Materials Testing Manual

Part 7: 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 6.70 - 4.75 mm slots in the thickness gauge, and
   c) 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. The method applies to aggregates having a nominal size not greater than 63.0 mm.

3 Definitions
For the purpose of this method, the following definitions shall apply:

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 - 110°C 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, 13.2 mm, 9.50 mm, 6.70 mm and 4.75 mm as required, complying with ISO 3310.

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 that, when dry, will comply with the minimum mass requirement of Test Method Q103A Table 1 or AS 1141.11.1 Table 1 as appropriate.
5.1.2 Place the test portion in the container and dry in the oven to a constant mass.

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 or AS 1141.11.1 (Note 8.1), 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 6.1), 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 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 ($m_1$).
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

Calculations shall be as follows:

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:

$$P_w = \frac{Pm_i}{M_T}$$

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:
Test Method Q201: Flakiness index of aggregate

\[ FI = \sum P_w \]

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 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 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>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.
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:

a) 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.

b) 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 will sit flat on the specimens and have minimum sideways movement and eccentricity. Discard the tyre when it shows signs of irregular wear or its Shore A hardness falls outside the specified range or its diameter falls below 210 mm.

c) 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:

i. the axes of rotation of the two wheels in both the horizontal and vertical planes are not more than 20 minutes of arc out of parallel (1 mm in 200 mm)
ii. the planes of rotation through the centres of the two wheels (tracking planes), measured at the two axes of rotation, not more than 0.8 mm apart, and

iii. abrasive grit feeder and water feed control 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 are enclosed as far as possible and all materials used suitably treated to prevent corrosion under wet conditions. Use and store the pendulum friction tester in a dust-free environment that is not subject to a large temperature variation. Calibrate the tester 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, will consist of the following:

a) 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 is square, clean cut and free from contamination. The rubber slider is to be 24 mm long, 32 mm wide and 6 mm thick with a rigid back. The rubber slider and rigid backing plate have a total mass of 20 g.

b) Avoid handling of the surface of a rubber slider and, when not in use, sliders are stored in the dark at a temperature between 10°C and 25°C. Discard a slider when:
   i. more than 12 months old from the date stamped on the slider
   ii. it does not comply with the requirements of Table 2, or
   iii. it does not comply with Step 5.6.8.

c) The mass of the pendulum including the slider is 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. Mount the slider 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. Spring load the slider against the test surface. The calibration procedure will set the nominal static force on the slider.

d) Means for levelling the instrument.

e) Means for raising and lowering the axis of suspension of the pendulum so that the slider can:
   i. swing clear of the surface of the specimen, and
   ii. be set to slide over a fixed length of the surface.

f) Means for holding and releasing the pendulum so that it falls freely from a horizontal position.

g) 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, is not more than 85 g. The friction in the pointer mechanism is adjustable so that, with the pendulum swinging freely from a horizontal position, will bring the outward tip of the pointer 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, and

h) Specimen holder for rigidly locating the specimens so that:
i. 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
ii. the slider and pendulum will pass over the specimen in the direction of polishing, and
iii. 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:
   a) oven of suitable capacity, having a temperature of 45-50°C and complying with AS 1141.2, and
   b) 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, 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, and
   e) thickness of not less than 12 mm.

3.6 Sieve, a 9.50 mm sieve complying with ISO 3310.

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, and
   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, and
   e) metal blade.
4 Materials

The following materials are required:

4.1 Reference aggregate, aggregate from a specified source for which the known polished aggregate friction value is 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), and
   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. Select the particles 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 that 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 is to 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, completely remove the mortar or discard the specimen.
   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 permits it to flow freely around the particles and, if necessary, thin the mixture 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, completely remove the resin or discard the specimen.

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 is to 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 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.

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 are numbered 13 and 14.
   b) If polishing specimens from three samples, number consecutively 1 to 4, 5 to 8 and 9 to 12.
c) If polishing specimens from two samples, number consecutively 1 to 4 and 5 to 8.

d) If polishing specimens from one sample, number consecutively 1 to 4.

e) If polishing fewer than three samples, use an appropriate number of dummy specimens 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 is to 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 23ºC.

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 use optical emery as the abrasive, perform feed rate checks at 15 minute intervals and terminate polishing after 2 h ± 1 min (Note 8.6).

5.4.10 Soak all specimens face downwards under water at a temperature of 23 ± 2ºC for at least 30 minutes. At no time prior to friction testing, allow test specimens or reference specimens 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 ± 2ºC 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 this cannot be achieved, correct the results 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 is to 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 is to 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 than two units, condition additional sliders 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 are not be used and testing will 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 is to be in contact with the specimen over an arc length of 75 ± 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 (T1).

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 ± 2ºC 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 are 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 is to 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 are tested in the following order:

12, 10, 8, 6, 4, 2, 14.

5.8.14 Record the air temperature to the nearest 1°C (T₁).

6 Calculations

Calculations shall be 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
- T₁ = 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 will 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
The following shall be reported:

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 should consult the relevant 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 will be such that there will be no clogging of the chute. Continuously feed the mixture of abrasive and water directly onto the road wheel near, and ahead of, the point of contact with the rubber -tyred wheel in such a way there is a uniform spread of the abrasive and water over the surface of the specimens when the road wheel contacts 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 23ºC) 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 BS ISO 4662.
+ Hardness in accordance with BS ISO 48.
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 and 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 ISO 3310.
   3.5.2 2.36 mm sieve of 300 mm diameter and complying with ISO 3310.
   3.5.3 Reinforced 0.075 mm sieve of 300 mm diameter and complying with ISO 3310.
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:
   a) 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, and
**Test Method Q208B: Degradation factor of coarse aggregate**

**b)** 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 for weighing reagents.

## 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 10.1, 10.2, 10.3 and 10.4).

### 4.2 Record the date of preparation of the stock solution on the reagent bottle. Use the stock solution for 5 days from the date of preparation after which fresh stock solution needs to be prepared.

## 5 Sample preparation

The sample shall be prepared 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 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 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 discoloration of the wash water. In such cases, discontinue washing once the surface of the particles first appear clean to the naked eye (Note 10.4).

### 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.
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 Before handling the reagents, the operator should consult the relevant SDS.

10.2 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.

10.3 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.

10.4 Insufficient washing may retain clay fines as adherent coatings. These are released subsequently 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.
### 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 AS 1141.6.1: Particle density and water absorption of coarse aggregate – weighing-in-water method.

2 Scope
This method describes the procedure for determining the quantity of binder absorbed by an aggregate. Make two determinations of aggregate volume, 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. Measure binder absorption 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. With 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 ISO 3310.

4 Materials
The following materials are required:

4.1 Cloth, suitable absorbent lintless cloth.
5 **Sample preparation**

The sample shall be prepared 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 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**

The following procedure shall be performed 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 ($m_2$).

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 ($m_3$).

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 ($m_4$).

6.9 Measure the temperature of the water in the container to the nearest 1ºC.

6.10 Remove the aggregate from the basket and dry to a constant mass in the drying oven.

6.11 Determine the dry mass of the aggregate ($m_1$).

7 **Binder absorption**

The following procedure shall be performed on two aggregate subsamples:

7.1 Place the aggregate subsample in the drying oven and dry to a constant mass.

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 ($m_5$).

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 ($m_6$) (Note 10.2).
7.6 Measure the temperature of the water in the container to the nearest 1ºC.

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. Pull the stirring rod back through the binder, retracing the same path but without being fully removed from the sample (Note 10.3).

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 (m₁).

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 (m₂) (Note 10.2).

7.15 Measure the temperature of the water in the container to the nearest 1ºC.

8 Calculations

Calculations shall be as follows:

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 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 (\( \bar{\rho}_D \)) 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:

\[
b = 100 \frac{\rho_B \left( \frac{1}{\rho_D} + \frac{(m_5 - m_6)}{(m_7 - m_5) \rho_1} - \frac{(m_7 - m_8)}{(m_7 - m_5) \rho_2} \right)}
\]

where

- \( b \) = binder absorption (%)  
- \( \rho_B \) = density of binder (t/m\(^3\)) (Note 10.4)  
- \( \rho_D \) = sample particle density on a dry basis (t/m\(^3\))  
- \( m_5 \) = 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/m\(^3\)) (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/m\(^3\)) (Table 1)

8.4 Provided 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 Use a gentle current of air to accelerate drying but take care to avoid over-drying.

10.2 Prior to weighing, check the water container is filled to the overflow.

10.3 As the binder cools, the viscosity of the mix will increase. To avoid entrapment of air, slow the stirring of the mix.

10.4 If unknown, the binder density may be determined using Test Method Q331.

**Table 1 – Water density**

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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 ± 3°C.
3.6 Water bath, thermostatically controlled at a temperature of 50 ± 1°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, where there is no requirement for the class of binder to be used in the test, use Class 170 bitumen complying with AS 2008 or MRTS 17.
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 9.2).

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 9.3):

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, and
   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 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 should consult the relevant SDS.
9.2 If necessary, the test plates may be placed in the oven for a short time to attain an even binder film distribution.
9.3 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.
9.4 If the difference is greater than 10, repeat the test. However, if the aggregate composition is highly variable, report the individual plate stripping values.
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
The test materials shall be prepared as follows:

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**
The procedure shall be as follows:

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:

\[
M_C = \frac{7.5D_C M_B}{100D_B}
\]

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

Calculations shall be as follows:

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 should consult the relevant 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, avoid those areas previously occupied on the binder surface by aggregate pieces. In this way, the test plate may be used for up to three aggregate types.
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 ISO 3310.
3.2 Drying oven of suitable capacity, having a temperature of 45-50ºC 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:

\[ P_{PC} = \frac{\sum a_i}{n} \]

where

\[ P_{PC} = \text{degree of aggregate precoating (\%)} \]
\[ a_i = \text{percentage of surface area of each particle covered by precoating agent} \]
\[ n = \text{number of particles in the test portion} \]
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 should consult the relevant SDS for the precoating agent used.
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 0.2ºC 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).

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 40ºC as follows (Note 8.7):

\[ \log f_2 = \log f_1 - 0.05(40-T) \]

where

- \( f_2 \) = pull-out force (g) corrected to 40ºC
- \( f_1 \) = pull-out force (g)
- \( T \) = surface temperature (ºC)

6.2 Examine the values of log pull-out force corrected to 40ºC 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%.

7.3 The number of this test method, that is Q227.

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 Scalping 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 ISO 3310.
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 will be fitted with a lid to hold water and an external diameter of 230 mm.
3.11 Reinforced 0.075 mm sieve of 300 mm diameter and complying with ISO 3310.
3.12 Oven tray.

4 Materials

The following material is required:

4.1 Distilled water.

5 Sample preparation

The sample shall be prepared 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.

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

The procedure shall be as follows:

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

Calculations shall be as follows

7.1 Calculate the mill abrasion value as follows:

$$MA = \frac{m_1 - m_2}{m_1} \times 100$$

where $MA$ = Mill Abrasion value
\[ m_1 = \text{original washed and dried test portion (g)} \]
\[ m_2 = \text{dried sample retained 0.075 mm (g)} \]

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

The following shall be reported:

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 discoloration of the wash water. In such cases, discontinue washing after all coatings of fines have been removed.

**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>
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 ISO 3310.

3.2.2 Reinforced 0.075 mm sieve complying with ISO 3310 (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 L capacity fitted with a lid to hold water, an external diameter of 198 mm and an internal height of 173.5 mm. The inside and outside surfaces need to be smooth and have no observable ridges or indentations.

3.9 Abrasion charge consisting of stainless steel ball of 9.5 mm diameter and with sufficient numbers for 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

The sample shall be prepared 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 and 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 9.3).

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

Calculations shall be as follows:

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)
\[ m_2 = \text{dried sample retained 0.075 mm (g)} \]

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 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>±5</td>
</tr>
<tr>
<td>Speed (rpm)</td>
<td>100</td>
<td>±5</td>
</tr>
<tr>
<td>Abrasion charge</td>
<td></td>
<td>±0.5</td>
</tr>
<tr>
<td>Diameter (mm)</td>
<td>9.5</td>
<td>±0.5</td>
</tr>
<tr>
<td>Abrasion Jars</td>
<td></td>
<td>±4</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>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 ISO 3310.

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 L capacity fitted with a lid to hold water, an external diameter of 198 mm and an internal height of 173.5 mm. The inside and outside surfaces need to be smooth and have no observable ridges or indentations.

3.9 Abrasion charge consisting of stainless steel ball of 9.5 mm diameter and with sufficient numbers for 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

The sample shall be prepared 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 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 \( 2.00 \pm 0.05 \) litres of distilled water.

6.3 Store the abrasion jar in an air-conditioned room at \( 23 \pm 3^\circ\text{C} \) 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
Calculations shall be as follows:

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**

The following shall be reported:

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.

### 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
For the purpose of this method, the following definitions shall apply:

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:

4.2.1 Single-opening templates made from steel rod, steel bar or similar rigid material, with square apertures of 500 mm, 300 mm, 250 mm, 200 mm and 150 mm. Add hand-grips or handles for ease of use. For larger size rock, it is useful to use C-shaped templates representing the sieve aperture and the diagonal of the sieve aperture. Refer to ASTM D5519 Figure 1 for an example of a single opening sieve template and a C-shaped template.

4.2.2 Sieves, perforated plate sieves, 120 mm, 100 mm and 75.0 mm complying with ISO 3310-2.

4.3 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.
4.4 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.

4.5 Tape measure for determining particle size dimensions to estimate mass.

4.6 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.

4.7 Proportional callipers, of suitable size with ratios of 2:1 and 3:1. Refer to ASTM D5519 Figure 1 for an example of a proportional calliper.

4.8 Containers suitable for holding and weighing finer fractions.

4.9 Spray paint for marking larger rock.

4.10 Tags and markers or small signs for identifying fractions.

4.11 Hand tools including crowbars, shovels and so on.

4.12 Gloves, glasses and dust masks.

5 Sampling

5.1 The sampling shall be performed as follows:

5.2 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 should be appropriate for existing conditions, available resources and requirements of the specification. The sampling process is to provide a representative sample of the material.

5.3 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).

5.3.1 Determine the mass of the empty truck from a registered weighbridge (m₁) or the mass of empty containers using a balance (m₁).

5.3.2 A single sample is taken for testing and placed in the transport vehicle or containers.

5.3.3 Determine the mass of the truck and sample (m₂) from a registered weighbridge or the mass of containers and sample using a balance (m₂).

6 Procedure

The procedure shall be as follows:

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 (m₃)
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

Calculations shall be as follows:

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)
\[ m_a = \text{mass of truck/container and fraction (kg)} \]
\[ m_c = \text{mass of truck/container (kg)} \]

7.1.2 Calculate the cumulative mass retained for each fraction as follows:

\[ M = \sum m_r \]

where
\[ M = \text{cumulative mass retained in each fraction (kg)} \]
\[ m_r = \text{individual mass retained for each fraction (kg)} \]

7.1.3 Calculate the cumulative percent retained for each fraction as follows:

\[ P_r = \frac{100M}{\sum (m_2 - m_1)} \]

where
\[ P_r = \text{cumulative percent retained for each fraction (\%)} \]
\[ M = \text{cumulative mass retained in each fraction (kg)} \]
\[ m_2 = \text{mass of truck/container and sample (kg)} \]
\[ m_1 = \text{mass of truck/container (kg)} \]

7.1.4 Calculate the percent passing each fraction (to nearest 0.1\%) as follows:

\[ P = 100 - P_r \]

where
\[ P = \text{cumulative percent passing for each fraction (\%)} \]
\[ P_r = \text{cumulative percent retained for each fraction (\%)} \]

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:

\[ M_t = \sum m_r \]

where
\[ M_t = \text{mass of sample from particle size distribution (kg)} \]
\[ m_r = \text{individual mass retained for each test fraction (kg)} \]

7.2.2 For each test fraction calculate the percentage of flat rocks as follows:

\[ P_f = \frac{m_3}{m_r} \times 100 \]

where
\[ P_f = \text{percentage of flat rocks} \]
\[ m_3 = \text{mass of flat rocks in each test fraction (kg)} \]
\[ m_r = \text{individual mass retained for each test fraction (kg)} \]

7.2.3 For each test fraction calculate the percentage of elongated rocks as follows:
$$P_e = \frac{m_e}{m_t} \times 100$$

where $P_e$ = percentage of elongated rocks

$m_e$ = mass of elongated rocks in each test fraction (kg)

$m_t$ = 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:

$$P_{fe} = \frac{m_{fe}}{m_t} \times 100$$

where $P_{fe}$ = percentage of flat and elongated rocks

$m_{fe}$ = mass of flat and elongated rocks in each test fraction (kg)

$m_t$ = individual mass retained for each test fraction (kg)

7.2.5 For each test fraction calculate the percentage of non-cubical rocks as follows:

$$P_{nc} = \frac{m_{nc}}{m_t} \times 100$$

where $P_{nc}$ = percentage of non-cubical rocks

$m_{nc}$ = mass of non-cubical rocks in each test fraction (kg)

$m_t$ = individual mass retained for each test fraction (kg)

7.2.6 For each test fraction calculate the weighted percentage of flat rocks as follows:

$$P_{wf} = \frac{P_f m_t}{M_T}$$

where $P_{wf}$ = weighted percentage of flat rocks

$P_f$ = percentage of flat rocks

$m_t$ = 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:

$$P_{we} = \frac{P_e m_t}{M_T}$$

where $P_{we}$ = weighted percentage of elongated rocks

$P_e$ = percentage of elongated rocks

$m_t$ = individual mass retained for each test fraction (kg)
\[ M_T = \text{mass of sample from particle size distribution (kg)} \]

7.2.8 For each test fraction calculate the weighted percentage of flat and elongated as follows:

\[ P_{we} = \frac{P_{fe} m_r}{M_T} \]

where

\[ P_{we} \] = 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:

\[ P_{wnc} = \frac{P_{nc} m_r}{M_T} \]

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:

\[ MR = \sum P_{wf} + \sum P_{we} + \sum P_{wfe} \]

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
The following shall be recorded:

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
The following shall be reported:

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 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:
\[ m_{\text{min}} = \frac{1}{2} \left( 1 + \frac{\pi}{6} \right) D^3 \rho_{\text{st}} 1000 \frac{100}{P} \]

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>
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<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>
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<td>1600</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
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<td>800</td>
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</tr>
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<td>150</td>
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<td>± 0.05</td>
</tr>
<tr>
<td>100</td>
<td>100</td>
<td>0.01</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>
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</thead>
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<td>500</td>
<td>± 6.0</td>
</tr>
<tr>
<td>300</td>
<td>± 6.0</td>
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<td>200</td>
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<tr>
<td>150</td>
<td>± 3.0</td>
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