E = \frac{100(t_2 - t_1)}{t_1}$$

where

- $E$ = expansion (%)
- $t_2$ = average final thickness of specimen (mm)
- $t_1$ = average initial thickness of specimen (mm)
5.2 Calculate the expansion as the average expansion for the two specimens.

6 **Reporting**

Report the expansion of the self-expanding joint filler to the nearest 1%.
Test Method Q460D: Accelerated weathering of preformed joint filler

1 Source
This method is based on ASTM D545-67: Preformed expansion joint fillers for concrete construction (non-extruding and resilient types), with only minor variations.

2 Scope
This method describes the procedure for determining the weathering resistance of joint filler materials.

3 Apparatus
The following apparatus is required:

3.1 Drying oven, capable of maintaining a temperature of 75 ± 1°C.
3.2 Cabinet, capable of maintaining a temperature between -10°C and -20°C.
3.3 Water bath, capable of maintaining a temperature between 20°C and 40°C.
3.4 Metal test container, at least 100 mm deep and 120 mm in diameter.
3.5 Glass beaker, or similar heat resistant container having a capacity of approximately 5 L (Note 6.1).
3.6 Hotplate, with temperature control capable of maintaining a temperature of at least 110°C (Note 6.1).
3.7 Clamps, for holding the test specimens in the metal test container.

4 Procedure
The procedure shall be as follows:

4.1 Sample preparation
4.1.1 For self-expanding cork joint fillers only, boil a 120 mm x 120 mm sample for 1 hour (using the glass beaker and hot plate) and air dry for 24 hours.
4.1.2 Cut a test specimen, 100 mm square (tolerance ± 0.5 mm), from the preformed joint filler such that each edge is freshly cut.

4.2 Testing
4.2.1 Place the two test specimens in the oven for a period of 7 days.
4.2.2 At the end of this period, remove the specimens and immerse them in a partly-filled beaker of water at room temperature for 24 hours.
4.2.3 Place the specimens on edge in the metal test container and clamp them securely in position such that they are not in contact with each other.
4.2.4 Partly fill the container with water to a depth of 50 mm (half the depth of the specimens), then place the container in the cabinet until the water has frozen.
4.2.5 Remove the container from the cabinet and partly immerse the container in the water bath until the ice in the test container has completely melted.
4.2.6 Repeat Steps 4.2.4 to 4.2.5 until 10 cycles have been completed.
4.2.7 At the completion of the last cycle, remove the specimens from the container and allow them to stand at room temperature for 48 hours.

4.2.8 Examine each specimen and record details of any evidence of disintegration.

5 Reporting
Report any evidence of disintegration of each specimen.

6 Notes on method
6.1 The glass beaker and hotplate are only required when a self-expanding cork joint filler is to be tested.
Test Method Q460E: Resistance to heat degradation of closed cell foam joint filler

1 Source
This method applies the principles of RTA Test Method T1154: Resistance to heat degradation of closed cell foam joint filler. It differs from this method in that details for the making and curing of the mortar blocks are included.

2 Scope
This method describes the procedure for determining the resistance of closed cell foam joint filler to degradation from contact with hot poured joint sealant when these materials are used together in a formed joint system.

3 Apparatus
The following apparatus is required:

3.1 Mortar moulds, 50 mm x 50 mm and 25 mm thick.
3.2 Glass plate, at least 150 mm x 150 mm.
3.3 Masking tape, 25 mm wide.
3.4 Scalpel, or similar sharp cutting tool.
3.5 Heating container and lid, made of metal with a diameter of approximately 100 mm, a depth of approximately 150 mm and a maximum wall thickness of 1 mm. The lid must have access holes for a thermometer and a mechanical stirrer.
3.6 Mechanical stirrer and stand.
3.7 Thermometer, a partial or total immersion thermometer or other suitable temperature measuring device having a temperature range of at least 0ºC–300ºC and graduated to 5ºC or less with an uncertainty of no more than 5ºC.
3.8 Oil bath, containing silicone oil or an oil with a flash point in excess of 285ºC, equipped with a mechanical stirrer.
3.9 Ruler, with a scale interval of 0.5 mm.
3.10 Trowel, made of steel with a blade approximately 100 mm–150 mm long.
3.11 Tamper, made of a rubber compound with a Shore A hardness of 80 ± 10 or of seasoned hardwood which has been immersed in paraffin wax at 200ºC for 15 minutes. The tamper shall have a rectangular face, 13 mm x 25 mm, which is at right angles to the length of the tamper. A convenient tamper length is 125 mm to 150 mm.

4 Materials
The following materials are required:

4.1 Mould oil, a light oil such as Caltex Mould Oil 20 (Notes 7.1 and 7.2).
4.2 Hot poured joint sealant (Note 7.1).
4.3 Release agent, for example, Potash soap (Note 7.1).
4.4 General purpose cement (GP).
4.5 Sand.
4.6 Water.
4.7 Masking tape.

5 Procedure

The procedure shall be as follows:

5.1 Preparation of cement mortar test blocks
5.1.1 Lightly oil two moulds, base plates and covers.
5.1.2 Mix 1 part of GP cement with 1.5 parts of sand by mass, adding sufficient water to the mixture to produce a consistency suitable for tamping. The mortar should be mixed for approximately 3 minutes.
5.1.3 Fill both the moulds in two equal layers, compacting each layer fully using the tamper.
5.1.4 Strike off the excess mortar and smooth the surface using the trowel, then place the covers on the moulds.
5.1.5 Undertake initial curing and standard moist curing as detailed in AS 1012.8, Clause 1.9.
5.1.6 At the completion of at least 7 days standard moist curing, surface dry the mortar blocks so they are ready for the application of the release agent.

5.2 Preparation of hot poured joint sealing compound
5.2.1 Heat the oil bath with the heating container fixed into position until the oil temperature is in the range 190°C - 220°C.
5.2.2 Melt approximately 250 g of hot poured joint sealant by placing of approximately 50 g pieces of the compound in the heating container at approximately 30 second intervals.
5.2.3 Place the lid on the container and insert the thermometer and mechanical stirrer.
5.2.4 Commence mixing the joint sealant and continue heating until its temperature is 190°C.

5.3 Sample preparation
5.3.1 Cut a test specimen 50 mm long and 25 mm wide from a sample of closed cell foam filler.

5.4 Testing
5.4.1 Apply release agent to one 50 mm square face of each cement mortar block.
5.4.2 Place the cement blocks on the glass plate such that the coated surfaces are facing each other in the vertical plane and are separated by at least the thickness of the specimen. Locate the test specimen centrally between the blocks such that a face formed by its 50 mm length and thickness is in contact with the glass plate.
5.4.3 Apply sufficient pressure to the mortar blocks to ensure there is intimate contact between the blocks and the foam filler. Wrap masking tape around the blocks and the foam filler to form a reservoir 25 mm deep, 50 mm long and having a width equal to the thickness of the specimen.
5.4.4 Rapidly fill the reservoir with hot poured sealant and allow the mould to stand for 24 hours at 16°C to 25°C.
5.4.5 Remove the filler and sealant from the mould.
5.4.6 Place the filler/sealant combination on a flat surface and cut through the two compounds along a line at right angles to the filler/sealer interface.

5.4.7 Measure the amount of penetration of the sealant into the filler to the nearest 0.5 mm at a number of locations along the interface.

6 Reporting

Report the average depth of penetration to the nearest 1 mm as the resistance to heat degradation.

7 Notes on method

7.1 Before handling oil, release agent or joint sealant, the operator must consult the relevant Safety Data Sheet (SDS).

7.2 Other mould oils such as Shellmould P5, Reochem Mould Oil 20 and Caltex Mould Oil 222 have also been found to be suitable.
Test Method Q460F: Resistance to disintegration of preformed cork joint filler

1 Source
This method is based on ASTM D545-84: Preformed expansion joint fillers for concrete construction (non-extruding and resilient types), Section 7.4: Boiling in hydrochloric acid, with only minor variations.

2 Scope
This method describes the procedure for assessing the effectiveness of the bonding materials in preformed cork joint fillers used to bond the granulated particles of natural cork.

3 Apparatus
The following apparatus is required:
3.1 Glass beaker, having a capacity of at least 5 L (Note 7.1).
3.2 Fume cabinet.
3.3 Hotplate, with temperature control capable of maintaining a temperature of at least 110ºC (Note 7.1).

4 Reagent
The following reagent is required:
4.1 Hydrochloric acid, 12.4M (concentrated) (Note 7.2).

5 Procedure
The procedure shall be as follows:

5.1 Sample preparation
5.1.1 For self-expanding cork joint fillers only, boil a 120 mm x 120 mm sample for 1 hour (using the glass beaker and hot plate) and air dry for 24 hours.
5.1.2 Cut a test specimen, 100 mm square (tolerance ± 0.5 mm), from the preformed joint filler such that each edge is freshly cut.

5.2 Testing
5.2.1 Half fill the beaker with hydrochloric acid and bring the acid to the boil using a hotplate located in a fume cabinet. The fume cabinet extraction system must be operating.
5.2.2 Immerse the specimen in the boiling hydrochloric acid for 1 hour.
5.2.3 Remove the specimen from the beaker and wash the specimen under running water.
5.2.4 Examine the test specimen and note any signs of disintegration, delamination, porosity or dislodged particles of cork.
5.2.5 Use the fingers to test for friability, lack of resiliency and resistance to abrasion by rubbing.

6 Reporting
Report any defects, ignoring discolouration and slight swelling.
7 Notes on method

7.1 The glass beaker and hotplate are only required when a self-expanding cork joint filler is to be tested.

7.2 Before handling concentrated hydrochloric acid, the operator must consult the relevant Safety Data Sheet (SDS).
Test Method Q461: Durability of sealant

1 Source

This method is based on RTA Test Method T1192-1992: Adhesion of sealant, and RTA Test Method T1193-1991: Accelerated aging of cured sealant, with only minor variations.

2 Scope

This method describes the procedure to assess the durability of sealant bonded to a substrate when tested for adhesion and cohesion. The method is applicable to sealant used to seal sawn joints in concrete pavements.

3 Apparatus

The following apparatus is required:

3.1 Oven, capable of maintaining a temperature of 70 ± 3ºC within all of the working space or a defined area of sufficient size to accommodate the test specimen assembly.
3.2 Refrigerated cabinet, capable of maintaining a temperature of 0 ± 3ºC.
3.3 Water bath, capable of maintaining a temperature of 35 ± 1ºC and of sufficient size to allow the test specimen assembly to be immersed to a depth of at least 20 mm below the surface.
3.4 Cabinet, capable of maintaining a temperature of 23 ± 2ºC.
3.5 Testing machine, capable of applying tensile and compressive forces at a rate of travel of 10 mm/minute.
3.6 Mould, made from non-absorbent material which will not react with concrete and be able to cast a concrete prism, 50 mm x 140 mm and about 200 mm long.
3.7 Saw, diamond tipped masonry saw.
3.8 Spacer blocks, made from non-absorbent material with machined surfaces 13 mm x 20 mm x 31 mm.
3.9 Backing foam, 15 mm thick.
3.10 Clamps, for example G clamps or quick release clamps.
3.11 Tension and compression testing jig, as shown in Figure 1.
3.12 Digital calliper, with a resolution of at least 0.1 mm and complying with AS 1984.
3.13 Vertical displacement measuring system, to measure the extension and compression of the moulded sealant. The system can use a dial gauge complying with the requirements of AS 2103 with a scale interval of 0.01 mm and a minimum travel of 25 mm, or a displacement transducer of at least equal performance.

4 Materials

The following materials are required:

4.1 Release agent, for example, Potash Soap.
4.2 Concrete.
4.3 Paper towel.
5 **Procedure**

The procedure shall be as follows:

5.1 **Preparation of concrete blocks**

5.1.1 Mould a concrete prism using at least 40 MPa concrete and allow it to cure for at least 28 days as detailed in AS 1012.8.1.

5.1.2 Cut 6 concrete blocks from the prism using the masonry saw, such that each block has 2 flat cut faces, 50 mm x 140 mm, and is approximately 25 mm thick.

5.1.3 Condition the blocks using one of the following methods:

   a) Dry blocks: allow the blocks to dry at room temperature for 7 days after cutting.

   b) Dry abraded blocks: allow the blocks to dry at room temperature for 7 days after cutting, then blast one flat surface (the bonding face) on each block with grit abrasive.

   c) Saturated surface-dry blocks: immerse the blocks in water at room temperature for 2 hours, then remove the blocks and blot them dry with folded paper towel to remove surface water.

5.2 **Moulding of sealant**

Mould 3 specimens of sealant as detailed below:

5.2.1 Apply the release agent to a 13 mm x 31 mm surface of each spacer block, that is, the face which will contact the sealant.

5.2.2 Cut a strip from the 15 mm thick backing foam, 100 mm x 19 mm (tolerance ± 0.5 mm). Apply release agent to the 100 mm x 15 mm face which will contact the sealant.

5.2.3 Assemble the concrete blocks, spacer blocks and foam using the clamps to hold the components in place such that a cavity 100 mm long, 13 mm wide and 12 mm deep, is formed between the blocks after compressing the foam to a thickness of 13 mm. Refer to Figure 2.

5.2.4 Prepare the sealant according to the manufacturer’s instructions and fill the cavity with sealant to the top of the spacer blocks.

5.2.5 Allow the sealant to cure for 7 days at 23 ± 2°C before removing the spacer blocks and backing foam.

5.3 **Aging**

Age the 3 specimens of sealant as detailed below:

5.3.1 Air cure the test specimen assemblies in the oven for 72 hours at 70 ± 3°C.

5.3.2 Air cure the test specimen assemblies in the refrigerated cabinet for 24 hours at 0 ± 3°C.

5.3.3 Submerge the test specimen assemblies in the water bath and cure for 48 hours at 35 ± 1°C.

5.3.4 Air cure the test specimen assemblies for 24 hours at 23 ± 2°C.

5.4 **Testing**

5.4.1 Measure the distance between the faces of the concrete blocks for one of the test specimen assemblies by taking at least three measurements along the top surface of the sealant and three measurements along the bottom surface.

5.4.2 Place the test specimen assembly in the testing jig and secure the concrete blocks firmly in the jaws.
5.4.3 Attach the testing jig to the testing machine ensuring that the distance between the blocks as measured in Step 5.4.1 is maintained.

5.4.4 Cycle the sealant specimen through 100 cycles of 70 per cent extension and 50 per cent compression as measured by the displacement measuring system (Note 7.2).

5.4.5 During the extension and compression cycles, monitor the specimen for cohesion failure or adhesion failure as follows:

a) Cohesion Failure - assess the extent of any cracking of the specimen during compression using a fine wire such as a straightened paper clip to probe the depth of any crack. Where the degree of failure is 10 per cent or greater than 10 per cent of the cross-sectional area of the specimen, the specimen is deemed to fail.

b) Adhesion Failure - assess the extent of any debonding at both sealant/concrete block interfaces. Again, use a fine wire such as a straightened paper clip to probe the extent of any debonding. Where the degree of failure at either interface is 10 per cent or greater than 10 per cent of the cross-sectional area of the specimen, the specimen is deemed to fail.

5.4.6 Repeat Steps 5.4.1 to 5.4.5 for the remaining two test specimen assemblies. If no more than one specimen fails the test, the sealant is acceptable, otherwise the sealant is unacceptable.

6 Reporting

Report the durability of the sealant as either acceptable or unacceptable.

7 Notes on method

7.1 Before handling release agent or concrete, the operator must consult the relevant Safety Data Sheet (SDS).

7.2 The extension and compression are determined from the specimen width measured in Step 5.4.1.
Figure 1 – Testing jig

4 SCREWS AT EACH END

METAL SPACER

STEEL JAWS

LEGEND

CONCRETE BLOCK

SEALANT
Figure 2 – Test specimen assembly
Test Method Q462: Resistance of vulcanised rubber to the absorption of oil

1 Source
This method is based on ASTM D471-96: Rubber property – Effects of liquids, Section 10: Procedure for change in mass, with only minor variations.

2 Scope
This method describes the procedure for determining the resistance of vulcanized rubber to absorption and consequent swelling when immersed in a standard oil.

3 Apparatus
The following apparatus is required:

3.1 Balance of suitable capacity, having a resolution of at least 0.0001 g and with a limit of performance within the range of ± 0.0005 g.
3.2 Test tube, having a diameter of 38 mm and a length of 300 mm fitted with a stopper.
3.3 Frame, for holding the test specimens in the test tube, for example, a wire frame with a horizontal arm.
3.4 Water bath, capable of maintaining a temperature of 50 ± 2°C.
3.5 Petri dish.

4 Materials
The following materials are required:

4.1 Standard oil, IRM 903 (Note 8.1).
4.2 Acetone (Note 8.1).

5 Procedure
The procedure shall be as follows:

5.1 Sample Preparation
5.1.1 Cut three test specimens from the rubber sample, 25 mm x 50 mm (tolerance ± 0.5 mm) with a thickness of 2.0 ± 0.1 mm. Samples with a thickness less than that specified are to be tested as received whereas those with a thickness above the upper tolerance must be buffed to a thickness of 2.0 ± 0.1 mm.
5.1.2 Drill a small hole in each specimen near one end to allow the specimens to be suspended in the test tube.

5.2 Testing
5.2.1 Determine the mass of each test specimen (m1).
5.2.2 Pour 100 mL of oil into the test tube.
5.2.3 Suspend the test specimens from the frame and immerse the specimens in the oil.
5.2.4 Stopper the test tube and place the test tube in the water bath for 22 hours at 50°C.
5.2.5 At the end of the immersion period, remove the specimens from the oil and allow them to cool in a container of clean oil at room temperature for 30 to 60 minutes.
5.2.6 After cooling, dip each specimen in turn in acetone, blot lightly with filter paper and place immediately in a petri dish of known mass \( m_3 \).

5.2.7 Determine the mass of each specimen and petri dish \( m_3 \).

6 Calculations

6.1 Calculate the gain in mass for each specimen as a percentage of its original mass as follows:

\[
M = \frac{m_3 - m_2 - m_1}{m_1} \times 100
\]

where

- \( M \) = gain in mass (%)
- \( m_3 \) = mass of oil soaked specimen and petri dish (g)
- \( m_2 \) = mass of petri dish (g)
- \( m_1 \) = mass of untested specimen (g)

7 Reporting

Report the average mass gain as the oil absorption to the nearest 0.5%.

8 Notes on method

8.1 Before handling oil or acetone, the operator must consult the relevant Safety Data Sheet (SDS).
Test Method Q463A: High temperature recovery of preformed polychloroprene elastomeric joint seals

1 Source
This method is based on RTA T1161: High temperature recovery of polychloroprene elastomeric joint seals for bridge structures, with only minor variations.

2 Scope
This method describes the procedure for determining the high temperature recovery of compressed polychloroprene elastomeric seals used for bridge structures.

3 Apparatus
The following apparatus is required:

3.1 Digital calliper, with a resolution of at least 0.2 mm and complying with AS 1984.
3.2 Compression plates, 125 mm x 200 mm, at least 5 mm thick and chrome plated or otherwise protected from corrosion. The plates shall be drilled at each corner and fitted with 10 mm diameter bolts and nuts.
3.3 Oven, capable of maintaining a temperature of 100 ± 1°C.
3.4 Room, capable of maintaining a temperature of 23 ± 2°C.

4 Procedure
The procedure shall be as follows:

4.1 Sample Preparation
Cut a test specimen 125 mm long from the joint seal.

4.2 Testing
4.2.1 Measure and record the width \( w_1 \) of the test specimen at the centre of the top surface of the seal, that is, the face to be exposed to traffic. Mark the position where the measurement was made.

4.2.2 Place the test specimen centrally between the compression plates such that the top surface is at right angles to the plates and the longitudinal axis of the specimen is parallel to the longitudinal axes of the compression plates.

4.2.3 Compress the joint seal uniformly between the compression plates by tightening the nuts on the bolts, ensuring that the top surface of the seal folds inwards towards the centre of the specimen. Continue until the specimen has been compressed to 50 per cent of its original thickness.

4.2.4 Place the compressed specimen in the oven for 72 hours.

4.2.5 At the end of the 72 hour period, remove the specimen from the oven, unclamp the compression plates and allow the specimen to recover at 23°C for 1 hour.

4.2.6 Immediately measure the recovered width \( w_2 \) of the marked centre position of the specimen.
5 Calculations

Calculate the percentage recovery as follows:

\[ R = \frac{w_2}{w_1} \times 100 \]

where
- \( R \) = high temperature recovery (%)
- \( w_2 \) = recovered specimen width (mm)
- \( w_1 \) = original specimen width (mm)

6 Reporting

Report the high temperature recovery to the nearest 0.5%.
Test Method Q463B: Low temperature recovery of preformed polychloroprene elastomeric joint seals

1 Source
This method is based on RTA T1160: Low temperature recovery of polychloroprene elastomeric joint seals for bridge structures, with only minor variations.

2 Scope
This method describes the procedure for determining the low temperature recovery of compressed polychloroprene elastomeric seals used for bridge structures.

3 Apparatus
The following apparatus is required:

3.1 Digital calliper, with a resolution of at least 0.2 mm and complying with AS 1984.
3.2 Compression plates, 125 mm x 200 mm, at least 5 mm thick and chrome plated or otherwise protected from corrosion. The plates shall be drilled at each corner and fitted with 10 mm diameter bolts and nuts.
3.3 Refrigerated cabinet, capable of maintaining both a temperature of –10 ± 1°C and a temperature of –29 ± 1°C.

4 Procedure
The procedure shall be as follows:

4.1 Sample preparation
4.1.1 Cut two test specimens, each 125 mm long, from the joint seal.

4.2 Testing
4.2.1 Measure and record the width \( w_1 \) of one of the test specimens at the centre of the top surface of the seal, that is the face to be exposed to traffic. Mark the position where the measurement was made.

4.2.2 Place the test specimen centrally between the compression plates such that the top surface is at right angles to the plates and the longitudinal axis of the specimen is parallel to the longitudinal axes of the compression plates.

4.2.3 Compress the joint seal uniformly between the compression plates by tightening the nuts on the bolts, ensuring that the top surface of the seal folds inwards towards the centre of the specimen. Continue until the specimen has been compressed to 50 per cent of its original width.

4.2.4 Place the compressed specimen in the refrigerated cabinet and maintain it at a temperature of -10 ± 1°C for 72 hours.

4.2.5 At the end of the 72 hour period, unclamp the specimen and allow it to recover in the cabinet at -10 ± 1°C for 1 hour.

4.2.6 Immediately measure the recovered width \( w_2 \) at the marked centre position on the specimen.
4.2.7 Repeat Steps 4.2.1 to 4.2.3 for the second specimen but recording the original measured width as \( w_3 \).

4.2.8 Place the compressed specimen in the refrigerated cabinet and maintain it at a temperature of \(-29 \pm 1^\circ C\) for 22 hours.

4.2.9 At the end of the 22 hour period, unclamp the specimen and allow it to recover in the cabinet at \(-29 \pm 1^\circ C\) for 1 hour.

4.2.10 Immediately measure the recovered width of the marked centre position on the specimen \( w_4 \).

5 Calculations

5.1 Calculate the percentage recovery at \(-10^\circ C\) as follows:

\[
R_{-10} = \frac{w_2}{w_1} \times 100
\]

where

- \( R_{-10} \) = recovery at test temperature \(-10^\circ C\) (%)
- \( w_2 \) = recovered specimen width (mm)
- \( w_1 \) = original specimen width (mm)

5.2 Calculate the percentage recovery at \(-29^\circ C\) as follows:

\[
R_{-29} = \frac{w_4}{w_3} \times 100
\]

where

- \( R_{-29} \) = recovery at test temperature \(-29^\circ C\) (%)
- \( w_4 \) = recovered specimen width (mm)
- \( w_3 \) = original specimen width (mm)

6 Reporting

Report the low temperature recoveries at the test temperatures of \(-10^\circ C\) and \(-29^\circ C\) to the nearest 0.5%.

Superseded
Test Method Q470: Coefficient of thermal expansion of concrete

1 Source
This method was developed in-house using techniques evolved through internal departmental research investigations.

2 Scope
This method describes the procedure for determining the coefficient of thermal expansion of concrete prisms when measured over a temperature range of -10°C to 45°C.

3 Apparatus
The following apparatus is required:

3.1 Thermocouple and indicator, Type T thermocouple and an indicator which has a minimum range of -15°C to 50°C and is readable to at least 0.1°C. The measuring system must have an uncertainty of no more than 0.1°C.

3.2 Drying room, as detailed in AS 1012.13 Section 5.

3.3 Comparator, as detailed in AS 1012.13 Section 5.

3.4 Drying oven, capable of maintaining a temperature of 45°C to 50°C.

3.5 Refrigerated cabinet, capable of maintaining a temperature of approximately -10°C.

4 Procedure
The procedure shall be as follows:

4.1 Moulding and Curing
4.1.1 Cast 3 concrete prisms, 100 mm x 100 mm x 250 mm as detailed in AS 1012.13 Sections 6 and 7 with a Type T thermocouple being cast into the centre of one prism.

4.1.2 At the completion of initial curing, demould the specimens and moist cure them at 27 ± 2°C for 7 days as detailed in AS 1012.8 Section 9.3.

4.1.3 At the completion of moist curing, place the specimens in the drying room for 21 days.

4.1.4 At the completion of the drying period, measure each specimen using the comparator and note the reading together with the specimen temperature.

4.2 Conditioning
4.2.1 Place each prism in a separate plastic bag such that the air gap is reduced to a minimum and seal each bag, but allowing the thermocouple wires to protrude.

4.2.2 Place the prisms in the oven and monitor the temperature of the instrumented prism until an equilibrium is reached (Note 7.1).

4.2.3 When an equilibrium is reached, remove the prisms one at a time from the oven, remove the plastic bag and measure and note the length \( (L_i) \), together with the specimen temperature \( (T_i) \).

4.2.4 Reseal each prism in its plastic bag as detailed in Step 4.2.1 and place the specimens in the refrigerated cabinet and leave overnight.
4.2.5 Remove the prisms one at a time from the cabinet, remove the plastic bag, and measure and note the length \((l_2)\) of each, together with the specimen temperature \((T_2)\) of the instrumented prism.

4.2.6 Reseal each prism in its plastic bag as detailed in Step 4.2.1, place the specimens in the drying room and leave overnight.

4.2.7 Remove each prism from its bag in turn and measure and note its length together with the temperature of the instrumented prism. Return the prisms to their plastic bags and seal.

4.3 Testing

4.3.1 At the completion of the conditioning cycle, repeat Steps 4.2.2 to 4.2.5 but recording the values of \((l)\) and \((T)\) for use in the calculations below.

5 Calculations

5.1 Calculate the coefficient of thermal expansion as follows:

\[
\alpha = 10^6 \frac{(l_1 - l_2)}{L(T_1 - T_2)} - \alpha^l
\]

where

- \(\alpha\) = coefficient of thermal expansion (\(\mu\epsilon/\degree\Celsius\))
- \(\alpha^l\) = coefficient of thermal expansion of the gauge studs (\(\mu\epsilon/\degree\Celsius\)) taken as 9 \(\mu\epsilon/\degree\Celsius\)
- \(l_1\) = specimen length at temperature \((T_1)\) (mm)
- \(l_2\) = specimen length at temperature \((T_2)\) (mm)
- \(L\) = gauge length (mm) taken as 250 mm
- \(T_1\) = temperature of specimen after storage in the oven (\(^\degree\Celsius\))
- \(T_2\) = temperature of specimen after storage in the refrigerated cabinet (\(^\degree\Celsius\))

6 Reporting

Report the coefficient of thermal expansion to the nearest 10 \(\mu\epsilon/\degree\Celsius\).

7 Notes on method

7.1 An equilibrium should be reached in 6 hours.
Test Method Q471: Making, curing and testing moulded concrete specimens - field simulated curing

1 Source
This method is based on RMS Test method T367: Field simulated curing and testing of moulded concrete specimens, with only minor variations.

2 Scope
This method describes the procedure to mould specimens of base course concrete and simulate the curing of these specimens in the field prior to determining compressive strength.

3 Apparatus
The following apparatus is required:

3.1 Spray bottle.
3.2 Shovel.
3.3 Steel rule or tape measure.
3.4 Thermometer, maximum and minimum reading thermometer or other suitable temperature measuring device, having a range of at least 0 - 50°C and graduated to 1°C or less with an uncertainty of no more than 1°C.
3.5 Vacuum desiccator.
3.6 Vacuum pump.

4 Materials
The following materials are required:

4.1 Concrete curing compound.
4.2 Bedding material such as sand or gravel.

5 Procedure
The procedure shall be as follows:

5.1 Sampling and moulding
5.1.1 Select the batch to be sampled within the lot under consideration using Random Sampling: Selection of Location – Interval (unless otherwise specified) as detailed in Test Method Q050.
5.1.2 Sample a batch of concrete which is to be incorporated into the works as detailed in Test Method AS 1012.1.
5.1.3 Mould test specimens as detailed in Test Method AS 1012.8.1 except that the mould covers are not to be fitted at the completion of moulding.

5.2 Simulated curing
5.2.1 After moulding and the disappearance of bleed water, spray the top surface of the specimens with a curing compound, using the same type and application rate as used in the works.
5.2.2 Cure the specimens either adjacent to the concrete pavement which is represented or at the place of specimen moulding. The location must duplicate the conditions of temperature,
moisture and wind to which the pavement is subjected, and the specimens must not be subjected to any artificial curing conditions nor protected from any natural ambient conditions. The top surfaces of the specimens are to be left exposed to ambient conditions unless the pavement is afforded cover and protection, in which case such protective treatment is to be duplicated in all regards for the specimens.

5.2.3 Within 6 hours of moulding, bed the specimens in bedding material to a level of 5 ± 5 mm below the top of the specimens. Extend the bedding to a horizontal distance of not less than 300 mm beyond the mould edge and grade the surface away from the specimen at not less than 2 percent such that water drains away. The bedding must not be treated in any way which is likely to provide artificially favourable curing conditions (Note 8.1).

5.2.4 Specimens are to remain undisturbed for a period as directed by the Principal. During this time, record details of weather conditions including daily maximum and minimum temperatures.

5.3 Preconditioning

5.3.1 At the completion of the simulated curing, remove the specimens from the bedding material. Immediately cover the trowelled surfaces using mould covers or, for previously demoulded specimens, plastic bags. Transport the specimens to the laboratory such that they are not damaged in transit nor subjected to any artificial temperature conditions.

5.3.2 Demould or remove specimens from their plastic bags and wet-condition each specimen using one of the following methods:
   a) Immerse the specimens in water at 27 ± 2°C for 24 ± 4 hours.
   b) Vacuum saturate the specimens by immersing in water in a desiccator and applying a partial vacuum of 13 kPa or less absolute pressure for 3 hours (Note 8.2).

5.4 Testing

5.4.1 At the completion of wet-conditioning, assess the specimens for acceptance as detailed in AS 1012.9, Section 4.

5.4.2 Determine the saturated surface-dry density of each specimen as detailed in Test Method Q473.

5.4.3 Cap the specimens and determine their unconfined compressive strength as detailed in AS 1012.9, Sections 5 to 8.

6 Calculations

Undertake calculations as detailed in Test Method Q473 and AS 1012.9.

7 Reporting

Report the following:

7.1 The density, compressive strength and general information as detailed in Test Method Q473 and AS 1012.9.

7.2 Duration of field simulated curing.

7.3 The daily maximum and minimum temperatures, together with details of daily weather conditions.

7.4 Wet conditioning method used.
7.5 Details of the concrete lot that the test results represent.

8 Notes on method

8.1 The specimens can remain in their moulds during the entire simulation period. Alternatively, they may be demoulded after 18 hours of curing provided the specimens are tightly wrapped in a dry water tight plastic bag while leaving the trowelled surface exposed and then returned to the sand/gravel bedding within 30 minutes of demoulding. During this time, specimens must be maintained in a constant condition of moisture at ambient temperature.

8.2 A partial vacuum of 13 kPa absolute pressure is approximately equivalent to a -88 kPa reading on a vacuum gauge at sea level.
Test Method Q473: Density of hardened concrete - water displacement

1 Source
This method combines the principles of RTA Test Method T368 – Draft: Dressing of voids in concrete specimens and adjustment for embedded steel, and of AS 1012.12.2: Determination of mass per unit volume of hardened concrete – Water displacement method; with only minor variations.

2 Scope
This method describes the procedure for the determination of the density of hardened concrete using a water displacement method. The method allows for testing of moulded and cored specimens for concrete pavements, but may be also applicable to other situations. The method provides for the inclusion of surface voids in the calculation of density and for the adjustment of the measured value for any embedded reinforcing steel, and is applicable to specimens having a diameter of 100 mm or larger.

3 Apparatus
The following apparatus is required:

3.1 Balance of suitable capacity, with a resolution of 1 g and with a limit of performance within the range of ± 5 g. The balance must be capable of below balance weighing.

3.2 Balance bench, equipped with a hole for below balance weighing.

3.3 Thermometer, total immersion or other suitable temperature measuring device having a temperature range which includes the test temperature, and graduated to 1ºC or less with an uncertainty of no more than 1.0ºC.

3.4 Water container, fitted with an overflow and of suitable dimensions to allow the sample to be completely immersed without contacting any part of the container.

3.5 Attachment, a non-absorbent device to suspend the concrete specimen, for example nylon or wire loop or wire support frame.

3.6 Basket, wire basket of suitable mesh and capacity to hold any reinforcing steel.

3.7 Calliper, with a resolution not exceeding 0.1 mm and complying with AS 1984 or JIS B 7507.

3.8 Steel rule.

3.9 Putty knife or scraper.

3.10 Absorbent cloth.

3.11 Masonry or diamond saw for trimming specimens.

4 Materials
The following material is required:

4.1 Filler, which is non-absorbent and mechanically stable to allow easy shaping, yet able to retain its shape during handling and immersion, for example plasticine or wax (Note 9.1).

5 Cored Specimens
5.1 Dressing of voids
5.1.1 Pre-condition the specimen using the wet conditioning procedure as detailed in AS 1012.14.
5.1.2 Remove the surplus water from the surface of the wet conditioned specimen using an absorbent cloth and continue drying until the surface appears just damp.

5.1.3 Determine the mass of the specimen (\(m_1\)).

5.1.4 Examine the specimen to identify which voids, if any, meet the criteria for filling as follows:
   a) voids with a maximum dimension less than 5 mm need not be filled
   b) voids with a maximum dimension between 5 and 15 mm must be filled if there are more than 10 on the surface
   c) voids with a maximum dimension greater than 15 mm must be filled.

5.1.5 For a specimen containing reinforcing steel embedded in the surface which can be removed without damaging the specimen, remove the steel and fill any air voids adjoining the resultant cavity with filler (Note 9.2).

5.1.6 Remove any non-concrete materials such as bitumen using a scraper.

5.1.7 Where required, remove surface texture and fractured surfaces using a masonry saw. Removal of concrete shall be limited to a maximum of 10 mm from each end.

5.1.8 Fill any surface voids which require filling by shaping the filler to match the specimen’s contour as if complete compaction had been achieved (Note 9.3).

5.2 Determine the average diameter (D) of the test specimen to the nearest 0.1 mm from two diameters measured at right angles to each other.

5.3 Determine the height (h) of the test specimen to the nearest 1 mm.

5.4 **Conditioning of specimens**

5.4.1 Immerse the specimen in water at a temperature of 23 ± 2ºC for approximately 1 hour.

5.4.2 Remove the specimen from the water, remove surplus water from its surface using an absorbent cloth and continue drying until the surface appears just damp.

5.4.3 Determine the mass of the specimen and filler in the saturated surface dry condition (\(m_2\)).

5.5 **Density measurement**

5.5.1 Place the container directly below the hole in the balance bench, fill it with water until water escapes from the overflow and allow the excess water to run to waste.

5.5.2 When water has ceased dripping from the overflow, fit the attachment to the balance, allow the remainder of the attachment to be immersed in the water container, and zero the balance.

5.5.3 Using the attachment, suspend the specimen from the balance and gently lower it into the water container until completely immersed, taking care to ensure that the suspended specimen hangs free of the sides and bottom of the container.

5.5.4 Add additional water if necessary until water escapes from the overflow, and allow the excess water to run to waste.

5.5.5 When water has ceased dripping from the overflow, determine the mass of the immersed specimen and filler (\(m_3\)).

5.5.6 Record the temperature of the water in the container to the nearest 1ºC (\(t_1\)).
### 5.6 Adjustment for reinforcing steel

5.6.1 Remove the specimen from the container and, for a specimen containing embedded reinforcing steel, remove this by breaking the concrete.

5.6.2 Determine the mass of the reinforcing steel ($m_4$).

5.6.3 Suspend the wire basket below the balance and add additional water if necessary until water escapes from the overflow, and allow the excess water to run to waste.

5.6.4 Zero the balance.

5.6.5 Remove the wire basket and place any steel in the basket.

5.6.6 Suspend the wire basket and steel from the balance and completely immerse them in the water.

5.6.7 Agitate the wire basket to remove any entrapped air.

5.6.8 Add additional water if necessary until water escapes from the overflow, and allow the excess water to run to waste.

5.6.9 When water has ceased dripping from the overflow, determine the mass of the immersed reinforcing steel ($m_5$).

5.6.10 Record the temperature of the water in the container to the nearest 1ºC ($t_2$).

### 6 Moulded specimens

#### 6.1 Conditioning of specimens

6.1.1 Immerse the specimen in water at a temperature of 23 ± 2ºC for approximately 1 hour.

6.1.2 Remove the specimen from the water, remove surplus water from its surface using an absorbent cloth and continue drying until the surface appears just damp.

6.1.3 Determine the mass of the specimen ($m_6$).

#### 6.2 Density measurement

6.2.1 Place the container directly below the hole in the balance bench, fill it with water until water escapes from the overflow and allow the excess water to run to waste.

6.2.2 When water has ceased dripping from the overflow, fit the attachment to the balance, allow the remainder of the attachment to be immersed in the water container, and zero the balance.

6.2.3 Using the attachment, suspend the specimen from the balance and gently lower it into the water container until completely immersed, taking care to ensure that the suspended specimen hangs free of the sides and bottom of the container.

6.2.4 Add additional water if necessary until water escapes from the overflow, and allow the excess water to run to waste.

6.2.5 When water has ceased dripping from the overflow, determine the mass of the immersed specimen and filler ($m_7$).

6.2.6 Record the temperature of the water in the container to the nearest 1ºC ($t_3$).
7 Calculations

7.1 Calculate the compacted density of concrete for the core specimen as follows:

\[
\rho_c = \frac{\frac{m_1 - m_4}{\rho_{w1}} - \frac{m_3 - m_5}{\rho_{w2}}}{m_2 - m_3}
\]

where
- \( \rho_c \) = compacted density of concrete (t/m³)
- \( \rho_{w1} \) = density of water at test temperature \( t_1 \) (t/m³) (Table 1)
- \( \rho_{w2} \) = density of water at test temperature \( t_2 \) (t/m³) (Table 1)
- \( m_1 \) = mass of saturated surface-dry specimen (g)
- \( m_2 \) = mass of moist specimen and filler (g)
- \( m_3 \) = mass of fully immersed specimen and filler (g)
- \( m_4 \) = mass of reinforcing steel (g)
- \( m_5 \) = mass of fully immersed reinforcing steel (g)

7.2 Calculate the reference density of concrete from the moulded specimen as follows:

\[
RD_c = \frac{m_6}{m_6 - m_3} \rho_{w3}
\]

where
- \( RD_c \) = reference density of concrete (t/m³)
- \( \rho_{w3} \) = density of water at test temperature \( t_3 \) (t/m³) (Table 1)
- \( m_6 \) = mass of saturated surface-dry specimen (g)
- \( m_3 \) = mass of fully immersed specimen (g)

8 Reporting

Report the following values and general information:

8.1 Description of test specimen providing information on:

8.1.1 Specimen type, that is, moulded specimen or core.
8.1.2 Moisture condition when tested, that is, saturated surface-dry.
8.1.3 Presence or not of reinforcing steel and, when present, whether steel was removed before or after testing.
8.1.4 Trimming of any fractured core surface.

8.2 For moulded specimens:

8.2.1 Reference density of concrete to the nearest 0.01 t/m³.

8.3 For core specimens:

8.3.1 Compacted density of the concrete to the nearest 0.01 t/m³.
8.3.2 Specimen diameter to the nearest 0.1 mm.

8.3.3 Specimen height to the nearest 1 mm.

9 Notes on method

9.1 Before handling any filler, the operator must consult the relevant Safety Data Sheet (SDS).

9.2 Do not fill the cavity left by the steel itself or any imprints from deformation patterns on the steel bar.

9.3 If voids are to be filled in a fractured surface at the bottom of a core, it is acceptable to trim the face by saw-cutting, provided there will be no significant change to the density of the specimen due to the removal of poorly compacted concrete.

Table 1 – Density of Water

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Density (t/m³)</th>
<th>Temperature (°C)</th>
<th>Density (t/m³)</th>
<th>Temperature (°C)</th>
<th>Density (t/m³)</th>
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Test Method Q474: Dowel pull-out test

1 Source
This method is based on a RTA Test Method T366: Dowel pull-out test, with only minor variations.

2 Scope
This method describes the procedure for the determination of the suitability of dowel debonder coatings, by measuring the tensile strength of the bond developed when a coated steel dowel is embedded in concrete. The method is applicable to steel dowels used in concrete road pavements for load transfer across joints.

3 Apparatus
The following apparatus is required:

3.1 Concrete cylinder moulds, having a diameter between 145 mm and 155 mm. The steel mould must be capable of moulding specimens which are right cylinders having height between 1.95 and 2.05 times the average diameter of the specimen.

3.2 Internal vibrator, having a vibrating element which operates at a frequency of at least 115 Hz and has a minimum diameter of 15 mm and a maximum diameter of 30 mm. The vibrator must be powered by a 240 volt, 50 Hz electric motor with a minimum rating of 1500 watts.

3.3 Scoop and wooden float.

3.4 Digital calliper, with a resolution of at least 0.1 mm and complying with the requirements of AS 1984.

3.5 Steel rule, with a scale interval of 0.5 mm.

3.6 Testing machine, capable of applying a tensile force at a constant rate of 0.5 mm per minute and complying with the requirements of AS 2193, Class C.

3.7 Vertical displacement measurement system, to measure the vertical displacement of the dowel bar. The system can use a dial gauge complying with the requirements of AS 2103 with a scale interval of 0.01 mm and a minimum travel of 10 mm, or a displacement transducer of at least equal performance.

4 Procedure
The procedure shall be as follows:

4.1 Sampling
Sample fresh concrete from the works or mix concrete in the laboratory complying with the relevant specification requirements, as detailed in AS 1012.1 or AS 1012.2 as appropriate.

4.2 Moulding and curing
Mould and cure two test specimens as follows:

4.2.1 Half fill each mould with concrete and insert a dowel which has been treated with the debonder coating. Locate the dowel centrally into the mould so that it touches the bottom of the mould.
4.2.2 Compact the concrete by inserting the vibrator element in at least two locations, approximately at the quarter points of one diameter, ensuring that the element does not come in contact with the sides or base of the mould.

4.2.3 After inserting the element, continue compacting the concrete until the surface becomes relatively smooth in appearance, and substantial air bubbles cease breaking the surface. Do not unduly prolong the vibration beyond this point. At this time, slowly extract the vibrator element over a period of 3 seconds or more.

4.2.4 Complete the filling of each mould by placing sufficient concrete in the last layer to overfill the mould when compacted.

4.2.5 Compact the second layer as detailed in Steps 4.2.2 and 4.2.3, inserting the vibrator to a depth which just penetrates the first layer (Note 7.1)

4.2.6 Strike off and smooth the surface of the concrete using the wooden float.

4.2.7 Cure the concrete cylinders for 7 days as detailed in AS 1012.8 Section 1.9, except that after initial curing, test specimens shall not be demoulded before being placed under standard moist-curing conditions.

4.3 Testing

4.3.1 At the completion of the 7 days curing, demould the test specimens and remove the debonding coating from the exposed part of the dowels.

4.3.2 For each specimen, measure the dowel diameter (\(d\)) to the nearest 0.1 mm and concrete specimen height (\(l\)) to the nearest 0.5 mm by averaging readings taken from a number of locations.

4.3.3 Position a test specimen in the testing machine and locate the displacement measuring system such that the movement of the dowel relative to the concrete can be measured.

4.3.4 Apply force to the specimen until a dowel displacement of at least 0.25 mm is achieved.

4.3.5 Record the maximum applied force (\(P\)) to the nearest 10 kN.

4.3.6 Repeat Steps 4.3.3 to 4.3.5 for the second specimen.

5 Calculation

5.1 Calculate the bond strength for each specimen as follows:

\[
S = \frac{P}{\pi dl}
\]

where

\(S\) = bond strength (MPa)
\(P\) = maximum applied force (kN)
\(d\) = dowel diameter (mm)
\(l\) = dowel embedded length (mm)

5.2 Calculate the average bond strength to the nearest 0.1 MPa.

6 Reporting

Report the following values and information:

6.1 Type of debonder coating used and the method of application.
6.2 Nominal diameter of dowels under test (mm)
6.3 Average bond strength to the nearest 0.1 MPa.

7 Notes on method
7.1 If, after partial compaction of the layer, it is apparent that the mould will not be completely filled, add additional concrete and then complete compaction.
Test Method Q475: Tie bar pull-out test

1 Source
This method was developed in-house using techniques evolved through departmental research investigations.

2 Scope
This method describes a field procedure for the determination of the tensile strength of the bond developed between a tie bar and the concrete into which it is embedded. This method is applicable to tie bars used at construction joints and sawn joints in concrete road pavements.

3 Apparatus
The following apparatus is required:

3.1 Hollow ram jack, capable of applying a tensile force at a constant rate of 10 mm per minute and having a force indicator which complies with the requirements of AS 2193, Class C.

3.2 Clamping mechanism, to allow load transfer from the jack to the tie bar.

3.3 Steel shims, of appropriate size for the jack, for example 150 mm x 25 mm x 1 mm.

3.4 Digital calliper, with a resolution of at least 0.1 mm and complying with the requirements of AS 1984.

3.5 Steel rule, with a scale interval of 0.5 mm.

4 Procedure
The procedure shall be as follows:

4.1 Ensure that the pavement edge which is adjacent to the tie bar and which will come into contact with the jack is free of concrete projections.

4.2 For the tie-bar of nominal length ($l_1$), measure the exposed length ($l_2$) to the nearest 1 mm and the tie bar diameter ($d$) to the nearest 0.1 mm by averaging readings taken from a number of locations.

4.3 Position the jack on the tie bar using any necessary supports to ensure that the base of the jack makes uniform contact with the pavement edge and the jack is centrally located about the bar using the necessary supports (Note 7.1).

4.4 Attach the clamping mechanism to the tie bar and apply a tensile force to the bar at a rate of 10 mm per minute.

4.5 Continue applying the force to the bar until a displacement of 5–10 mm relative to the pavement edge is achieved. Record the maximum force (P) to the nearest 10 kN.
5 Calculation

Calculate the bond strength as follows:

\[ S = \frac{P}{\pi d (l_1 - l_2)} \]

where

- \( S \) = bond strength (MPa)
- \( P \) = maximum applied force (kN)
- \( d \) = average tie bar diameter (mm)
- \( l_1 \) = nominal tie bar length (mm)
- \( l_2 \) = average tie bar exposed length (mm)

6 Reporting

Report the following:

6.1 The nominal diameter and bonded length of the tie bar (mm).
6.2 The age of the concrete at the time of testing (days).
6.3 The bond strength to the nearest 0.1 MPa.

7 Notes on method

7.1 Where irregularities in the shape of the pavement edge will not allow the jack to act parallel to the tie bar, use steel shims to pack the base of the jack.
Test Method Q476: Compressive strength of mortar or grout

This test shall be performed in accordance with AS/NZS 1012.8.3: Methods for testing concrete – Methods of making and curing concrete – Mortar and grout specimens and AS/NZS 1012.9: Methods for testing concrete – Compressive strength tests – Concrete, mortar and grout specimens.
Test Method Q477: Foreign materials content of recycled crushed concrete

1 Source
This method is based on RMS Test Method T276: Foreign Materials Content of Recycled Crushed Concrete. It differs from this method by providing for the identification of two additional foreign material types.

2 Scope
This test method sets out the procedure for the determination of the foreign materials content in a sample of recycled crushed concrete.

3 Apparatus
The following apparatus is required:
3.1 Sieve, 4.75 mm complying with AS 1152.
3.2 Sieve brush.
3.3 Drying oven of suitable capacity, having a temperature of 45 - 50°C and complying with AS 1289.0.
3.4 A metal mixing and quartering tray.
3.5 Mixing apparatus such as a trowel and quartering tools.
3.6 Sample dividers (optional).
3.7 Balance of suitable capacity, having a resolution of at least 0.1 g and with a limit of performance within the range of ± 0.5 g.
3.8 Suitable metal dishes.

4 Procedure
The procedure shall be as follows:
4.1 Prepare a bulk sample as detailed in Section 5 of Test Method Q101 to produce a representative test portion of about 6000 g.
4.2 Place the test portion in the oven and dry to a constant mass (Note 7.1).
4.3 Allow the test portion to cool to ambient temperature and determine the mass of the test portion \( m_1 \).
4.4 Sieve the test portion by hand through the 4.75 mm sieve, ensuring that the sieve is not overloaded (Refer to Table 1) and using a lateral and vertical motion accompanied by a slight jarring action to keep the material moving over the sieve. Continue sieving until no more than 1 per cent by mass of residue passes the sieve during a further 1 minute of continuous hand sieving.
4.5 Sort and separate by hand all foreign material retained on the 4.75 mm sieve, and classify it in accordance with Table 2.
4.6 Determine the mass of each foreign material type retained on the 4.75 mm sieve \( m_i \).
5 Calculations

5.1 Calculate the percentage of each foreign material type as follows:

\[ F_i = \frac{m_i}{m_t} \times 100 \]

where

- \( F_i \) = percentage of each foreign material type retained on the 4.75 mm sieve (%)
- \( m_i \) = mass of each foreign material type (g)
- \( m_t \) = mass of test portion (g)

6 Reporting

Report the percentage of each foreign material type retained on the 4.75 mm sieve to the nearest 0.1%.

7 Notes on method

7.1 A test portion is considered to have reached a constant mass when the difference between successive weighings, after a further 4 hours drying at 45 - 50°C, is not more than 1 percent of the total of the previous moisture losses.

Table 1 – Recommended maximum sieve loading

<table>
<thead>
<tr>
<th>AS sieve (mm)</th>
<th>Maximum loading (g)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>200 mm diameter</td>
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<tr>
<td>4.75</td>
<td></td>
</tr>
<tr>
<td></td>
<td>200</td>
</tr>
</tbody>
</table>

Table 2 – Classification of foreign material types

<table>
<thead>
<tr>
<th>Foreign material type</th>
<th>Material retained</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Brick and glass</td>
</tr>
<tr>
<td>2</td>
<td>Metal, ceramics and slag (other than blast furnace slag)</td>
</tr>
<tr>
<td>3</td>
<td>Plaster, clay lumps and other friable material</td>
</tr>
<tr>
<td>4</td>
<td>Rubber, plastic, bitumen (not part of asphalt), paper, cloth, paint, wood and other vegetable matter</td>
</tr>
<tr>
<td>5</td>
<td>Asphalt</td>
</tr>
</tbody>
</table>
Test Method Q480: Relaxation of prestressing and posttensioning material

Perform the test in accordance with AS/NZS 4672.1-2007 Appendix B: Isothermal relaxation test, but with the following changes, as detailed below. These changes are aimed at:

- a) addressing deficiencies in the published standard
- b) restricting testing options permitted under AS/NZS 4672.1-2007 rather than altering the procedure
- c) defining how to determine relaxation at both 1000 hours and 10,000 days.

Sub-clause B5 (a)

In the first line, delete “60%, 70% or”.

Sub-clause B5

Replace Clause (e) with:

"Continue the test for 330 ± 24 h and, without halting the test, perform an extrapolation to 1000 h and 10,000 days using Method 2 of Clause B8. The test may be finalised at this point if:

i) the relaxation at 10 000 days is outside the range of 4.20%–5.80% inclusive, and
ii) the regression coefficient is greater than or equal to 0.98.

If these conditions are not met, the test must continue in accordance with Clause (f)."

Add Clause (f):

"Continue the test to 1000 hours, and perform an extrapolation to 10,000 days using Method 2 of Clause B8, and using all data from 8 hours to 1000 hours. If the regression coefficient is less than 0.98, the 10,000 day relaxation value is not to be accepted. Reasons for the regression coefficient being less than 0.98 shall be investigated and reported."

Add the following to below Clause (f):

"All data points shall be recorded, and a reading that appears anomalous shall be investigated, and if valid reasons are found, such information shall be recorded on the test report."

Sub-clause B6 (a)

Add “and 10,000 days” after “1000 h”.

Sub-clause B8

In the first sentence, replace “160” with “330 ± 24” in both instances.

Replace the third sentence with “The regression shall be performed using Method 2.”

Replace the first sentence under Method 2 with:

"To extrapolate to 1000 h or 10,000 days, a regression shall be performed on the available data from 8 hours onwards using the following equation:"

Sub-clause B9 (d)

After the first “1000 h” add “and 10,000 days” and replace “at least 160” with “330 ± 24”.

Sub-clause B9 (f)

Replace “either Equation B7 (1) or B7 (2)” with “Equation B7 (2)”. 
Sub-clause B9 (g)

Replace with "Reference to this Standard Appendix, AS/NZS 4672.1, as modified by Q480".
Test Method Q482: Relative compaction of concrete

1 Source
This method applies the principles of Roads and Maritime Services QA Specification R83: Concrete pavement base. It varies from this specification by allowing the use of a nuclear gauge to determine the compacted density of the concrete.

2 Scope
This method describes the procedure for determining the relative compaction of concrete. It is determined as the ratio of the core density and the reference density values for the concrete expressed as a percentage.

3 Procedure
The procedure shall be as follows:

3.1 Select test locations within the lot under consideration using Random Stratified Sampling: Selection of Location – Available Area (unless otherwise specified) as detailed in Test Method Q050. The locations should be chosen to exclude joints and, where applicable, steel reinforcement or tie bars (located with the aid of a metal detector or similarly appropriate device).

3.2 Compacted density of concrete by coring
3.2.1 Extract 75 – 100 mm diameter cores from the full depth of the concrete base as detailed in AS 1012.14.
3.2.2 Place the cores in either:
   a) a tank of lime-saturated water, or
   b) individual plastic bags which are sealed to prevent moisture loss and shaded to reduce temperature extremes.
3.2.3 Determine the compacted density of the concrete ($\rho_c$) as detailed in Test Method Q473 and record the value to the nearest 0.01 t/m$^3$.

3.3 Compacted density of concrete by nuclear gauge
3.3.1 Determine the compacted density of the concrete ($\rho_c$) in accordance with Test Method Q484 and record the value to the nearest 0.01 t/m$^3$.
3.4 For each lot determine the assigned reference density of the concrete ($LRD_c$) in accordance with Test Method Q483 and record the value to the nearest 0.01 t/m$^3$.

4 Calculations
4.1 Calculate the relative compaction to the nearest 0.1% as follows:

$$RC_c = \frac{100\rho_c}{LRD_c}$$

where

$RC_c$ = relative compaction of concrete (%) 
$\rho_c$ = compacted density of concrete (t/m$^3$)
$LRD_c = \text{ assigned reference density of concrete (t/m}^3\text{)}$

4.2 Where a number of tests have been performed on a lot, calculate the minimum characteristic value of relative compaction as detailed in Test Method Q020.

5 Reporting

5.1 Report the relative compaction of concrete to the nearest 0.1%.

5.2 If required, report the minimum characteristic value of relative compaction as detailed in Test Method Q020.
Test Method Q483: Assignment of reference density for concrete

1 Source
This method applies the principles of Roads and Maritime Services QA Specification R83: Concrete pavement base to the assignment of a reference density for a concrete lot. It varies in using all available tests in each lot to establish a reference density.

2 Scope
This method sets out the procedure for assigning a reference value of density for a concrete lot and is applicable only to concrete pavements.

3 Procedure
The procedure shall be as follows:

3.1 Obtain all pairs of specimens sampled, manufactured and cured for the determination of the 28 day compressive strength of concrete and remove from curing at 7 days.

3.2 Test each specimen separately and determine the density as detailed in Test Method Q473.

3.3 Return each specimen to the curing environment at the completion of testing and no longer than 1 hour after their removal.

4 Calculations

4.1 For each pair of specimens calculate the mean density and if the difference in density between the pair of specimens is greater than 10% of the mean density of the pair, exclude the lower density from further calculations.

4.2 Using the remaining specimens calculate the mean of the density values. This value is the assigned reference density of the concrete lot ($LRD_c$).

5 Reporting
Report the following values and general information:

5.1 The assigned reference density to the nearest 0.01 t/m³.

5.2 Identification of the nominated mix or trial section.

5.3 Identification of the lot.

6 Notes on method
Control charts of the progressively assigned values may be plotted to assess whether there is drift in the values being used.
Test Method Q484: Compacted density of concrete - nuclear gauge

This test shall be performed in accordance with Test Method N06: Compacted Density of Concrete contained within the department's *Nuclear Gauge Testing Manual*.
Test Method Q485: Carbonation depth of concrete

1 Source
This method was developed in house using techniques evolved through internal departmental research investigations.

2 Scope
This method describes a procedure for determining the depth of carbonation in concrete using phenolphthalein indicator solution.

3 Apparatus
The following apparatus is required:

3.1 Spray bottle or paint brush.
3.2 Steel rule with 1 mm graduations.
3.3 Compression testing machine and Brazil jig (optional).

4 Reagents
4.1 Phenolphthalein indicator solution (Note 8.1).
   - Dissolve 1 g of phenolphthalein and 50 ml of ethanol in 50 ml of distilled water (proportionally larger quantities may be used if necessary).

5 Definitions
5.1 Carbonation is the term referring collectively to a number of natural processes causing neutralisation of concrete. The most significant process occurs when carbon dioxide in the atmosphere reacts with calcium hydroxide in the cement in the presence of moisture forming calcium carbonate. This results in a reduction in pH of the concrete and an increased potential for corrosion of steel reinforcement.

6 Procedure
The procedure shall be as follows:

6.1 Obtain a concrete core and determine its length (Note 8.2).
6.2 Place the specimen so that, in the case of a cylindrical specimen, it is resting on its side between the platens of the corresponding testing machine (that is, in a manner similar to that used in the Brazil or splitting test).
6.3 Apply a force without shock until the specimen fails diametrically. The objective is to cause a single fracture plane.
6.4 Remove the pieces of the specimen from the testing machine and place them so as to enable the reagent to be sprayed on the newly exposed surfaces of the specimen.
6.5 Ensure the newly exposed surfaces are dry. Paint or spray the newly exposed surfaces uniformly with the indicator solution. Areas of the newly exposed surfaces not subjected to carbonation will turn purple. Areas where carbonation of the concrete has occurred will not change colour.
6.6 Measure the depth of carbonation at three points to the nearest 1 mm, from the original external surface of the specimen to the border between the carbonated and un-carbonated areas (Note 8.2).

6.7 Calculate the average of the three depths and record as the depth of carbonation to the nearest 1 mm.

7 Reporting
The report shall include the following:

7.1 Identification of the specimen.

7.2 Carbonation depth or range of depths, to the nearest 1 mm.

7.3 Length of the specimen to the nearest 1 mm.

8 Notes on method

8.1 Before handling phenolphthalein indicator solution, the operator must consult the relevant Safety Data Sheet (SDS).

8.2 Samples other than concrete cores may be tested.

8.3 It will be evident from an inspection of the specimen, that one or more of the external surfaces formed part of the external surfaces of the structure from which the specimen was removed. It is from these surfaces that measurements of carbonation depth should be made. If the border between the two areas is approximately parallel to the outer surface record the average depth of carbonation. If the border is very uneven or diverges from the outer surface record the range of depths observed.
Materials Testing Manual

Part 10: Chemical
Test Method Q601: Amine value of bitumen anti-stripping agent

1 Source

This method is based on ASTM Test Method D2073-92: Total, Primary, Secondary and Tertiary Amine Values of Fatty Amines, Amidoamines and Diamines by Referee Potentiometric Method. It differs from the ASTM method in that it is restricted to the determination of total and tertiary amine values only and also includes minor procedural variations.

2 Scope

This method describes a procedure for the potentiometric determination of the total and tertiary amine values of amino type products used as bitumen anti-stripping agents. It is applicable to the measurement of total amine value in fatty amines, diamines and amidoamines and tertiary amine value in fatty amines and diamines. The total amine value is the number of milligrams of potassium hydroxide equivalent to the basicity of 1 g of sample. The tertiary amine value is the number of milligrams of potassium hydroxide equivalent to the tertiary amine basicity of 1 g of sample.

3 Apparatus

The following apparatus is required:

3.1 pH meter, equipped with a combination of pH electrode and millivolt scale and accurate and readable to 0.05 pH units and 1 mV.

3.2 Balance of suitable capacity, having a resolution of at least 0.0001 g and with a limit of performance within the range of ± 0.0005 g.

3.3 Balance of suitable capacity, having a resolution of at least 0.01 g and with a limit of performance within the range of ± 0.05 g.

3.4 Oven or furnace, thermostatically controlled at a temperature of 265 ± 5°C.

3.5 Oven, thermostatically controlled at a temperature of 120 ± 5°C.

3.6 Thermostatically controlled hotplate.

3.7 Microburette of 10 mL capacity, accurate and readable to 0.02 mL.

3.8 Burette of 50 mL capacity, accurate and readable to 0.1 mL.

3.9 Graduated pipettes of 10 mL and 25 mL capacity.

3.10 Volumetric flask of 2 L capacity.

3.11 Conical flasks of 250 mL capacity with a ground glass neck.

3.12 Measuring cylinder of 100 mL capacity.

3.13 Air condenser, 500 mm long tube with a ground glass cone and appropriate adaptor, if necessary, to allow it to fit the conical flasks.

3.14 Beakers of 250 mL and 2 L capacity.

3.15 Magnetic stirrer, equipped with a teflon coated stirring bar.

3.16 Glass filter funnel.

3.17 Desiccator.
4 **Materials**

The following materials are required:

4.1 Distilled water or equivalent (for example, reverse osmosis water).
4.2 Buffer solution(s), proprietary buffer solution(s) for calibrating the pH meter.

5 **Reagents**

The following reagents are required which shall be prepared using analytical reagent grade chemicals (Notes 10.1 and 10.2).

5.1 Acetic anhydride.
5.2 Chloroform.
5.3 Concentrated hydrochloric acid, 31.5% mass/mass.
5.4 Glacial acetic acid.
5.5 Isopropanol, 99%.
5.6 Methyl orange indicator.
5.7 Perchloric acid, 70% mass/mass.
5.8 Potassium hydrogen phthalate.
5.9 Hydrochloric acid solution
   - Add 100 mL of concentrated hydrochloric acid to 1000 mL of isopropanol and dilute with isopropanol to the mark in a 2 L volumetric flask.
5.10 Isopropanol solution
   - Add 5 mL of distilled water (or equivalent) to 95 mL of isopropanol.
5.11 Perchloric acid solution
   - Add 28.7 g of perchloric acid with stirring to 1000 mL of glacial acetic acid in a 2 L beaker. Slowly add 46.6 g of acetic anhydride with stirring.
   - Pour this solution into a 2 L volumetric flask and dilute to 2000 mL with glacial acetic acid.
   - Thoroughly mix the solution and allow to stand for 24 hours before standardising.

6 **Preparation of apparatus**

Calibrate the pH meter by means of the buffer solution(s), following the procedure recommended by the manufacturer.

7 **Procedure**

7.1 **Standardisation of hydrochloric acid solution**

Perform the following standardisation procedure in duplicate.

7.1.1 Dry sufficient sodium carbonate in an oven or furnace at a temperature of 265 ± 5°C for at least 30 minutes (Note 10.3).
7.1.2 Allow the sodium carbonate to cool to room temperature in a desiccator.
7.1.3 Weigh about 0.5 g of the dry sodium carbonate into a 250 mL conical flask and record the mass of sodium carbonate to the nearest 0.0001 g (mₐ).
7.1.4 Add 100 mL of distilled water to the flask and dissolve the sodium carbonate.

7.1.5 Add 1 mL of methyl orange indicator to the conical flask.

7.1.6 Fill the burette with hydrochloric acid solution.

7.1.7 Position the conical flask on a filter paper under the burette and, while constantly agitating the flask, titrate the hydrochloric acid solution to obtain an orange to red colour change.

7.1.8 Record the titre to the nearest 0.1 mL.

7.1.9 Repeat Steps 7.1.3 to 7.1.8 twice, average the three results and record this average to the nearest 0.1 mL ($V_1$).

7.2 Standardisation of perchloric acid solution

Perform the following standardisation procedure in duplicate.

7.2.1 Dry sufficient potassium hydrogen phthalate in an oven at a temperature of 120 ± 5ºC for at least two hours.

7.2.2 Allow the potassium hydrogen phthalate to cool to room temperature in a desiccator.

7.2.3 Weigh 0.31 to 0.39 g of the dry potassium hydrogen phthalate into a 250 mL beaker and record the mass of the potassium hydrogen phthalate to the nearest 0.0001 g ($m_2$).

7.2.4 Add 50 mL of glacial acetic acid by measuring cylinder to the beaker and gently warm the contents of the beaker on a hotplate to dissolve the potassium hydrogen phthalate.

7.2.5 Allow the solution to cool to room temperature, then wash down the inside of the beaker with a further 50 mL of glacial acetic acid.

7.2.6 Fill the microburette with perchloric acid solution.

7.2.7 Position the beaker on the magnetic stirrer under the microburette. Add a stirring bar to the beaker, immerse the electrode in the solution in the beaker and adjust the stirrer to obtain vigorous stirring without spattering.

7.2.8 Using the millivolt scale on the pH meter, titrate the solution potentiometrically. Record the potentiometric readings to the nearest 2 mV corresponding to each 1 mL increment in the titre with the exception that readings shall be taken at 0.1 mL increments as the end point (point of inflection) is approached.

7.2.9 Remove the pH electrode from the solution, rinse the electrode with distilled water and wipe it dry.

7.2.10 Plot the millivolt readings against the volume of perchloric acid solution and draw a best fit curve through the points. Determine the volume at the end point and record this value to the nearest 0.1 mL ($V_2$) (Note 10.4).

7.3 Total amine value

Perform the following procedure in duplicate.

7.3.1 Melt the sample, if necessary, and mix it thoroughly.

7.3.2 Weigh about 0.5 g of sample into a 250 mL beaker and record the mass of the sample to the nearest 0.0001 g ($m_3$).
7.3.3 Add 90 mL of chloroform and 10 mL of isopropanol solution to the beaker and boil the contents on a hotplate in the fume cupboard for approximately 1 minute. Remove the beaker from the hotplate and allow it to cool to room temperature.

7.3.4 Thoroughly rinse the microburette with two 5 mL portions of the hydrochloric acid solution, then fill it with the hydrochloric acid solution.

7.3.5 Position the beaker on the magnetic stirrer under the microburette. Add a stirring bar to the beaker, immerse the electrode in the solution in the beaker and adjust the stirrer to obtain vigorous stirring without spattering.

7.3.6 Using the millivolt scale on the pH meter, titrate the solution potentiometrically. Record the potentiometric readings to the nearest 1 mV corresponding to each 1 mL increment in the titre with the exception that readings shall be taken at 0.1 mL increments as the end point (point of inflection) is approached.

7.3.7 Remove the pH electrode from the solution, rinse the electrode with distilled water and wipe it dry.

7.3.8 Plot the millivolt readings against the volume of hydrochloric acid solution and draw a best fit curve through the points. Determine the volume at the end point and record this value to the nearest 0.02 mL ($V_{B}$) (Note 10.4).

7.4 Tertiary amine value

Perform the following procedure in duplicate.

7.4.1 Melt the sample, if necessary, and mix it thoroughly.

7.4.2 Weigh about 0.5 g of sample into a 250 mL beaker and record the mass of the sample to the nearest 0.0001 g ($m_4$).

7.4.3 Add to the flask 25 mL of acetic anhydride and 2 mL of glacial acetic acid.

7.4.4 Attach the air condenser to the flask and gently reflux the contents on a hotplate at a low heat setting such that the condensate rises only about 50 mm in the condenser. Allow refluxing to continue for 45 minutes.

7.4.5 Remove the flask from the hotplate and pour the contents into a 250 mL beaker.

7.4.6 Using 50 mL of glacial acetic acid, rinse the condenser and flask, ensuring all washings are added to the beaker.

7.4.7 Allow the solution to cool to room temperature.

7.4.8 Thoroughly rinse the microburette with two 5 mL portions of the perchloric acid solution, then fill it to the mark with perchloric acid solution.

7.4.9 Position the beaker on the magnetic stirrer under the microburette. Add a stirring bar to the beaker, immerse the electrode in the solute in the beaker and adjust the stirrer to obtain vigorous stirring without spattering.

7.4.10 Using the millivolt scale on the pH meter, titrate the solution potentiometrically. Record the potentiometric readings to the nearest 1 mV corresponding to each 1 mL increment in the titre with the exception that readings shall be taken at 0.1 mL increments as the end point (point of inflection) is approached.

7.4.11 Remove the pH electrode from the solution, rinse the electrode with distilled water and wipe it dry.
7.4.12 Plot the millivolt readings against the volume of hydrochloric acid solution and draw a best fit curve through the points. Determine the volume at the end point and record this value to the nearest 0.02 mL ($V_4$) (Note 10.4).

8 Calculations

8.1 Calculate the molarity of the hydrochloric acid solution as follows and average the duplicate results to the nearest 0.01 moles L$^{-1}$.

$$M_1 = \frac{1000 m_1}{52.99 V_1}$$

where

- $M_1$ = molarity of hydrochloric acid solution (moles L$^{-1}$)
- $m_1$ = mass of sodium carbonate (g)
- $V_1$ = average volume of titre (mL)

8.2 Calculate the molarity of the perchloric acid solution as follows and average the duplicate results to the nearest 0.01 moles L$^{-1}$.

$$M_2 = \frac{4.8967 m_2}{V_2}$$

where

- $M_2$ = molarity of perchloric acid solution (moles L$^{-1}$)
- $m_2$ = mass of potassium hydrogen phthalate (g)
- $V_2$ = volume of perchloric acid solution at the end point (mL)

8.3 Calculate the total amine value of the sample as follows and average the duplicate results to the nearest 1 mg.

$$A_{Tot.} = \frac{56.1 V_3 M_1}{m_3}$$

where

- $A_{Tot.}$ = total amine value (mg of potassium hydroxide)
- $V_3$ = volume of hydrochloric acid solution at the end point (mL)
- $M_1$ = molarity of hydrochloric acid solution (moles L$^{-1}$)
- $m_3$ = mass of sample (g)

8.4 Calculate the tertiary amine value of the sample as follows and average the duplicate results to the nearest 0.1 mg.

$$A_{Ter.} = \frac{56.1 V_4 M_2}{m_4}$$

where

- $A_{Ter.}$ = tertiary amine value (mg of potassium hydroxide)
- $V_4$ = volume of perchloric acid solution at the end point (mL)
\[ M_2 = \text{molarity of perchloric acid solution (moles L}^{-1}) \]
\[ m_4 = \text{mass of sample (g)} \]

9 **Reporting**

Report the following:

9.1 Total amine value to the nearest 5 mg.
9.2 Tertiary amine value to the nearest 0.5 mg.

10 **Notes on method**

10.1 Before handling chemicals and preparing reagents, the operator must consult the relevant Safety Data Sheet (SDS).

10.2 Unless otherwise indicated, all reagents are to conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.

10.3 When handling oven dried sodium carbonate it is important to be aware that anhydrous sodium carbonate is hygroscopic and exhibits a tendency to pass into the monohydrate state.

10.4 The end point is the mid-point of inflection on the titration curve.
Test Method Q603: Heat stability of bitumen anti-stripping agent

1 Source

This method was developed in-house using techniques evolved through internal departmental research investigations.

2 Scope

This method describes the procedure for determining the stability to heat treatment of a bitumen anti-stripping agent. It assesses the loss in effectiveness of the agent due to heating through measurement of binder aggregate adhesion using Test Method Q212C – Binder stripping value (immersion tray). The method is applicable to anti-stripping agents which are added directly to bituminous binders.

3 Apparatus

The following apparatus is required:

3.1 Test oven, thermostatically controlled at a temperature of 163 ± 1°C.
3.2 Preparation oven, thermostatically controlled at a temperature of 105 ± 5°C.
3.3 Sample containers, five metal containers of approximately 70 mm diameter and 250 mL volume, with one fitted with a tightly fitting level lid.
3.4 Sample lids, metal lids having a diameter of approximately 150 mm and a raised edge around the circumference (Note 8.1).
3.5 Water bath, maintained at a temperature of 40 ± 1°C.
3.6 Hotplate.
3.7 Balance, of suitable capacity, having a resolution of at least 0.01 g and with a limit of performance within the range of ± 0.05 g.

4 Materials

The following materials are required:

4.1 Aggregate, suitable aggregate of 20 mm nominal size (Note 8.2).
4.2 Bitumen, Class 170 bitumen complying with MRTS 17.
4.3 Cutter, bitumen cutter complying with MRTS 19.

5 Procedure

The procedure shall be as follows:

5.1 Aggregate preparation

Wash and dry at least 150 representative pieces of the dominant size fraction of the aggregate.

5.2 Calibration sample preparation and testing

Prepare four calibration samples covering a range of anti-stripping agent concentrations and test as follows (Note 8.3):

5.2.1 Heat at least 200 g of bitumen on the hotplate until pourable.
5.2.2 Select one of the anti-stripping agent concentrations and calculate the mass of agent required to produce this concentration in 100 to 140 g bitumen. Weigh the calculated mass into a sample container to the nearest 0.01 g.

5.2.3 Weigh the mass of bitumen required to produce the anti-stripping agent concentration into the sample container to the nearest 1 g.

5.2.4 Gently heat the contents of the sample container on the hotplate and stir vigorously for about 5 minutes.

5.2.5 Calculate the mass of cutter (to the nearest 0.1 g) required to produce a 7.5 percent by volume cutback bitumen as follows:

\[ M_c = \frac{7.5D_c M_B}{100D_B} \]

where

- \( M_c \) = mass of cutter (g)
- \( M_B \) = mass of bitumen (g)
- \( D_B \) = density of bitumen (t/m³)
- \( D_C \) = density of cutter (t/m³)

5.2.6 Add the mass of cutter calculated in Step 5.2.5 to the sample container with continuous stirring of the contents to achieve complete solution (Note 8.4).

5.2.7 Check the mass of the sample container and contents and if necessary add additional cutter to compensate for any cutter loss. Combine repeated additions of cutter with continuous stirring until the required mass of cutter in the sample (to the nearest 0.1 g) is obtained (Note 8.5).

5.2.8 Pour immediately 25.5 ± 2.0 g of the prepared sample from the sample container onto each of three lids. Spread the sample on each lid as quickly as possible to form a continuous and even film over the lid (Note 8.6).

5.2.9 Allow the three lids to cool to nearly room temperature and then immerse them to a depth of at least 25 mm in the water bath for at least 20 minutes.

5.2.10 Remove the lids from the water bath and then firmly press 10 pieces of aggregate into the binder of each lid. Return each lid to the water bath for a further 10 ± 1 minutes and then remove.

5.2.11 Select one of the lids and pull (by hand) each piece of aggregate in turn from the binder and examine for binder adhesion (Note 8.7).

5.2.12 Visually determine the quantity of binder retained on the underside of each piece of aggregate and score it on a scale of 0 to 10, with 10 being full cover. When all 10 pieces of aggregate have been examined, add the scores and record the total as percent.

5.2.13 Repeat Steps 5.2.11 and 5.2.12 for the remaining two lids.

5.2.14 Repeat Steps 5.2.2 to 5.2.13 for the three remaining anti-stripping agent concentrations.

5.3 Test sample preparation and testing

Prepare the test sample containing the specified anti-stripping agent concentration and test as follows (Note 8.8):

5.3.1 Heat at least 200 g of bitumen on the hotplate until pourable.
5.3.2 Calculate the mass of agent required to produce the specified anti-stripping concentration in 100 to 140 g bitumen and weigh the calculated mass into a sample container to the nearest 0.01 g.

5.3.3 Weigh the mass of bitumen required to produce the anti-stripping agent concentration into the sample container to the nearest 1 g.

5.3.4 Gently heat the contents of the sample container on the hotplate and stir vigorously for about 5 minutes.

5.3.5 Allow the sample container to cool to room temperature and then fit its lid.

5.3.6 Place the sample container in the test oven for 360 ± 5 minutes.

5.3.7 Remove the sample container from the test oven and allow to cool to room temperature.

5.3.8 Calculate the mass of cutter (to the nearest 0.1 g) required to produce a 7.5 percent by volume cutback bitumen as follows:

\[ M_C = \frac{7.5D_C M_B}{100D_B} \]

where

- \( M_C \) = mass of cutter (g)
- \( M_B \) = mass of bitumen (g)
- \( D_B \) = density of bitumen (t/m³)
- \( D_C \) = density of cutter (t/m³)

5.3.9 Remove the lid and gently heat the sample container on the hotplate until the contents are fluid.

5.3.10 Add the mass of cutter calculated in Step 5.3.8 to the sample container with continuous stirring of the contents to achieve complete solution (Note 8.4).

5.3.11 Check the mass of the sample container and contents and if necessary add additional cutter to compensate for any cutter loss. Combine repeated additions of cutter with continuous stirring until the required mass of cutter in the sample (to the nearest 0.1 g) is obtained (Note 8.5).

5.3.12 Repeat Steps 5.2.8 to 5.2.13.

6 Calculations

6.1 Stripping values

Calculate the stripping values for each set of three sample lid results as follows:

6.1.1 Record the total score obtained for each sample lid as the binder adhesion result.

6.1.2 Calculate the stripping result for each sample lid by subtraction of the binder adhesion result from 100.

6.1.3 If the difference between the stripping results of the three sample lids is less than 20 %, calculate the average of the three results and record the average as the stripping value to the nearest 1 %.
6.1.4 If the difference between the stripping results of the three sample lids exceeds 20 % but two of the results agree to within 10 %, calculate the average of these two results and record this average as the stripping value to the nearest 1 %.

6.1.5 If the difference between the stripping results of the three sample lids exceeds 20 % and no two results agree within 10 %, repeat the test.

6.2 Calibration samples

Plot the stripping values obtained for the four calibration samples against the respective anti-stripping agent concentrations and apply the best fit curve.

6.3 Test sample

6.3.1 Using the calibration curve obtained in Step 6.2, determine the effective anti-stripping agent concentration corresponding to the stripping value obtained for the test sample.

6.3.2 Calculate the heat stability of the test sample to the nearest 1 % as follows:

\[ S = \frac{100C_2}{C_1} \]

where

- \( S \) = heat stability (%)
- \( C_1 \) = specified anti-stripping agent concentration (%)
- \( C_2 \) = effective anti-stripping agent concentration (%) determined in Step 6.3.1.

7 Reporting

Report the heat stability of the sample to the nearest 1 %.

8 Notes on method

8.1 Press-on lids from 4 litre capacity tins have been found suitable.

8.2 A suitable aggregate is one which provides a wide range of bitumen stripping values over the selected range of anti-stripping agent concentration.

8.3 The anti-stripping agent concentrations selected for the calibration samples should include 0 % and that specified for the test sample. The remaining two concentrations should be selected between these two extremes at equidistant intervals.

8.4 If the contents have cooled so that thorough mixing is difficult, gentle warming of the contents is permitted.

8.5 It is important to reasonably ensure that the correct quantity of cutter is added to the binder. Varying quantities of cutter will lead to varying binder viscosities which have considerable influence on the stripping value obtained.

8.6 If the sample on the lid has cooled so that spreading of the sample to form a continuous film over the lid is difficult, minimal warming of the lid in the oven is permitted. However, under no circumstances shall a hotplate be used for this purpose.

8.7 Pieces of aggregate must be extracted evenly with a direct upward pull without any twisting or shoving motion. Where only collar or edge adhesion has taken place, care must be exercised so that the ductile binder retained at the edge of the aggregate does not contact or overlay the underside of the aggregate before assessment of stripping is made.
8.8 The specified anti-stripping agent concentration will normally be that concentration recommended for field use. However, where the heat stability of a number of anti-stripping agents is to be compared, the one specified concentration should be adopted for all such agents.
Test Method Q604: Pourability of a liquid bitumen anti-stripping agent

1 Source
This method was developed in-house using techniques evolved through internal departmental research investigations.

2 Scope
This method describes the procedure for determining the pourability of a liquid bitumen anti-stripping agent. It may be used to indicate how readily a liquid bitumen anti-stripping agent will pour from a supply container at low temperature.

3 Apparatus
The following apparatus is required:

3.1 Measuring cylinders, three unstoppered measuring cylinders of 25 mL capacity, graduated in 0.5 mL increments and conforming to AS 2163.
3.2 Receivers, two crow receivers of 100 mL capacity conforming to BS658.
3.3 Water bath, maintained at a temperature of 5 ± 0.5°C.
3.4 Thermometer, a partial immersion liquid in glass thermometer with a range of at least 0-10°C, graduated in subdivisions of 0.5°C or less, with an uncertainty of no more than 0.2°C (for example, ASTM 90C).
3.5 Retort stand, boss head and clamp.
3.6 Travelling side arm stop (as illustrated in Figure 1 and detailed in Figure 2).
3.7 45° set square or protractor.
3.8 Digital stopwatch.
3.9 Steel rule, of at least 300 mm length and accurate and readable to 1 mm.
3.10 Pipette, a pipette of 10 mL capacity.
3.11 Stirring rods, 2 glass stirring rods.

4 Procedure
Perform the following procedure:

4.1 Thoroughly mix the sample and add approximately 30 mL to each of two 25 mL measuring cylinders (that is, approximately 5 mL above the 25 mL mark).
4.2 Place the cylinders containing the samples into the water bath.
4.3 Stir the samples regularly with the stirring rods until they attain a temperature of 5 ± 0.5°C.
4.4 Assemble the clamp, travelling side arm stop, boss head, retort stand and remaining 25 mL measuring cylinder on a level bench as illustrated in Figure 1.
4.5 Adjust the cylinder location within the clamp so that the clamp is positioned near the base of the cylinder.
4.6 Loosen the grub screw and set the side of the measuring cylinder at 45° to the horizontal using the set square or protractor. Retighten the grub screw.
4.7 Check the angle to ensure that the measuring cylinder is at 45° to the horizontal when stopped by the travelling side arm stop. The cylinder is now in the pour position.

4.8 Return the cylinder to the vertical position and then adjust the cylinder within the clamp so that the 20 mL mark on the cylinder is level with the upper edge of the clamp.

4.9 Return the cylinder to the pour position. Adjust the boss head, travelling sidearm stop and clamp so that the lower edge of the cylinder mouth is 255 ± 5 mm above the bench. This is the height at which the apparatus is to be set during testing.

4.10 Position a 100 mL crow receiver on the bench in a suitable location to receive sample draining from the measuring cylinder.

4.11 Return the cylinder to the vertical position and remove the cylinder.

4.12 Remove any excess liquid above the 25 mL mark on each measuring cylinder in the water bath using the pipette.

4.13 Remove one of the measuring cylinders from the bath, quickly dry and clamp into position so that the 20 mL mark on the cylinder is level with the upper edge of the clamp.

4.14 Rapidly move the cylinder to the pour position and immediately start the stopwatch.

4.15 At the 5 second time increment, rapidly return the measuring cylinder to the vertical position, and then remove it from the clamp.

4.16 Record the volume of sample in the receiver \( (V_1) \) to the nearest 1 mL.

4.17 Position the second 100 mL crow receiver on the bench in a suitable location to receive sample draining from the measuring cylinder.

4.18 Repeat Steps 4.13 to 4.15 for the remaining measuring cylinder.

4.19 Record the volume of sample in the receiver \( (V_2) \) to the nearest 1 mL.

4.20 If the difference between \( V_1 \) and \( V_2 \) exceeds 4 mL, repeat the test.

5 Calculations

Calculate the pourability of the sample as follows:

\[ P = 2 \left( \frac{V_1 + V_2}{2} \right) \]

where

\[ P \] = pourability (%)

\[ V_1 \] = volume of sample drained in the first receiver (mL)

\[ V_2 \] = volume of sample drained in the second receiver (mL)

6 Reporting

Report the pourability of the sample to the nearest 1%.
Figure 1 - Pourability apparatus configuration
Figure 2 - Travelling side arm stop
Test Method Q605: Short term settlement of bitumen anti-stripping agent

1 Source
This method was developed in-house using techniques evolved through internal departmental investigations.

2 Scope
This method describes a procedure for determining the difference in the amine content between the upper and lower layers of a bitumen anti-stripping agent when it is allowed to settle under specified conditions.

3 Apparatus
The following apparatus is required:
3.1 Pipette of 25 mL capacity.
3.2 Syringe, hypodermic syringe of 5 mL capacity.
3.3 Needles, hypodermic needles of 18 gauge and of length 25 mm and 75 mm.
3.4 Phials, screw top pill phials having approximate dimensions of 75 mm height and 25 mm outside diameter.
3.5 Water bath, maintained at a temperature of 100ºC.
3.6 Beaker of 200 mL capacity.
3.7 Glass stirring rod.
3.8 Constant temperature environment, maintained at a temperature of 25 ± 3ºC.

4 Procedure
Perform the following procedure in duplicate.
4.1 Mix the sample in the supply container as thoroughly as possible by means of slow inversion (Note 7.1).
4.2 Place approximately 100 mL of the mixed sample into a 200 mL beaker. Heat the beaker and contents on the water bath until the sample becomes less viscous.
4.3 Thoroughly remix the heated sample in the beaker to produce a homogeneous mixture.
4.4 Pour the mixed sample into the phial to a height of about 60 mm and seal the phial.
4.5 Store the phial undisturbed in an upright position for 28 days at a temperature of 25 ± 3ºC.
4.6 Using the syringe and 25 mm needle, withdraw 1.0 mL of sample from the top 1.5 mm in the phial, taking care not to mix the contents of the phial.
4.7 Determine the total amine value of the 1.0 mL subsample in accordance with Test Method Q601.
4.8 Reduce the height of the contents of the phial to about 10 mm using the 25 mL pipette to withdraw sample from the top of the phial, taking care to ensure that no undue mixing of the sample occurs.
4.9 Warm the phial and remaining sample on the water bath until the viscosity of the sample is such that it can be thoroughly mixed with a glass stirring rod, to produce a homogeneous mixture.

4.10 Using a clean dry syringe and 75 mm needle, withdraw 1.0 mL of the sample in the phial.

4.11 Determine the total amine value of this 1.0 mL subsample in accordance with Test Method Q601.

5 Calculations

5.1 Calculate the settlement of the anti-stripping agent in each phial as follows:

\[
S = \frac{200 \times (A_2 - A_1)}{A_2 + A_1}
\]

where
- \( S \) = phial settlement value (%)
- \( A_1 \) = total amine value of the top of the subsample (mg of potassium hydroxide)
- \( A_2 \) = total amine value of the bottom of the subsample (mg of potassium hydroxide)

5.2 Calculate the average of the phial settlement values and record it as the settlement value for the sample.

6 Reporting

Report the settlement value to the nearest 0.5%.

7 Notes on method

7.1 Before handling bitumen anti-stripping agent the operator must consult the relevant Safety Data Sheet (SDS).
Test Method Q606: Estimation of component content within precoating agents

1 Source

This method was developed in-house using data gathered from internal departmental research investigations.

2 Scope

This method is predicated on an assumption that precoating agent components consist mostly of a carrier solvent (commonly diesel), bitumen and perhaps waste oil. The method describes the procedure for estimating the content of these primary components by calculation from data obtained from simulated distillation analysis on a sample of the precoating agent and, when applicable, on a sample of the waste oil component used as an ingredient within the precoating agent. The simulated distillation is based on ASTM D2887: Boiling Range Distillation of Petroleum Fractions by Gas Chromatography, but with extended ranges in boiling point distribution from below 55°C and up to 750°C.

3 Procedure

The procedure shall be as follows:

3.1 Obtain the boiling point distribution from the simulated distillation analysis of the precoating agent tested. From the distribution, determine the cumulative mass per cent distilled at 360°C \( (m_1) \) and the residual mass per cent distilling above 565°C \( (m_2) \) to the nearest 0.01%.

3.2 Where applicable, obtain the boiling point distribution from the simulation distillation analysis of the waste oil component tested. From this distribution, determine the cumulative mass per cent distilled at 360°C \( (m_3) \) and the residual mass per cent distilling above 565°C \( (m_4) \) to the nearest 0.01%.

4 Calculations

4.1 Calculate the percentage of waste oil within the precoating agent as follows:

\[
W = \frac{100(d - d - b - m_1)}{100d - b - m_2 - m_3 - m_4}
\]

where

\( W \) = estimated waste oil content in precoating agent (%) (Note 6.1)

\( d \) = fraction of carrier solvent presumed to distil below 360°C (Note 6.2)

\( b \) = fraction of bitumen presumed to distil above 565°C (Note 6.2)

\( m_1 \) = cumulative mass per cent of precoating agent distilled to 360°C (%)

\( m_2 \) = residual mass per cent of precoating agent distilling above 565°C (%)

\( m_3 \) = cumulative mass per cent of waste oil component distilled to 360°C (%)

\( m_4 \) = residual mass per cent of waste oil component distilling above 565°C (%)
4.2 Calculate the percentage of bitumen within the precoating agent as follows:

\[ B = \frac{100m_2 - Wm_4}{100b} \]

where

- \( B \) = estimated bitumen content in precoating agent (%)
- \( m_2 \) = residual mass per cent of precoating agent distilling above 565°C (%)
- \( W \) = estimated waste oil content in precoating agent (%) (Note 6.1)
- \( m_4 \) = residual mass per cent of waste oil component distilling above 565°C (%)
- \( b \) = fraction of bitumen presumed to distil above 565°C (Note 6.2)

4.3 Calculate the percentage of carrier solvent within the precoating agent as follows:

\[ D = \frac{100m_1 - Wm_3}{100d} \]

where

- \( D \) = estimated carrier solvent content in precoating agent (%)
- \( m_1 \) = cumulative mass per cent of precoating agent distilled to 360°C (%)
- \( W \) = estimated waste oil content in precoating agent (%) (Note 6.1)
- \( m_3 \) = cumulative mass per cent of waste oil component distilled to 360°C (%)
- \( d \) = fraction of carrier solvent presumed to distil below 360°C (Note 6.2)

5 Reporting

Report the estimation of the content of each component to the nearest 1%.

6 Notes on method

6.1 If calculated values for \( W \) are negative, set \( W \) at 0 to calculate \( B \) and \( D \) and then estimate the percentage of bitumen as \( \frac{100B}{B+D} \) and the percentage of carrier solvent as \( \frac{100D}{B+D} \).

6.2 Experimental values of \( d = 0.935 \) for diesel carrier solvent and \( b = 0.700 \) for bitumen have previously been determined. Where the nature or sources of these components are suspected to be different, an independent determination of their fractional distillation characteristics may be required.
Test Method Q607: Characterisation of waste oil component within precoating agents

1 Source
This method was developed in-house using data gathered from internal departmental research investigations.

2 Scope
This method provides calculation procedures for determining various characterising temperatures to describe the waste oil component proposed as an ingredient within a precoating agent. The method processes data obtained from simulated distillation analysis on a sample of the waste oil. The simulated distillation is based on ASTM D2887: Boiling Range Distillation of Petroleum Fractions by Gas Chromatography, but with extended ranges in boiling point distribution from below 55ºC and up to 750ºC.

3 Procedure
The procedure shall be as follows:

3.1 Obtain the boiling point distribution from the simulated distillation analysis of the waste oil sample tested. This distribution is in the form of:

\[\text{IBP, } T(x), \text{ FBP}\]

where

\[T(x) = \text{the temperatures (ºC) at which } x\% \text{ of waste oil has distilled and } x = 1, 2, 3, \ldots, 97, 98, 99.\]

\[\text{IBP = initial boiling point of waste oil (ºC), that is, } T(0)\]

\[\text{FBP = final boiling point of waste oil (ºC), that is, } T(100)\]

3.2 Where the termination temperature of the simulated distillation (750ºC) has not produced the FBP of the waste oil, it is necessary to estimate FBP by examining the sequence in a number of temperatures prior to 750ºC and incrementally progressing the sequence beyond 750ºC until \(T(100)\) is reached (Note 6.1).

3.3 Select class interval boundaries for the distribution in \(x\) increments of 5 to produce 20 class intervals of: IBP to \(T(5)\); \(T(5)\) to \(T(10)\); \ldots; \(T(90)\) to \(T(95)\); \(T(95)\) to FBP.

3.4 Determine temperature midpoints, \(T(y)\), for each of the class intervals where \(y = 2.5, 7.5, \ldots, 92.5, 97.5.\)

4 Calculations
4.1 Central characteristics

4.1.1 Record the median temperature from \(T(50)\).

4.1.2 Within the range of \(T(20)\) to \(T(80)\), calculate the temperature differences over the following spans:

\[T(25)\) to \(T(20); T(30)\) to \(T(25); \ldots; T(75)\) to \(T(70); T(80)\) to \(T(75).\)

4.1.3 Select the span with the minimum difference and record the average temperature of the span as the mode temperature (Note 6.2).
4.1.4 Calculate the mean temperature, $T(\bar{x})$, as follows:

$$T(\bar{x}) = \frac{\sum T(y)}{20}$$

where $y = 2.5, 7.5, ..., 92.5, 97.5$.

4.2 **Dispersion characteristics**

4.2.1 Calculate the standard deviation in temperature(s) as follows:

$$s = \sqrt{\frac{20 \sum T(y)^2 - (\sum T(y))^2}{380}}$$

where $y = 2.5, 7.5, ..., 92.5, 97.5$.

4.2.2 Calculate the mean deviation in temperature (d) as follows:

$$d = \frac{\sum |T(y) - T(\bar{x})|}{20}$$

where $|T(y) - T(\bar{x})| = \text{absolute difference between class interval midpoint and mean temperature}$

$y = 2.5, 7.5, ..., 92.5, 97.5$.

4.2.3 Calculate the quartile deviation in temperature (q) as follows:

$$q = \frac{T(75) - T(25)}{2}$$

4.2.4 Calculate the 10-90 percentile range in temperature (p) as follows:

$$p = T(90) - T(10)$$

5 **Reporting**

Report the following waste oil component characteristics to the nearest 0.1°C.

5.1 Median temperature.
5.2 Mode temperature.
5.3 Mean temperature.
5.4 Standard deviation in temperature.
5.5 Mean deviation in temperature.
5.6 Quartile deviation in temperature.
5.7 10-90 percentile range in temperature.
6 Notes on method

6.1 The sequence in temperatures is most appropriately discerned by examining a number of incremental differences (say eight) from \( \Delta T = T(x) - T(x-1) \), then anticipating the further differences which might apply for temperatures above 750°C until \( T(100) \) is attained.

6.2 Where the same minimum difference is found for adjacent spans, the average temperature across the adjacent spans is recorded as the mode.
Test Method Q631: Heavy metal content of glass beads

1 Source
This method was developed in-house and is based on Appendix A of the Australian Paint Approval Scheme (APAS) Specification 0042: Sampling and testing of glass beads for heavy metals. It allows for different combinations of reagents for sample digestion.

2 Scope
This method describes a framework for determining the heavy metal content of glass beads using complete dissolution and Inductively Coupled Plasma - Mass Spectrometry (ICP-MS) analysis. The heavy metal elements analysed are arsenic, antimony, lead, mercury, cadmium (as oxide) and chromium.

3 Apparatus
   The following apparatus is required:
   3.1 Appropriate apparatus to crush glass beads to a size smaller than 0.075 mm.
   3.2 Balance of suitable capacity, having a resolution of at least 0.001 g and with a limit of performance within the range of ± 0.005 g.
   3.3 Sieve, 0.075 mm complying with AS 1152.
   3.4 Assorted laboratory apparatus, suitable for acid digestion involving hydrofluoric acid.
   3.5 Fume cupboard.
   3.6 ICP-MS instrument.

4 Reagents
   The following reagents are required:
   4.1 Nitric acid, analytical reagent grade (Note 8.1).
   4.2 Perchloric acid, analytical reagent grade (Note 8.1).
   4.3 Hydrochloric acid, analytical reagent grade (Note 8.1).
   4.4 Hydrofluoric acid, analytical reagent grade (Note 8.1).
   4.5 Deionised water, having a resistivity of no less than 18 Mohm.cm.

5 Procedure
   The procedure shall be as follows:
   5.1 Crush a representative sample of the glass beads to pass a 0.075 mm sieve.
   5.2 Obtain a 0.250 g representative portion of the passing 0.075 mm material.
   5.3 Completely digest the glass beads portion using an appropriate combination of perchloric, nitric, hydrochloric and hydrofluoric acids and associated laboratory techniques.
   5.4 Analyse the solution containing the digested glass beads for arsenic, antimony, lead, mercury, cadmium and chromium content using ICP-MS.
6 Calculations

Calculate the concentration of each of the heavy metals of arsenic, antimony, lead, mercury, cadmium (as oxide) and chromium expressed in mg of the heavy metal per kg of the original sample.

7 Reporting

Report the concentration of the following to the nearest 1 mg/kg:

7.1 Arsenic (As).
7.2 Antimony (Sb).
7.3 Lead (Pb).
7.4 Mercury (Hg).
7.5 Cadmium (as oxide) (CdO).
7.6 Chromium (hexa-valent) (Cr₆⁺).

8 Notes on method

8.1 Before handling nitric, perchloric, hydrochloric or hydrofluoric acids, the operator must consult the relevant Safety Data Sheet (SDS).
Materials Testing Manual

Part 11: Pavements
Test Method Q704: Skid resistance - portable pendulum

1 Source
This method applies the principles of AS 1141.42: Pendulum friction test. It differs from this standard by:

a) performing testing in the field and correcting values for measured surface temperature
b) using the 75 mm wide slider for all testing
c) correcting the skid resistance value to a test temperature of 30°C.

2 Scope
This method describes the procedure for the determination of the resistance of a road surface to skidding. The apparatus measures the frictional resistance between a rubber slider mounted on the end of a pendulum arm and the road surface.

3 Apparatus
Where appropriate, the working tolerances of particular apparatus are contained in Tables 1 and 2.

3.1 Pendulum friction tester, comprising a tester and auxiliary scale constructed in accordance with details available from the Australian Road Research Board, Melbourne. An example is shown in AS 1141.42 Figure 1. All bearings and working parts of the instrument shall be enclosed as far as possible and all materials used shall be suitably treated to prevent corrosion under wet conditions. The tester shall be calibrated to ensure compliance with the following requirements at intervals not exceeding two years. The tester shall incorporate the following:

3.1.1 Spring-loaded rubber slider mounted on the end of a pendulum so that the sliding edge is 515 mm from the axis of suspension. The sliding edge shall be square, clean cut and free from contamination. The rubber slider shall be 76.0 mm long, 25.4 mm wide and 6.4 mm thick. The slider shall be rigidly backed and, together with the rigid backing plate shall have a total mass of 35 g.

The slider material shall be Slider 55 (IRHD 55) and complying with the resilience requirements of Table 2. Handling of the surface of a rubber slider shall be avoided and, when not in use, sliders shall be stored in the dark at a temperature between 10°C and 25°C. A slider shall be discarded when:

a) more than 12 months old from the date stamped on the slider, or
b) it does not comply with the requirements of Table 2, or
c) the sliding edges become burred or rounded or have a chamfer greater than 4 mm. One slider edge can normally be used for at least 500 swings. The chamfer measurement shall be made on the most representative portion of the trailing edge.

The mass of the pendulum including the slider shall be 1.50 kg with the centre of gravity lying on the axis of the pendulum at a distance of 410 mm from the centre of suspension. The slider shall be mounted on an axis set at an angle of 25° to the horizontal when the pendulum is at the lowest point of its swing, so that only the rear edge of the slider contacts the test surface. The slider can turn about its axis without obstruction to follow unevenness of the surface. It
Test Method Q704: Skid resistance – portable pendulum

shall be spring loaded against the test surface and the nominal static force on the slider is set by the calibration procedure.

3.1.2 Means for levelling the instrument.

3.1.3 Means for raising and lowering the axis of suspension of the pendulum so that the slider can:
   a) swing clear of the road surface
   b) be set to slide over a fixed length of the road surface.

3.1.4 Means for holding and releasing the pendulum so that it falls freely from a horizontal position.

3.1.5 Pointer balanced about the axis of suspension, indicating the position of the pendulum throughout its forward swing and moving over the circular scale attached to the instrument. The mass of the pointer, excluding felt friction washers, shall be not more than 85 g. The friction in the pointer mechanism shall be adjustable so that, with the pendulum swinging freely from a horizontal position, the outward tip of the pointer may be brought to rest on the forward swing of the pendulum at a point 10 mm below the horizontal, the point corresponding to the zero position on the attached circular scale.

3.2 Bannister brush.

3.3 Spray bottle and water container.

3.4 Temperature measurement device covering the range of 0°C to 60°C and graduated to 1°C and an uncertainty of no more than 0.5°C. A thermocouple or infra-red thermometer has been found to be suitable.

4 Materials

The following materials are required:

4.1 Potable water.

4.2 Suitable insulation material for temperature measurements (for example, polystyrene block or fine sand).

5 Procedure

The procedure shall be as follows:

5.1 Determine the test location (Note 8.1).

5.2 Set the instrument in line with the traffic flow so that the pendulum will swing in the same direction as the traffic flow.

5.3 Clear the road surface of loose materials by brushing briskly with a bannister brush.

5.4 Place the temperature measurement device on the road surface adjacent to the test site under the insulating material.

5.5 Set the base level, by means of the levelling device and the three levelling screws on the base frame. Secure a rubber slider on its pivot ensuring the correct positioning of the two washers and spring.

5.6 Raise the axis of suspension of the pendulum so that the arm swings freely. Adjust the friction rings in the pointer mechanism so that, when the pendulum arm and pointer are released from the right-hand horizontal position, the pointer will zero repeatedly (Note 8.2).
5.7 Adjust the height of the axis of suspension of the pendulum by means of the rack and pinion so that the whole trailing edge of the slider is in contact with the test surface for the set length while traversing the test surface. This length is set by aligning the trailing edge of the slider against the marks on the scale supplied with the friction tester. When the apparatus has been set correctly, the sliding length should be between 125 and 127 mm on the scale. The outer marks are 127 mm apart and the inner one each indicates the 2 mm tolerance allowed.

5.8 Using the spray bottle, thoroughly wet the rubber slider and road surface with water.

5.9 Return the pendulum to its horizontal position and move the pointer against its stop. Release the pendulum and pointer from the horizontal position, allowing them to swing over the test surface. As the pendulum and slider falls back from its peak after traversing the test surface, catch it before the slider again makes contact and note the reading indicated by the pointer (Note 8.3).

5.10 Lift the slider using the lifting lever keeping it clear of the road surface and return the pendulum and pointer to the horizontal position and lock in the release position.

5.11 Repeat Steps 5.7 to 5.10 four times and record the mean of the five readings provided they do not differ by more than three units. If the range exceeds three units, repeat Steps 5.7 to 5.10 until three successive readings are the same and record this value.

5.12 Raise the head of the pendulum so that the pendulum arm swings clear of the surface and check the free swing for zero error. If the free swing does not zero, then adjust the pendulum as detailed in Step 5.6 and repeat the testing at the location as detailed in Steps 5.7 to 5.12. If the check of the free swing for zero error fails again, remove the pendulum from service and partially or fully recalibrate the pendulum.

5.13 Record the test surface temperature.

6 Calculations

6.1 Calculate the mean wet skid resistance value at 30°C as follows:

\[ SRV_{30} = \frac{SRV_t}{1-0.00525(t-30)} \]

where

- \( SRV_{30} \) = mean wet skid resistance value corrected to 30°C
- \( SRV_t \) = mean skid resistance value at the test temperature
- \( t \) = test surface temperature (°C)

7 Reporting

Report the following values and general information:

7.1 The mean wet skid resistance value (SRV30) corrected to 30°C to the nearest whole number (Note 8.4).

7.2 The description of surface being tested.

8 Notes on method

8.1 The location of the test site may be variable according to the investigation being conducted. However, for routine testing, readings are usually taken along a wheel path.
8.2 Adjustment of the friction rings is necessary as the testing is carried out under varying conditions of temperature and wind velocity.

8.3 If the slider is allowed to hit the test surface on the return swing it can be damaged and effect the zero adjustment.

8.4 The skid resistance of a dry surface may also be measured using the same method except that water is not applied to either the rubber slider or road surface. However, the appropriate correction for temperature is not known.

Table 1 - Dimensions and tolerances for pendulum friction tester

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Dimension</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pendulum friction tester</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance of sliding edge from axis of suspension (mm)</td>
<td>515</td>
<td>± 2</td>
</tr>
<tr>
<td>Length of rubber slider (mm)</td>
<td>75.0</td>
<td>± 1.0</td>
</tr>
<tr>
<td>Width of rubber slider (mm)</td>
<td>24.0</td>
<td>± 1.0</td>
</tr>
<tr>
<td>Thickness of rubber slider (mm)</td>
<td>6.0</td>
<td>± 0.5</td>
</tr>
<tr>
<td>Mass of rubber slider and backing plate (g)</td>
<td>35</td>
<td>± 2</td>
</tr>
<tr>
<td>Mass of slider and pendulum (kg)</td>
<td>1.50</td>
<td>± 0.03</td>
</tr>
<tr>
<td>Distance from centre of gravity of pendulum to the centre of suspension (mm)</td>
<td>410</td>
<td>± 5</td>
</tr>
<tr>
<td>Angle of slider to horizontal at lowest point of swing (°)</td>
<td>25</td>
<td>± 1</td>
</tr>
<tr>
<td>Mass of pointer (g)</td>
<td>85</td>
<td>maximum</td>
</tr>
</tbody>
</table>

Table 2 - Properties of rubber slider

<table>
<thead>
<tr>
<th>Property</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Resilience (%)*</td>
<td>44 to 49</td>
</tr>
<tr>
<td>Hardness (IRHD)+</td>
<td>55 ± 5</td>
</tr>
</tbody>
</table>

* Lupke rebound test in accordance with BS903: Part A8.
+ International rubber hardness degrees in accordance with BS903: Part A26.
Test Method Q705: Surface texture depth - sand patch

This test shall be performed in accordance with Austroads Test Method AG:PT/T250: Modified surface texture depth (Pestle method), except that sample site selection may also be in accordance with Test Method Q050: Selection of sampling and test locations.

Superseded
Test Method Q705B: Surface texture depth - silicone putty

1 Source

This method was developed in house using information obtained from the following technical references:


2 Scope

This method covers the measurement of the surface texture depth of a pavement surface using the silicone putty technique. This method is based on a procedure developed by the Texas Transportation Institute (1970 & 1977) and is particularly suited to measurement of texture depths of less than 0.5 mm.

The method involves placement of a known volume of silicone putty on the pavement surface and pressing the putty into the surface texture using a recessed plate. The average diameter of the flattened putty is recorded. The recess is circular with a depth of 1.587 mm (1/16 inch). The diameter of the recess is such that the volume of putty will completely fill it if the surface has zero texture. A decrease in diameter of the deformed putty, relative to the recess diameter, is related to an increase in texture depth. The texture depth determined by this method is the average height of the volume of putty that has filled the texture as related to the circular area covered.

The primary reference test for volumetric texture depth determination is still Q705 (2010). This is a supplementary test method for use on low textured surfaces and other situations where the traditional sand patch test is unsuited. For texture depths greater than 0.5 mm, this method has been found to correlate well with the traditional sand patch test TMR (2011).

3 Apparatus

The following apparatus is required:

3.1 A test plate either 160 or 200 mm square by 25 mm thick of flat acrylic plastic, with a centrally machined 101.6 or 143.42 mm (respectively) diameter by 1.578 mm deep recess on one side (Note 8.1).
- 25 kg surcharge weight.
- Soft hand brush.
- 500 mL spray bottle for application of putty release agent.
- 150 mm or greater steel ruler, graduated in mm, for measuring flattened putty diameter.
- A metal knife, spatula of paint scraper (for separation of the plate from the pavement surface at the end of the test).
3.7 Suitable containers for storage of premeasured putty quantities for the test (for example, small takeaway plastic containers).

4 Materials

The following materials are required:

4.1 A dental grade, skin safe fast curing two component Flexible Silicone Impression Putty with a specific gravity of 1.44. The quantities required for a test are 12.82 or 25.64 ml depending on the size of the plate to be used. The two parts should be pre-measured off site and stored in the small containers for transport to the test site.

4.2 Dilute solution of domestic detergent (for example, dishwashing liquid) for use as a mould release agent.

5 Procedure

The procedure shall be as follows:

5.1 Select a sample location as detailed in Test Method Q050.

5.2 Clean the surface to be tested by sweeping using the soft hand brush.

5.3 Spray the surface to be tested with the dilute solution of detergent.

5.4 Select the plate size and corresponding putty volume to be used for the test. The small plate and 12.82 mL putty volume should be selected for fine textured surfaces while the large plate and 25.64 mL putty volume is preferred for coarse textured surfaces.

5.5 Combine the two parts of the pre measured silicone putty together, mix by kneading and form into an approximate sphere.

5.6 Place the sphere of putty on the pavement surface.

5.7 Centre the recess of the test plate over the putty and press the plate down in firm contact with the pavement surface. Use of the 25 kg weight on the test plate for 1 minute is sufficient to achieve this contact.

5.8 After 1 - 2 minutes, remove the weight and the test plate from the pavement surface. The flattened silicone putty should remain on the pavement surface.

5.9 Measure the diameter of the flattened putty at 4 approximately equally spaced locations to the nearest 1 mm and record the results.

5.10 After 5 minutes, the flattened silicone putty should have cured sufficiently to be removed intact from the pavement surface.

6 Calculations

Calculate as follows:

6.1 Calculate the average flattened putty diameter to the nearest 1 mm.

6.2 Calculate the surface texture depth as follows:

\[
STD = \frac{4V \times 1000}{\pi D^3} - 1.587
\]

where

- STD = surface texture depth (mm)
- V = proportion of the aggregate component in the mix design (%)

Superseded
D = average diameter of flattened putty (mm)

7 Reporting

Report the surface texture depth to the nearest 0.1 mm.

8 Notes on method

8.1 Before the apparatus is used for field measurements, the standard calibration procedure shall be followed in the laboratory, using a flat sheet of glass as a surface with zero texture depth. If the putty is measured out correctly, it should completely fill the test plate recess.
Test Method Q706: Ball penetration of road surface

This test shall be performed in accordance with Austroads AG:PT/T251: Ball penetration test.
Test Method Q707A: Permeability of road surfacing and granular materials – even flow field permeameter

1 Source

This method was developed in-house using techniques evolved through internal departmental research investigations (Waters T.J., “Permeability of Road Surfacing and Granular Materials (Evenflow Field Permeameter)”, Report TT363, 2001).

2 Scope

This method describes the procedure for the determination of the permeability of pavement materials using the Evenflow Field Permeameter. It is applicable to bituminous materials (for example sprayed seal, asphalt) and granular materials (where the surface is reasonably flat and well compacted) having permeability values within the range 0.04 to 1500 µm/s. The guidelines included for categorising permeability values were developed specifically for asphalt, although they do have application to other materials.

3 Apparatus

The following apparatus is required:

3.1 Field permeameter, consisting of an inverted clear plastic conical funnel attached to a rigid plastic base plate as follows (Figure 1):

3.1.1 The base plate (Figure 2) shall have a diameter of about 200 mm and a thickness of about 20 mm. It shall contain a centrally located circular hole of diameter 100 ± 1 mm. A circular groove shall be formed around the hole in the top surface of the base plate to locate the top edge of the inverted funnel centrally over the hole. The top surface of the base plate shall extend beyond the bottom surface by about 10 mm to enhance removal of the base plate from the pavement at the completion of the test.

3.1.2 The funnel shall have a top internal diameter of about 150 mm and a height of about 230 mm. The stem of the funnel shall have an external diameter of about 14 mm and an internal diameter of about 12 mm.

3.1.3 With the inverted funnel inserted into the groove on the base plate, silicone sealant shall be applied externally over the join between the funnel and the base plate to secure the funnel. The funnel shall then be marked at heights of 100 mm, 150 mm and 200 mm above the bottom of the base plate.

3.2 Small funnel, with a top internal diameter of about 65 mm and a ribbed stem to provide an air gap when fitted into the permeameter funnel. The length of the stem shall be reduced as required so that, when it is positioned in the permeameter funnel, the bottom of its stem is approximately 10 mm above the 200 mm mark on the stem of the permeameter funnel.

3.3 Annular template, of diameter 190 mm and containing a centrally located hole of 110 mm diameter (bituminous materials only).

3.4 Annular restraining weight, of mass about 4 kg and of suitable dimensions to allow it to be positioned over the permeameter funnel to rest on the base plate.

3.5 Stop watch or other suitable timing device readable to 0.1 s.

3.6 Measuring cylinder, plastic measuring cylinder of 100 mL capacity.

3.7 Beakers, plastic beakers of appropriate capacity (for example 100 mL, 600 mL and 1000 mL).
3.8 Water container, having a capacity of at least 10 litres.
3.9 Spatula, to aid application of the silicone sealant to the pavement or base of the permeameter.
3.10 Marking crayon.
3.11 Assorted implements, for cleaning of the pavement before and after testing (for example wire brush, broom, paint scraper).

4 Materials

The following materials are required:
4.1 Silicone sealant, neutral cure (Note 8.1).
4.2 Potable water.

5 Procedure

The procedure shall be as follows:
5.1 Remove any loose material from the pavement.
5.2 Attach the permeameter to the pavement using the appropriate method as follows:
5.2.1 Granular Material (Note 8.2)
   a) Apply silicone sealant to the base of the permeameter to a thickness of about 2 mm.
   b) Press the permeameter firmly onto the pavement.
5.2.2 Sprayed Seal/Asphalt Material
   a) Place the annular template on the pavement and use the crayon to mark two concentric circles of diameter 100 mm and 200 mm (Note 8.3).
   b) Apply silicone sealant to the pavement between the two concentric circles and spread it out evenly to a final thickness of about 2 mm using a spatula (Note 8.4).
   c) Align the base plate with the 200 mm diameter circle and press the permeameter firmly onto the pavement.
5.3 Position the restraining weight onto the base plate.
5.4 Place the small funnel into the stem of the permeameter funnel.
5.5 Using a beaker of appropriate capacity, pour water into the small funnel to fill the permeameter funnel to the 100 mm mark.
5.6 Check for leaks at the base of the permeameter. If any leakage is observed, caulk the area with additional silicone sealant (Note 8.5).
5.7 Continue adding water to the permeameter to maintain the water level above the 100 mm mark for 5 minutes or until 600 mL of water has passed through the pavement.
5.8 Immediately add additional water as required to raise the water level to just above the 200 mm mark. Discontinue the addition of water and record the time taken for the water level to drop from the 200 mm mark to the 150 mm mark to the nearest 0.1 seconds.
5.9 If the time recorded in Step 5.8 exceeds 2 seconds, use the falling head method. Otherwise, use the constant head method. The relevant method shall be as follows:

5.9.1 Falling head method

Repeat Step 5.8 twice.

5.9.2 Constant head method

a) Allow the water level in the permeameter funnel to fall to the 100 mm mark, start the timer and then progressively pour 100 mL of water from the measuring cylinder into the funnel at a rate which maintains the water level in the permeameter funnel at the 100 mm mark.

b) Record the time in seconds to transfer 100 mL of water to the permeameter funnel to the nearest 0.1 seconds.

c) Add additional water as required to raise the water level in the permeameter above the 100 mL mark.

d) Repeat Steps 5.9.2 a) to c).

e) Repeat Steps 5.9.2 a) to b).

5.10 Remove the silicone sealant from the base of the permeameter and the bulk of the silicone sealant from the pavement.

6 Calculations

6.1 Falling head method

6.1.1 Calculate the average of the three time measurements (t).

6.1.2 Calculate the volume of the stem of the permeameter funnel between the 150 mm and 200 mm marks as follows (Note 8.6):

\[ V = \frac{\pi D^2}{80} \]

where

- \( V \) = volume of stem between 150 mm and 200 mm marks (mL)
- \( D \) = internal diameter of stem at 175 mm mark (mm)

6.1.3 Calculate the permeability as follows:

\[ k = \frac{25.5V}{t} \]

where

- \( k \) = permeability (µm/s)
- \( V \) = volume of stem between 150 mm and 200 mm marks (mL)
- \( t \) = average time (s)

6.2 Constant head method

6.2.1 Calculate the average of the three time measurements (t).
6.2.2 Calculate the permeability as follows:

\[ k = \frac{3819}{t} \]

where \( k \) = permeability (µm/s)
\( t \) = average time (s)

7 Reporting

Report the following values and general information:

7.1 Test location including a longitudinal (chainage) and a lateral (offset) reference.
7.2 Test site description including pavement type and surface condition.
7.3 Permeability to three significant figures (µm/s).
7.4 Permeability category and description (Table 1).

8 Notes on method

8.1 Before handling the silicone sealant, the operator must consult the relevant Safety Data Sheet (SDS).
8.2 For granular materials, trial runs may be necessary to ensure that there is sufficient silicone sealant to effectively seal the permeameter without contaminating the exposed surface with an excess of sealant. It is desirable to keep the diameter of the exposed surface as close as possible to 100 mm.
8.3 The dimensions of the annular template allow for a 5 mm gap between the line marked by the crayon and the edge of the template. If necessary, the marking technique should be adjusted to ensure that the internal diameter of the smaller circle is 100 mm.
8.4 The sealant should be applied in a manner which spreads the sealant to, but not inside, the 100 mm diameter circle when the permeameter is pressed into position on the pavement.
8.5 It is normal for water to escape through the pavement surface at the outside edge of the base plate and this does not constitute leakage.
8.6 Alternatively, the stem end of the permeameter funnel can be stoppered, the permeameter inverted and water added to the 200 mm mark. The volume of water between the 200 mm and 150 mm marks can then be measured directly to the nearest 0.1 mL using a burette.

### Table 1 – Permeability category and description

<table>
<thead>
<tr>
<th>Permeability (µm/s)</th>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.01 - 0.10</td>
<td>A1</td>
<td>Very low permeability</td>
</tr>
<tr>
<td>0.11 - 1.00</td>
<td>A2</td>
<td>Low permeability</td>
</tr>
<tr>
<td>1.01 – 10.0</td>
<td>B</td>
<td>Moderately permeable</td>
</tr>
<tr>
<td>10.1 - 100</td>
<td>C</td>
<td>Permeable</td>
</tr>
<tr>
<td>101 - 1000</td>
<td>D</td>
<td>Moderately free draining</td>
</tr>
<tr>
<td>1001 - 10000</td>
<td>E</td>
<td>Free draining</td>
</tr>
</tbody>
</table>
Figure 1 – Evenflow field permeameter
Figure 2 – Plastic base plate
Test Method Q707B: Permeability of road surfacing and granular materials – rapid flow field permeameter

1 Source

This method was developed in-house using techniques evolved through internal departmental research investigations (Waters, T.J., “Permeability of Road Surface Materials Using the Rapidflow Field Permeameter”, Report TT305, 1999).

2 Scope

This method describes the procedure for the determination of the permeability of pavement materials using the Rapid Flow Field Permeameter. It is applicable to bituminous materials (for example sprayed seal, asphalt) and granular materials (where the surface is reasonably flat and well compacted) having permeability values within the range 10 to 5000 mm/s.

3 Apparatus

The following apparatus is required:

3.1 Field permeameter (Figure 1), consisting of a cylinder of clear rigid plastic (for example Perspex) attached to a rigid plastic base plate as follows:

3.1.1 The base plate (Figure 2) shall have a diameter of about 200 mm and a thickness of about 20 mm. It shall contain a centrally located circular hole of diameter 100 ± 1 mm. A circular groove shall be formed around the hole in the top surface of the base plate to locate the bottom of the cylinder centrally around the hole. The top surface of the base plate shall extend beyond the bottom surface by about 10 mm to enhance removal of the base plate from the pavement at the completion of the test.

3.1.2 The cylinder shall have a height of about 215 mm, an internal diameter of about 145 mm and an outside diameter of about 152 mm.

3.1.3 With the bottom of the cylinder inserted in the groove on the base plate, silicone sealant shall be applied externally over the join between the cylinder and the base plate. The cylinder shall then be marked with etched lines at heights of 165 mm and 185 mm above the bottom of the base plate. The top of the cylinder shall be about 225 mm above the bottom of the base plate (the base plate accounts for approximately 10 mm).

3.2 Annular template, of diameter 190 mm and containing a centrally located hole of 110 mm diameter (bituminous materials only).

3.3 Stop watch or other suitable timing device readable to 0.1 seconds.

3.4 Containers, of 10 L and 1 L capacity and fitted with a pouring lip.

3.5 Water container, having a capacity of at least 20 L.

3.6 Spatula, to aid application of the silicone sealant to the pavement or base of the permeameter.

3.7 Marking crayon.

3.8 Assorted implements, for cleaning of the pavement before and after testing (for example wire brush, broom, paint scraper).
4 Materials
The following materials are required:

4.1 Silicone sealant, neutral cure (Note 8.1).
4.2 Potable water.

5 Procedure
The procedure shall be as follows:

5.1 Remove any loose material from the pavement.

5.2 Attach the permeameter to the pavement using the appropriate method as follows:

5.2.1 Granular Material (Note 8.2)
   a) Apply silicone sealant to the base of the permeameter to a thickness of about 2 mm.
   b) Press the permeameter firmly onto the pavement.

5.2.2 Sprayed Seal/Asphalt Material
   a) Place the annular template on the pavement and use the crayon to mark two concentric circles of diameter 100 mm and 200 mm (Note 8.3).
   b) Apply silicone sealant to the pavement between the two concentric circles and spread it out evenly to a final thickness of about 2 mm using a spatula (Note 8.4).
   c) Align the base plate with the 200 mm diameter circle and press the permeameter firmly onto the pavement.

5.3 Using the containers as appropriate, pour water into the cylinder to fill it to the 165 mm mark.

5.4 Check for leaks at the base of the permeameter. If any leakage is observed, caulk the area with additional silicone sealant (Note 8.5).

5.5 Continue adding water to the permeameter to maintain the water level at the 165 mm mark for 5 minutes or until 600 mL of water has passed through the pavement.

5.6 Immediately add additional water as required to raise the water level to the 185 mm mark. Discontinue the addition of water and record the time taken for the water level to drop from the 185 mm mark to the 165 mm mark to the nearest 0.1 seconds.

5.7 Repeat Step 5.6 twice.

5.8 Remove the silicone sealant from the base of the permeameter and the bulk of the silicone sealant from the pavement.

6 Calculations
6.1 Calculate the average of the three time measurements (t).

6.2 Calculate the volume of the cylinder between 165 mm and 185 mm marks as follows:

\[ V = \frac{\pi D^2}{200} \]

where \( V \) = volume of cylinder between 165 mm and 185 mm marks (mL),

\( D \) = internal diameter of the cylinder (mm)
6.2.1 Calculate the permeability as follows:

\[ k = \frac{25.5V}{t} \]

where

\( k \) = permeability (µm/s)

\( V \) = volume of cylinder between 165 mm and 185 mm marks (mL)

\( t \) = average time (s)

7 Reporting

Report the following values and general information:

7.1 Test location including a longitudinal (chainage) and a lateral (offset) reference.

7.2 Test site description including pavement type and surface condition.

7.3 Permeability to three significant figures (µm/s).

7.4 Permeability category and description (Table 1).

8 Notes on method

8.1 Before handling the silicone sealant, the operator must consult the relevant Safety Data Sheet (SDS).

8.2 For granular materials, trial runs may be necessary to ensure that there is sufficient silicone sealant to effectively seal the permeameter without contaminating the exposed surface with an excess of sealant. It is desirable to keep the diameter of the exposed surface as close as possible to 100 mm.

8.3 The dimensions of the annular template allow for a 5 mm gap between the line marked by the crayon and the edge of the template. If necessary, the marking technique should be adjusted to ensure that the internal diameter of the smaller circle is 100 mm.

8.4 The sealant should be applied in a manner which spreads the sealant to, but not inside, the 100 mm diameter circle when the permeameter is pressed into position on the pavement.

8.5 It is normal for water to escape through the pavement surface at the outside edge of the base plate and this does not constitute leakage.

Table 1 – Permeability category and description

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<td>E</td>
<td>Free draining</td>
</tr>
</tbody>
</table>
Figure 1 – Rapid flow field permeameter
Figure 2 – Plastic base plate
Test Method Q708B: Road roughness – surface evenness - two laser profilometer

1 Source

This method was developed in-house using information obtained from the following technical references:


2 Scope

This test method defines the procedure for measuring the road roughness or surface evenness of road pavements, for construction compliance testing. The roughness is determined from direct measurement of the longitudinal profile in each wheel path using a vehicle-mounted inertial laser based non-contact device (that is, a two laser Profilometer).

The roughness measurement is expressed in terms of International Roughness Index (IRI). This index is obtained by quarter-car simulation at a set speed of 80 km/h using standardised suspension characteristics over a longitudinal profile.

The single roughness measurement produced by this method is the lane IRI, using quarter-car simulation of the average of the two wheel path profiles, of a test lot of road. Conversion of IRI to equivalent NAASRA Roughness Meter counts is included. A test lot is generally defined as having minimum length of 100 m and a maximum length of 500 m.

3 Definitions

3.1 Longitudinal profile

A longitudinal profile is a vertical section along the wheel path (that is, the elevation of the surface as a function of longitudinal distance).

3.2 Two laser profilometer

A two laser profilometer is a vehicle fitted with lasers and accelerometers that record the longitudinal profile, to class 1 standard, in each wheel path at highway speed. Class 1 Profile Standard requires a maximum sample interval, between elevation points, of 250 mm and a precision of the elevation measures of 0.5 mm.

3.3 International Roughness Index (IRI)

The IRI is a mathematic model of the dynamic response of a vehicle travelling at 80 km/h along a single wheel path of longitudinal profile using standardised suspension characteristics and is referred to as the quarter-car (or World Bank) model. The IRI is expressed in terms of accumulated displacement of the simulated suspension in metres per measured kilometre (m/km), as either:
- Wheel Path IRI which is based on a quarter-car model run over a single wheel path of longitudinal profile, or
- Lane IRI which is determined by averaging two individual wheel path profiles of a lane and running the quarter-car model over the averaged profile.

3.4 Wheel path
A wheel path is defined as being at 0.75 m on either side of the centre of the lane.

3.5 NAASRA Roughness Meter
The NAASRA Roughness Meter is a standard mechanical device used extensively in Queensland since the mid-1970s for measuring road roughness. It records the upward movement of the rear axle of a large sedan or station wagon relative to the vehicle’s body as the vehicle travels at a standard speed along the road being tested. A cumulative upward vertical movement of 152.4 mm corresponds to 10 NAASRA Roughness Counts.

4 Apparatus
A Two Laser Profilometer comprising the following equipment is required:

4.1 Vehicular platform, capable of transporting the profilometer testing equipment and operators at highway speeds.

4.2 Two accelerometers to establish the inertial reference which enables reference to be maintained at the level of resolution and accuracy required for the laser displacement measurement transducers. Typically for this application a minimum sample rate of 100 Hz and a range of ±2 g is sufficient.

4.3 Two laser displacement transducers which measure the distance between the accelerometers and the road surface. The laser displacement transducers shall be set to ensure mid-range operation during normal testing. Lasers suitable for this application typically have a stand-off height of 300 mm, a measuring range of 200 mm and a sample rate of 8-16 kHz.

4.4 The lasers and accelerometers shall be mounted 750 mm left and right of the longitudinal centreline of the vehicle.

4.5 Distance measuring rotational encoder capable of measuring the distance travelled to an accuracy of ± 0.1% over a distance of 1.0 km and having a resolution of 5 mm per pulse to enable data acquisition to be triggered at a minimum interval of 250 mm.

4.6 Data logger, capable of capturing the output from the lasers and accelerometers at equal intervals of 250 mm (minimum).

4.7 Computer, to calculate the profile from the laser and accelerometer data and analyse the profile data using the quarter-car model to obtain the IRI.

4.8 Manufacturer’s user manual for operating the test equipment.

5 Calibration and validation
5.1 Equipment calibration

5.1.1 Distance encoder
a) Calibrate the distance encoder by driving the host vehicle over a known distance (1 km to an accuracy of ± 1 m) and recording the number of pulses produced by the encoder.
b) Store the calibration factor and associated information (such as the date and time of calibration) and use this for all subsequent testing until such time as a new distance calibration is performed.

c) Calibration of the distance encoder shall be performed whenever a new distance encoder is fitted to the vehicle or the wheels or tyres are changed. Calibration shall also be carried out periodically to compensate for tyre wear.

5.1.2 Accelerometers

Undertake calibration and checking of the accelerometers in accordance with the procedures and requirements stated in the manufacturer’s user manual.

5.1.3 Laser Displacement Transducers

a) Calibration of the laser displacement transducers shall be performed immediately following any change to the transducers or a change to any part of the host vehicle that may interfere with the existing calibration.

b) Calibration of the laser displacement transducers must be performed using the gauge blocks and flat plates in accordance with the procedures and requirements stated in the manufacturer’s user manual.

5.2 Equipment validation

5.2.1 Perform the manufacturer’s operation validation test (bounce test) before the start of each day’s testing as detailed in the manufacturer’s user manual (Note 9.1).

5.2.2 If the recorded roughness during the bounce phase of the test exceeds 0.15 lane IRI m/km or 3 NAASRA counts/km, the validation test has failed and the equipment shall be recalibrated, repaired or replaced as appropriate.

6 Procedure

The procedure shall be as follows (Note 9.2):

6.1 Select the section to be tested such that it includes sufficient length of pavement to allow for acceleration and deceleration of the vehicle. This is particularly important where the pavement surface being tested does not join the existing pavement smoothly or includes incomplete structures. In such situations, a length of 100 m at the start and finish of the section shall be allowed as ‘lead in’ and ‘lead out’ areas which are not included in the test section. All start and finish points shall be related to either job chainages or other fixed references such as bridges, intersections, and so on.

6.2 Determine the test interval to be used (Note 9.3).

6.3 Ensure that the test section is dry and sufficiently clean and note any abnormal surface conditions that could affect the roughness results (Note 9.4).

6.4 Select the vehicle speed to be used for testing (Note 9.5).

6.5 Check the vehicle tyre pressures against the vehicle manufacturer’s recommendation and adjust if necessary, to maintain the calibration of the distance encoder.

6.6 Follow the instructions in the manufacturer’s user manual to measure the surface profile along each wheel path in the test lane, at a relatively constant speed, with the vehicle travelling along the centre of the lane being tested (Note 9.6), ensuring the following:
6.6.1 The test vehicle is travelling within the operating speed range prior to the defined start point of the survey.

6.6.2 No attempt is made to avoid pavement defects unless they are likely to damage the vehicle and/or jeopardise safety.

6.6.3 Testing is not performed if the surface is wet as this can affect the accuracy of the laser readings.

6.6.4 Testing is not performed in extremely dusty conditions as this can affect the accuracy of the laser readings.

6.7 Conduct one test run per traffic lane.

6.8 Record any events during testing that may affect roughness measurements or provide location references including the following (Note 9.7):

a) Change of seal/construction joint
b) Pothole/patch/pavement defect
c) Bridge or culvert
d) Intersection
e) Railway crossing or grids
f) Reference points.

7 Calculations

From the measured profile in each wheel path, calculate the following roughness parameters for each test lot of each lane:

7.1 The IRI for each wheel path using the quarter-car model (m/km).

7.2 The lane IRI using the averaged profile of the two wheel paths and the quarter-car model (m/km).

7.3 The NAASRA roughness counts/km as follows:

\[ N = (33.67 \times IRI) - 1.95 \]

where

- \( N \) = NAASRA roughness (counts/km)
- \( IRI \) = Lane IRI (m/km)

8 Reporting

8.1 Report the following general information for each test run:

a) Survey title/file name
b) Date and time of test
c) Test vehicle/equipment identification
d) Calibration relationship used
e) Operator and driver
f) Road number or job number
g) Test direction

8.2 Report the following values for each test lot:

a) Test lot end distance

b) Left/outer/passenger wheel path IRI to the nearest 0.01 m/km

c) Right/inner/driver wheel path IRI to the nearest 0.01 m/km

d) Lane IRI (profile averaging) to the nearest 0.01 m/km

e) NAASRA roughness to the nearest 1 count/km

f) Lane IRI (if required) to the nearest 0.01 m/km

g) Test speed (km/h)

h) Any event recorded during testing.

9 Notes on method

9.1 This test simulates a bouncing vehicle travelling along a completely flat surface. The measured profile should be zero as the movement of the laser transducers is expected to be cancelled out by the accelerometers. However, due to electronic noise and other factors, a negligible roughness value is usually recorded.

9.2 A driver and operator are required to perform this test.

9.3 The maximum test interval shall be the test lot size. However, adoption of a shorter test interval such as 20 m still enables roughness data to be aggregated up to the required test lot while providing an indication of the roughness distribution within the test lot.

9.4 Unsealed pavement layers shall have been recently swept prior to testing.

9.5 Profile based roughness testing is not speed dependent within the recommended operating speed range which is generally 30 to 120 km/h. As a safety precaution, most systems automatically cut power to the lasers if the vehicle speed drops below around 10 km/h. When testing under traffic, a test speed of no less than 15 km/h under the posted or signed speed limit shall be adopted. When testing on construction sites, the test speed is not critical; however, it is preferable but not essential that the selected test speed, within the equipment's operating range, be maintained throughout the test run.

9.6 In the absence of defined traffic lanes, testing shall be carried out in areas as directed by the site engineer or supervisor.

9.7 The number of events that can be recorded is a function of the test equipment system.
Test Method Q708C: Road roughness – surface evenness - static level and staff

1 Source

This method was developed in-house using information obtained from the following technical references:


2 Scope

This test method defines a procedure for measuring the road roughness or surface evenness of road pavements, for construction compliance testing. The roughness is determined from direct measurement of the longitudinal profile in each wheel path using a static level and staff.

Although labour intensive, this method is suitable for testing short sections of pavements which cannot be tested with vehicle based test methods.

The roughness measurement is expressed in terms of International Roughness Index (IRI). This index is obtained by quarter-car simulation, at a set speed of 80 km/h, using standardised suspension characteristics over a longitudinal profile.

The single roughness measurement produced by this method is the lane IRI, using quarter-car simulation of the average of the two wheel path profiles, of a test lot of road. Conversion of IRI to equivalent NAASRA Roughness Meter counts is included. A test lot is generally specified as having a minimum length of 100 m and a maximum length of 500 m.

3 Definitions

3.1 Longitudinal profile

A longitudinal profile is a vertical section along the wheel path (that is, the elevation of the surface as a function of longitudinal distance).

3.2 Level and staff profiles

An automatic surveyor's level and staff can produce profiles to Class 2 standard. Class 2 Profile Standard requires a maximum sample interval, between elevation points, of 500 mm and a precision of the elevation measures of 1.0 mm. The precision of Class 2 is adequate for the calibration of vehicle based response type roughness meter systems such as the NAASRA Roughness Meter.

3.3 International Roughness Index (IRI)

The IRI is a mathematic model of the dynamic response of a vehicle travelling at 80 km/h along a single wheel path of longitudinal profile using standardised suspension characteristics and is referred to as the quarter-car (or World Bank) model. The IRI is expressed in terms of...
accumulated displacement of the simulated suspension in metres per measured kilometre (m/km), as either:

- Wheel Path IRI which is based on a quarter-car model run over a single wheel path of longitudinal profile, or
- Lane IRI which is determined by averaging two individual wheel path profiles of a lane and running the quarter-car model over the averaged profile.

3.4 Wheel path

A wheel path is defined as being at 0.75 m on either side of the centre of the lane.

3.5 NAASRA Roughness Meter

The NAASRA Roughness Meter is a standard mechanical device used extensively in Queensland since the mid-1970s for measuring road roughness. It records the upward movement of the rear axle of a large sedan or station wagon relative to the vehicle’s body as the vehicle travels at a standard speed along the road being tested. A cumulative upward vertical movement of 152.4 mm corresponds to 10 NAASRA Roughness Counts.

4 Apparatus

4.1 Tape, surveyor’s tape to locate and mark the positions along the wheel paths of the lane where the elevation measures are to be taken, having an accuracy within 0.2% of its total length.

4.2 Level, automatic surveyor’s level to provide the height readings from the staff (Note 8.1).

4.3 Staff, standard metric staff, which enables 10 mm values to be read directly and the 1 mm values to be visually estimated. A bubble level attached to the staff is required to keep the staff vertical to maintain the precision of the height measurements (Note 8.1).

4.4 Computer, to process the height measurements, generate the longitudinal profiles and analyse the profile data using the quarter-car model to obtain the IRI.

4.5 Means for securing the tape (for example, weights, adhesive tape).

4.6 Means for marking the wheel paths (for example, chalk, paint).

5 Procedure

The procedure shall be as follows (Note 8.2):

5.1 Clearly mark the transverse location of the wheel paths with chalk or paint at a maximum of 15 m intervals from the start and ensure that the start and end points for each tape set-up are also marked.

5.2 Place the tape on a wheel path with the zero position on the tape at the start of the wheel path to be tested. Secure the tape with weights or adhesive tape.

5.3 Place the level at a location that allows focusing on the staff at the start of the tape and over as much of the length of the tape as possible. Location of the level in line with the wheel path will minimise viewing adjustment.

5.4 At 500 mm intervals along the tape, measure and record the distance between the road surface and an arbitrary height associated with the level.

5.5 Move the tape such that the new zero point coincides with the old end point and secure the tape with weights or adhesive tape.
5.6 Before moving the level, identify the last measurement in the field notes. Also mark the location of the measurement on the road if necessary. This point on the road is the pivot point for the change in instrument height that occurs with the new set-up.

5.7 Repeat Steps 5.3 to 5.6 until the end of the section being tested is reached.

5.8 Repeat Steps 5.2 to 5.7 for the other wheel path to be tested.

6 Calculations

6.1 Using a computer, enter the level measurements for each wheel path and calculate the longitudinal profile for each wheel path using a start chainage of 0 m and an arbitrary start elevation.

6.2 Plot the first 10 to 20 m of each longitudinal profile and use this to estimate an elevation at a location 11 m before the profile start, such that a line joining this point to the profile provides a smooth lead-in to the profile. This lead-in slope is used for initialising the IRI computation. The 11 m represents 0.5 seconds of travel at 80 km/h of the quarter-car model.

6.3 Add this point (chainage - 11.0 m with its estimated elevation) to the start of the profile data.

6.4 Average the two wheel path longitudinal profiles.

6.5 From the profile of each wheel path, compute the IRI for each wheel path using the quarter-car model (m/km) (Note 8.3).

6.6 Using the averaged profile of the two wheel paths, compute the Lane IRI using the quarter-car model (m/km) (Note 8.3).

6.7 Calculate the NAASRA roughness in counts/km as follows:

\[ N = \frac{33.67 \times IRI - 1.95}{1000} \]

where

- \( N \) = NAASRA roughness (counts/km)
- \( IRI \) = Lane IRI (m/km)

7 Reporting

7.1 Report the following general information for each test run:

a) Survey title/file name
b) Date and time of test
c) Operators
d) Road number or job number
e) Test direction and lane description
f) Start and end references.

7.2 Report the following values for each test lot:

a) Test lot end distance
b) Left/outer/passenger wheel path IRI to the nearest 0.01 m/km
c) Right/inner/driver wheel path IRI to the nearest 0.01 m/km
d) Lane IRI (profile averaging) to the nearest 0.01 m/km
e) NAASRA roughness to the nearest 1 count/km.
8 Notes on method

8.1 This will provide the required Class 2 precision.

8.2 Three operators are recommended for this procedure. One operator positions the staff, the second reads the heights on the level and the third operator records the results.

8.3 For all IRI computations, use an interval of 20 m. These results can then be aggregated to produce a Road Roughness – Surface Evenness value for each test lot.
Test Method Q708D: Road roughness – surface evenness - ARRB walking profiler

1 Source
This method was developed in-house using information obtained from the following technical references:


2 Scope
This test method defines a procedure for measuring the road roughness or surface evenness of road pavements, for construction compliance testing. The roughness is determined from direct measurement of the longitudinal profile in each wheel path using the ARRB Walking Profiler.

Although slow in operation, this method is suitable for testing short sections of pavements which cannot be tested with vehicle based test methods.

The roughness measurement is expressed in terms of International Roughness Index (IRI). This index is obtained by quarter-car simulation at a set speed of 80 km/h, using standardised suspension characteristics over a longitudinal profile.

The single roughness measurement produced by this method is the lane IRI, using quarter-car simulation of the average of the two wheel path profiles, of a test lot of road. Conversion of IRI to equivalent NAASRA Roughness Meter counts is included. A test lot is generally specified as having a minimum length of 100 m and a maximum length of 500 m.

3 Definitions

3.1 Longitudinal profile
A longitudinal profile is a vertical section along the wheel path (that is, the elevation of the surface as a function of longitudinal distance).

3.2 Walking profiler
An ARRB Walking Profiler is a precision mechanical device with a moveable platform (241.3 mm in length), fitted with a horizontally mounted accelerometer that can record the longitudinal profile, to Class 1 standard, along a wheel path at a speed of 800 metres/hour. Class 1 Profile Standard specifies a maximum sample interval between elevation points of 250 mm and a precision of the elevation measures of 0.5 mm.
3.3 **International Roughness Index (IRI)**

The IRI is a mathematical model of the dynamic response of a vehicle travelling at 80 km/h along a single wheel path of longitudinal profile using standardised suspension characteristics and is referred to as the quarter-car (or World Bank) model. The IRI is expressed in terms of accumulated displacement of the simulated suspension in metres per measured kilometre (m/km), as either:

- Wheel Path IRI which is based on a quarter-car model run over a single wheel path of longitudinal profile, or
- Lane IRI which is determined by averaging two individual wheel path profiles of a lane and running the quarter-car model over the averaged profile.

3.4 **Wheel path**

A wheel path is defined as being at 0.75 m on either side of the centre of the lane.

3.5 **NAASRA Roughness Meter**

The NAASRA Roughness Meter is a standard mechanical device used extensively in Queensland since the mid-1970s for measuring road roughness. It records the upward movement of the rear axle of a large sedan or station wagon relative to the vehicle’s body as the vehicle travels at a standard speed along the road being tested. A cumulative upward vertical movement of 152.4 mm corresponds to 10 NAASRA Roughness Counts.

4 **Apparatus**

4.1 ARRB Walking Profiler, calibrated in accordance with the procedure specified in the manufacturer's user manual.

4.2 Tape measure, to locate and mark the positions along the wheel paths of the lane to provide guidance for the walking profiler operator.

4.3 Paint, crayon or similar for marking alignment reference points along the wheel paths to be tested.

4.4 Broom to sweep the wheel paths to be tested, if required.

4.5 Thermometer for measuring the ambient operational air temperature of the walking profiler. The thermometer shall have a range of -5º to 100ºC (minimum) and resolution of 1ºC.

4.6 Computer, to analyse the individual wheel path and averaged wheel path longitudinal profile data using the quarter-car model to obtain the IRI.

4.7 Manufacturer's data acquisition user manual.

5 **Procedure**

The procedure shall be as follows (Note 8.1):

5.1 Clearly mark the transverse location of the wheel paths at 3 to 5 m intervals from the start, along the length to be tested, to facilitate accurate tracking of the walking profiler.

5.2 Ensure that the wheel paths are free from any loose materials, by sweeping if necessary.

5.3 Place the walking profiler at the start point of the first wheel path to be tested and record the ambient air temperature within the profiler cowling. If operating without a cowling, record the ambient air temperature within the workings of the profiler.
5.4 Over the first 20 m of the wheel path to be tested, carry out the Field Offset Trim in accordance with the manufacturer’s data acquisition user manual.

5.5 Conduct the survey of the first wheel path to be tested in accordance with the manufacturer’s data acquisition user manual ensuring that metric units have been selected in the set-up.

5.6 Record the profiler’s ambient air temperature as described in Step 5.3.

5.7 If the temperature at the end of the survey is within ± 10°C of the start point temperature, accept the survey and move the profiler to the start of the next wheel path to be tested. Otherwise, repeat Steps 5.3 to 5.7.

5.8 Repeat Steps 5.3 to 5.7 for the second wheel path to be tested.

6 Calculations

6.1 Using a computer, load the profile data files for each wheel path from the walking profiler into a spreadsheet.

6.2 Plot the first 10 to 20 m of each longitudinal profile and use this to estimate an elevation at a location 11 m before the profile start, such that a line joining this point to the profile provides a smooth lead-in to the profile. This lead-in slope is used for initialising the IRI computation. The 11 m represents 0.5 seconds of travel at 80 km/h of the quarter-car model.

6.3 Add this point (chainage -11.0 m with its estimated elevation) to the start of the profile data to produce a new profile data file for each wheel path suitable for input into the IRI computation program.

6.4 Average the two wheel path longitudinal profiles.

6.5 From the profile of each wheel path, compute the IRI for each wheel path using the quarter-car model (m/km) (Note 8.2).

6.6 Using the averaged profile of the two wheel paths, compute the Lane IRI using the quarter-car model (m/km) (Note 8.2).

6.7 Calculate the NAASRA roughness in counts/km as follows:

\[ N = (33.67 \text{ IRI}) - 1.95 \]

where 
- \( N \) = NAASRA roughness (counts/km)
- \( \text{IRI} \) = Lane IRI (m/km)

7 Reporting

7.1 Report the following general information for each test run:

a) Survey title/file name
b) Date and time of test
c) Operator
d) Road number or job number
e) Test direction and lane description
f) Start and end references.
7.2 Report the following values for each test lot:
   a) Test lot end distance
   b) Left/outer/passenger wheel path IRI to the nearest 0.01 m/km
   c) Right/inner/driver wheel path IRI to the nearest 0.01 m/km
   d) Lane IRI (profile averaging) to the nearest 0.01 m/km
   e) NAASRA roughness to the nearest 1 count/km.

8 Notes on method

8.1 Only one operator is required to perform this test.

8.2 For all IRI computations, use an interval of 20 m. These results can then be aggregated to produce a Road Roughness – Surface Evenness value for each test lot.
Test Method Q711A: Field spread rate of cover aggregate - canvas mat

1 Source
This method was developed in-house using techniques evolved through internal departmental investigations.

2 Scope
This method describes the procedure for the determination of the spread rate of cover aggregate delivered from a mechanical spreading device to determine spreader performance in a trial run prior to use on sprayed sealing works or just beyond the conclusion of a spray run.

3 Apparatus
The following apparatus is required:

3.1 Balance of suitable capacity, having a resolution of at least 100 g and with a limit of performance within the range of ± 500 g. A spring balance with a capacity of 30 kg and an attached hook has been found to be suitable.

3.2 Square mats, made from heavy duty fabric such as canvas with a reinforced lip around the perimeter and lifting points at each corner. The reinforced lip should be approximately 35 mm in height and stand perpendicular to the mat. The mat area enclosed within the lip should be as close as practicable to one square metre (that is 1 m x 1 m) (Figure 1).

3.3 Tape measure, with a resolution of 1 mm.

3.4 Small pegs to hold the mats in place during testing.

3.5 Brush and scoop.

4 Procedure
The procedure shall be as follows:

4.1 Determine the length and breadth of each mat used (l, b).

4.2 Determine the mass of each mat used (m1).

4.3 Arrange the one or more of the mats on a level surface in an arrangement so that the spread rate across the spreading width of the aggregate spreader can be determined (Note 7.1). If required, secure the mat(s) to the surface using pegs.

4.4 With the spreading device travelling at the desired operating speed and other mechanical spreading equipment (for example gates, rollers) adjusted to the desired settings, drive the spreader over the arrangement of mats. Record all equipment settings.

4.5 After the spreader has passed over the mat(s), remove excess aggregate spread over and outside the reinforced lip of the mat. A scoop may be required to move the aggregate from the outside of the mat.

4.6 Determine the mass of each mat and aggregate (m2).

4.7 Where the spread rate is required as an area spread per volume (m²/m³), perform a loose unit mass test as detailed in Test Method Q221A on either a sample of retained aggregate collected from the mat(s) or on a representative sample of aggregate collected prior to spreading.
5 Calculations

Calculate as follows:

5.1 Calculate the area of each mat as follows:

\[ A_i = \frac{l_i b_i}{10^6} \]

where
- \( A_i \) = area of mat (m²)
- \( l_i \) = length of mat (mm)
- \( b_i \) = breadth of mat (mm)

5.2 Calculate the spread rate for each mat as follows:

\[ R_{ii} = \frac{m_{2i} - m_{1i}}{1000A_i} \]

where
- \( R_{ii} \) = spread rate for mat (kg/m²)
- \( m_{2i} \) = mass of mat and aggregate (g)
- \( m_{1i} \) = mass of mat (g)
- \( A_i \) = area of mat (m²)

5.3 If required, calculate the mean spread rate when more than one mat is used as follows:

\[ R_1 = \frac{\sum R_{ii}}{n} \]

where
- \( R_1 \) = mean spread rate (kg/m²)
- \( R_{ii} \) = spread rate for mat (kg/m²)
- \( n \) = number of mats used

5.4 If required, calculate the spread rate on an area spread per volume basis for each mat as follows:

\[ R_{2i} = \frac{1000\rho}{R_{ii}} \]

where
- \( R_{2i} \) = spread rate for mat (m²/m³)
- \( \rho \) = loose unit mass of aggregate (t/m³) obtained from Test Method Q221A
- \( R_{ii} \) = spread rate for mat (kg/m²)

5.5 If required, calculate the mean spread rate when more than one mat is used as follows:

\[ R_2 = \frac{\sum R_{2i}}{n} \]
where \[ R_2 \] = mean spread rate \((m^2/m^3)\)
\[ R_{2i} \] = spread rate for mat \((m^2/m^3)\)
\[ n \] = number of mats used

6 Reporting
Report the following values:

6.1 Individual spread rate(s) to the nearest 0.1 kg/m².
6.2 Mean spread rate to the nearest 0.1 kg/m².
6.3 Individual spread rate(s) to the nearest 1 m²/m³, if required.
6.4 Mean spread rate to the nearest 1 m²/m³, if required.

7 Notes on method
7.1 Where several mats are used, they can be placed diagonally across the path of the spreader, avoiding overlap of the mats, while allowing the full width to be sampled.

Figure 1 – Example of canvas mat
Test Method Q712: Surface evenness of road surface – three metre straightedge

1  Source
This method was developed in-house with reference to AS 1003: Engineers straightedges and Roads and Maritime Services Test Method T183: Surface deviation using a straightedge.

2  Scope
This method describes the procedure for obtaining a measure of the evenness of a pavement surface as determined by the deviation from a three metre straightedge. It is applicable only to the measurement of depressions in the pavement surface and to those straightedges which can be positioned in direct contact with the pavement surface.

3  Apparatus
The following apparatus is required:

3.1 Straightedge, a 3 m rigid length of metal of either rectangular or I-section shape. The working face of the straightedge shall be flat with deviations along its entire length less than ± 0.5 mm from true, and less than ± 1.0 mm from true when resting on supports at both ends. The straightedge shall be of such construction that it can rest unsupported on the pavement with its working face in contact with the pavement.

3.2 Depth gauge, a suitable device for measuring the gap between the straightedge and the pavement to the nearest 1 mm. One such device is a metal wedge which is slid beneath the straightedge and calibrated in such a way that the gap width can be read directly from the wedge as determined by the distance penetrated by the wedge at its first contact with the straightedge.

3.3 Tape measure, steel rule and wheel meter as required.

4  Procedure
The procedure shall be as follows:

4.1 Select the test location and remove any loose material from the surface of the pavement.

4.2 Place the straightedge at the required orientation (normally longitudinal or transverse to the centre-line) so that the working face of the straightedge is in contact with the surface of the pavement (Note 6.1).

4.3 Reposition the straightedge, if necessary, to ensure that:

4.3.1 The straightedge sits firmly on the pavement surface without rocking (Note 6.2).

4.3.2 The straightedge is at right angles to any linear feature that is under the straightedge (for example, joint, edge, tie-in).

4.3.3 For other than joint testing, the length of the straightedge that is cantilevered is minimised (Note 6.3).

4.4 Where the test location is on a crown or superelevation of the road or there is any feature which may affect the measurement, record these details.

4.5 Visually estimate the point at which the greatest deviation appears to occur between the straightedge and the pavement surface (Note 6.4).
4.5.1 Using the depth gauge, determine the deviation at this point and record the value to the nearest 1 mm.

4.6 Repeat Steps 4.5 to 4.6 for other points along the straightedge as necessary until the maximum deviation has been recorded.

5 Reporting

Report the following:

5.1 Surface type and layer.

5.2 Test location (for example, chainage, direction, lane, offset/wheel path and so on).

5.3 Orientation of straightedge relative to centreline.

5.4 Maximum deviation to the nearest 1 mm.

5.5 Where the cantilever is greater than 750 mm, the length of the cantilever to the nearest 5 mm.

5.6 Test location features (for example, convex shape, linear feature, crown, superelevation and so on).

6 Notes on method

6.1 Where a joint is to be tested, one end of the straightedge should be positioned directly over the joint with the remainder of the straightedge supported on the surface to be tested.

6.2 Where a convex surface prevents the straightedge from being positioned firmly on the pavement without rocking, the test should be terminated. “Convex shape” should be recorded for the test location.

6.3 Where the cantilever is greater than 750 mm, measure the length of cantilever to the nearest 5 mm.

6.4 Maximum deviation may be under the supported or cantilevered portion of the straightedge.
Test Method Q713: Skid resistance – mobile, variable slip technique

1 Source

This test shall be performed in accordance with ASTM E1859–06, Standard test method for Friction Coefficient Measurements Between Tire and Pavement Using a Variable Slip Technique, but with the following changes, as detailed below. These changes are due to:

a) amendment specific to the ViaFriction Skid Tester
b) local terminology and operational procedures.

The changes to the ASTM Standard Test Method were developed in-house based on information obtained from the following technical references:


2 Scope

This method covers the direct measurement of the braking force coefficient of friction at a slip speed of 60 km/h (F60) and the speed dependency (Sp) of that measure (that is, the two components of International Friction Index (IFI)) using the ViaTech – ViaFriction skid tester operating in variable slip mode. Also measured during the test is Peak Friction, the slip speed at which it occurred (Vcrit.) and the coefficient of friction at a slip speed of 30 km/h (F30 – commonly referred to as European Friction Index (EFI)).

3 Definitions

The terminology use is as detailed in ASTM E1859-06, except as shown below:

- 3.2.1 peak friction number, n is referred to as Peak Friction
- 3.2.1.1 SNF peak(S) – S is the slip speed at which peak friction occurs and is referred to as Vcrit.
- 3.2.1.1 SNF peak = Peak Friction x 100
- 3.2.2.1 SNF Characteristic is the slip friction at a specified slip speed. At the 60 km/h adopted slip speed, this friction value is denoted as F60 where SNF(60)/100 = F60.
- 3.2.3 “slip – to-skid Friction number” is the friction value at wheel lockup and is only a meaningful measure when testing at constant speed. This value is not reported.

Superseded
3.2.5 slope indicator is equivalent to Speed Number and is designated as Sp. F60 and Sp are the two components of International Friction Index (IFI).

3.2.6 tire longitudinal stiffness indicator is not recorded or reported.

4 Apparatus

The apparatus required is as detailed in ASTM E1859-06, except as shown below:

5.4.1.1 The ViaFriction skid tester operates under a 71 kg (156.1 lbs) load not the ASTM specified 1.423 kN (320 lbf) load.

5.4.1.2 Initial calibration is supplied by the manufacturer against a reference device used in the PIARC International Trial. Annual stability of calibration is undertaken using a relative calibration approach over a number of established test sites.

5.4.5 The distance encoders on the ViaFriction skid tester have a resolution of 100 and 25 mm on the test wheel and test vehicle respectively. With a brake cycle of 0.5 seconds, at a test speed of 60 to 80 km/h, the 100 mm distance resolution on the test wheel provides approximately 100 data points in the braking cycle which provides a slip speed resolution of < 1 km/h.

5 Test procedure

The procedure shall be as follows:

5.1 Testing is not speed dependent and can be carried out, under traffic conditions, at test speeds between 40 and 90 km/h. When testing on construction sites or runways (that is, not under traffic), a test speed of 60 to 80 km/h is preferred.

5.2 A water film depth of 0.5 mm is selected for road testing while a 1.0 mm water film depth is used for runway testing.

5.3 Unless specified, testing shall be carried out in the left hand wheel path of the test lane.

5.4 Although the testing operation is continuous, at the adopted brake profile (ramp setting) of 500 ms, the braking system takes 0.5 seconds to do a test and 4 to 5 seconds to dissipate its energy and reset for the next test. At a test speed of 80 km/h the combined braking and reset cycles take around 5 seconds and cover a travelled distance of 100 to 120 m. Therefore, the minimum test intervals that shall be adopted are 100 and 150 m for speed zones ≤ 60 km/h and > 60 km/h respectively.

5.5 The water temperature and ambient temperature shall be recorded during testing in addition to the ViaFriction test unit’s automatic acquisition of surface temperature.

6 Calculations

Calculate as follows:

6.1 The ViaFriction system reports for each test interval, the test speed, peak friction, Vcrit, F30, F60, Friction Slip Slope, surface temperature and GPS coordinates. The Friction Slip Slope can be converted to Sp using the following relationship:
\[ S_p = \frac{-1}{FSS} \]

where \( S_p \) = slope indicator
\( FSS \) = Friction Slip Slope

6.2 The recorded F60 skid resistance value shall be temperature corrected as follows:

6.2.1 The Transport and Main Roads adopted reference surface temperature for skid resistance measurement correction is 30ºC. It is proposed that this be raised to 35ºC for areas west of the Charleville, Alpha, Hughenden, Georgetown and Weipa line to reflect the higher operating surface temperature conditions in that area (TMR (2010)).

6.2.2 For correction of F60 skid resistance results to a 30ºC reference temperature, the following relationship shall be used:

\[ F60_{30} = F60_{(t)} + 0.0015(t) - 0.045 \]

where \( F60_{30} \) = corrected F60 value for a 30ºC reference temperature
\( F60_{(t)} \) = recorded F60 value at \( t \)ºC
\( (t) \) = surface temperature at time of test (ºC)

6.2.3 For correction to 35ºC reference temperature, the following relationship shall be used:

\[ F60_{35} = F60_{(t)} + 0.0015(t) - 0.0525 \]

where \( F60_{35} \) = corrected F60 value for a 35ºC reference temperature
\( F60_{(t)} \) = recorded F60 value at \( t \)ºC
\( (t) \) = surface temperature at time of test (ºC)

7 Reporting

For each test interval the following shall be reported:

7.1 Location of the test (road, chainage, lane, wheel path, GPS coordinates).

7.2 Date and time of test.

7.3 International Friction Index comprising the two components, that is, the temperature corrected F60 friction coefficient to the nearest 0.01 and the speed dependency (Sp) factor to the nearest 1 km/h (Note 8.1).

7.4 Other measured friction coefficients and parameters (optional).

7.5 Ambient and water temperatures (optional) (Note 8.2).

8 Notes on method

8.1 The speed dependency (Sp) factor is the slope of the friction/slip speed curve at 60 km/h. As the coefficient of friction is dimensionless, Sp is expressed in km/h.

8.2 These are only recorded for future use with possibly more refined temperature correction procedures.
Test Method Q714: Skid resistance - mobile, continuous reading, fixed slip technique

This test shall be performed in accordance with ASTM E2340/E2340M Standard Test Method for Measuring the Skid Resistance of Pavements and Other Trafficked Surfaces Using a Continuous Reading, Fixed-Slip Technique and ASTM E1960 Standard Practice for Calculating International Friction Index of a Pavement Surface, but with the following changes, as detailed below. These changes are due to:

a) amendment specific to the ViaFriction Skid Tester.
b) local terminology and operational procedures.

1 Scope

This method covers the measurement of the braking force coefficient of friction at a slip speed of 60 km/h (that is, F60, the friction component of International Friction Index (IFI)) using the ViaTech – ViaFriction skid tester operating in continuous fixed slip mode.

The changes were developed in house based on information obtained from the following technical references:


For test speeds greater than 60 km/h, the slip ratio is selected to enable direct measurement of the braking force coefficient of friction at a slip speed of 60 km/h (F60). For slower test speeds, the maximum effective slip ratio of 90% is selected and the measured coefficient of friction is corrected to F60 using the Penn State relationship (J.J. Henry & M. Marasteanu (1992)), as adopted by PIARC (1995) and described in ASTM (E1960 – 07).

The Penn State relationship uses the speed dependency factor (Sp), the second component of International Friction Index. Sp can be measured directly with a supplementary test using the Via Friction in variable slip mode (Q713) or calculated from surface texture measurements (Q705 (2010)) and the PIARC (1995) relationship for device A8 (Sand Patch Test using glass beads).
2 Test procedure
2.1 Testing is carried out at the test speeds and their associated slip ratio in Table 1. Note: 100% slip is a locked wheel.
2.2 A water film depth of 0.5 mm is selected for road testing while a 1.0 mm water film depth is used for runway testing.
2.3 Unless specified, testing shall be carried out in the left hand wheel path of the test lane.
2.4 Although testing is continuous, data shall be processed in 10 m (maximum) test lots and reported either individually or averaged into reporting lots of 100 m minimum length.
2.5 Surface temperature, water temperature and ambient temperature shall be recorded.

3 Data processing
3.1 Transformation sequence
3.1.1 Convert the measured friction to a slip speed of 60 km/h – Speed Correction.
3.1.2 Convert the speed corrected friction measure to F60 – the friction component of IFI.
3.1.3 Temperature correction of F60.
3.2 Speed correction
3.2.1 The first step is to convert the measured friction level to what would have been measured at a slip speed of 60 km/h using the Penn State relationship:

\[
FR60 = FRS e^{Sp}
\]

where

- \( FR60 \) = adjusted value of friction to a slip speed of 60 km/h
- \( FRS \) = friction measured at slip speed \( S \)
- \( S \) = slip speed at which the friction value was measured (km/h)
- \( Sp \) = speed dependency factor

3.2.2 The speed dependency factor (Sp) is determined either by direct measurement in variable slip mode (Q713 (2011)) or from Sand Patch texture depth (MTD) as detailed in PIARC (1995) as follows:

\[
Sp = -11.6 + (113.6 \times MTD)
\]

where

- \( Sp \) = speed dependency factor
- \( MTD \) = sand patch texture depth (mm)
3.3 Harmonisation

3.3.1 The next step is to convert the adjusted friction measure (FR60) to the harmonised International Friction Index (IFI) friction measure F60 as detailed in PIARC (1995) as follows:

\[ F60 = A + (B \cdot FR60) \]

where
- \( F60 \) = Harmonised International Friction Index (IFI)
- \( A \) = constant for reference test device used in PIARC harmonisation trial
- \( B \) = constant for reference test device used in PIARC harmonisation trial
- \( FR60 \) = adjusted value of friction to a slip speed of 60 km/h

3.3.2 The ViaFriction test unit is internally calibrated, against OSCAR, a reference device used in the PIARC harmonisation trial. This relationship as detailed in ViaTech (2009) is:

\[ OSCAR = -0.0366 + (0.9934 \cdot \text{ViaFriction}) \]

3.3.3 The relationship for OSCAR as detailed in Norsemeter (1996) is:

\[ F60 = -0.000074 + (1.000022 \cdot FR60) \]

3.3.4 In practical terms, as the A & B constants nearly equal zero and 1, the OSCAR and units calibrated against it, measure F60 directly when testing at a 60 km/h slip speed. Therefore, this step is not required for ViaFriction test results.

3.4 Temperature correction

3.4.1 The TMR adopted reference temperature for skid resistance measurement correction is 30°C. It is proposed that this be raised to 35°C for areas west of the Charleville, Alpha, Hughenden, Georgetown and Weipa line to reflect the higher operating surface temperature conditions in that area (TMR (2010)).

3.4.2 For correction of F60 skid resistance results to a 30°C reference temperature, the following relationship shall be used:

\[ 30(F60) = F60 + 0.0015(t) - 0.045 \]

where
- \( 30F60 \) = corrected \( F60 \) value for a 30°C reference temperature
- \( F60(t) \) = recorded \( F60 \) value at \( t \)°C
- \( (t) \) = surface temperature at time of test (°C)

3.4.3 For correction to 35°C reference temperature, the following relationship shall be used:

\[ 35(F60) = F60 + 0.0015(t) - 0.0525 \]

where
- \( 35F60 \) = corrected \( F60 \) value for a 35°C reference temperature
- \( F60(t) \) = recorded \( F60 \) value at \( t \)°C
- \( (t) \) = surface temperature at time of test (°C)
3.5 Application of speed and temperature correction

Speed correction shall be applied first at the processing 10 m test lot stage when the calculated slip speed varies by more than ± 3% of the targeted slip speed. Temperature correction shall be applied last at the reporting test lot stage using the average surface temperature recorded for the test lot.

4 Calibration

The ViaFriction has been dynamically calibrated by the manufacturer (ViaTech) against OSCAR, a reference device used in the PIARC (1995) trial. The data produced by ViaFriction, when testing at a slip speed of 60 km/h, is a direct measure of F60, the friction component of International Friction Index. In Australia, we do not undertake static calibration tests but rely in the equipments in-build diagnostics and regular dynamic reference calibration checks over our Nudgee Beach Road test site and the Department’s Mt. Cotton test track in Brisbane. For major projects, dynamic reference calibration checks are carried out before and after each skid resistance survey.

Table 1 – Nominal test speeds and slip ratios

<table>
<thead>
<tr>
<th>Posted speed (km/h)</th>
<th>Test speed (km/h)</th>
<th>Slip ratio (%)</th>
<th>Friction measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>110</td>
<td>90</td>
<td>67</td>
<td>FR60</td>
</tr>
<tr>
<td>100</td>
<td>80</td>
<td>75</td>
<td>FR60</td>
</tr>
<tr>
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* Maximum effective slip ratio  
** Needs to be corrected to FR60 using a measured or calculated Sp  
*** Minimum test speed.
Test Method Q719: Field spread rate of solid stabilisation agents - fabric mat

1 Source
This method was developed in-house using techniques evolved through internal departmental investigations.

2 Scope
This method describes the procedure for the determination of the spread rate of solid stabilising agents delivered from a mechanical spreading device to determine spreader performance in terms of spread rate and uniformity of distribution.

3 Apparatus
The following apparatus is required:

3.1 Balance of suitable capacity, having a resolution of at least 100 g and with a limit of performance within the range of ± 500 g. A spring balance with a capacity of 30 kg and an attached hook has been found to be suitable.

3.2 Square mats, made from heavy duty fabric such as canvas or polyester with a reinforced lip around the perimeter and lifting points at each corner. The mat should be as close as practicable to one square metre (that is 1 m x 1 m).

3.3 Tape measure, with a resolution of 1 mm.

3.4 Small masses or pegs to hold the mats in place during testing.

3.5 Brush and scoop.

4 Procedure
The procedure shall be as follows:

4.1 Determine the length and breadth of each mat used ($l_1$, $b_1$).

4.2 Determine the mass of each mat used ($m_{i1}$).

4.3 Arrange one or more of the mats on a level surface so that the spread rate across the spreading width of the spreader can be determined (Note 7.1). Secure the mat(s) to the surface using masses or pegs.

4.4 After the spreader has passed over the mat(s), carefully brush the stabilising agent from the periphery of each mat towards the centre of the mat. A scoop may be required to move the stabilising agent from the periphery of the mat.

4.5 Determine the mass of each mat and stabilising agent used ($m_{i2}$).

4.6 Return the stabilising agent to the surface and spread over the area previously covered by the mat(s).
5 Calculations

Calculate as follows:

5.1 Calculate the area of each mat as follows:

\[ A_i = \frac{l_i b_i}{10^6} \]

where

- \( A_i \) = area of mat (m²)
- \( l_i \) = length of mat (mm)
- \( b_i \) = breadth of mat (mm)

5.2 Calculate the spread rate for each mat as follows:

\[ R_i = \frac{m_{2i} - m_{1i}}{1000A_i} \]

where

- \( R_i \) = spread rate for mat (kg/m²)
- \( m_{2i} \) = mass of mat and stabilising agent (g)
- \( m_{1i} \) = mass of mat (g)
- \( A_i \) = area of mat (m²)

5.3 Calculate the mean spread rate when more than one mat is used as follows:

\[ \bar{R} = \frac{\sum R_i}{n} \]

where

- \( \bar{R} \) = mean spread rate (kg/m²)
- \( R_i \) = spread rate for mat (kg/m²)
- \( n \) = number of mats used

6 Reporting

Report the following values:

6.1 Individual spread rate(s) to the nearest 0.1 kg/m².
6.2 Mean spread rate to the nearest 0.1 kg/m².

7 Notes on method

7.1 Where several mats are used, they can be placed diagonally across the path of the spreader, avoiding overlap of the mats, while allowing the full width to be sampled.
Test Method Q720: Loose aggregate on sprayed seals

1 Source
This method is based on the RMS Test Method T277: Measurement of loose aggregate on sprayed seals.

2 Scope
This method describes the procedure for determining the quantity of loose aggregate particles on the surface of a sprayed seal constructed with aggregates of 10 mm nominal size or larger.

3 Apparatus
The following apparatus is required:

3.1 Square template, of rigid construction and with internal dimensions as close as practicable to 1 m by 1 m. The template must be of suitable design to allow ready removal of aggregate from the template area.

3.2 Brush, a stiff-bristled brush suitable for removing loose aggregate particles.

3.3 Container, suitable for collecting aggregate particles removed from the template area.

3.4 Tape measure, with a resolution of 1 mm.

3.5 Sieve, 6.70 mm complying with AS 1152.

4 Procedure
The procedure shall be as follows:

4.1 Determine the length and breadth of the template (l, b).

4.2 Place the template on the sprayed seal surface.

4.3 Using the brush, remove any loose aggregate particles from within the template area and collect them in the container, taking care not to dislodge any aggregate particles which are embedded in the seal binder.

4.4 Screen the collected loose aggregate particles over a 6.70 mm sieve.

4.5 Count the number of aggregate particles retained on the 6.70 mm sieve (n).

5 Calculations
Calculate as follows:

5.1 Calculate the area of the template as follows:

\[ A = \frac{lb}{10^6} \]

where

\( A \) = area of template (m²)

\( l \) = length of template (mm)

\( b \) = breadth of template (mm)
5.2 Calculate loose aggregate as follows:

\[ L = \frac{n}{A} \]

where

- \( L \) = loose aggregate (particles/m²)
- \( A \) = area of mat (m²)
- \( n \) = number of loose aggregate particles

6 Reporting

Report the following values and general information:

6.1 Loose aggregate to the nearest 1 particles/m².

6.2 The stage or time at which the testing was performed, for example, “after rolling and before sweeping”.

Superseded