Materials Testing Manual

Part 10: Concrete
Test Method Q456: Sulfate content of hardened concrete

1 Source

This method was developed in-house with reference to the procedures described in A Text-Book of Quantitative Inorganic Analysis including Elementary Instrumental Analysis (3rd Edition) – Arthur I. Vogel: Section V, 6 – Determination of Sulphate as Barium Sulphate.

2 Scope

This method describes the procedure for determining the sulfate content of hardened concrete. Sulfate content of finely ground hardened concrete is determined gravimetrically as barium sulfate following hydrochloric acid extraction and precipitation of the sulfate with barium chloride solution.

3 Definition

For the purpose of this method, the following definition shall apply:

3.1 Constant mass – is attained when successive determinations of mass of the crucible do not vary by more than ± 0.0002 g.

4 Apparatus

The following apparatus is required:

4.1 Balance of suitable capacity, with a resolution of at least 0.0001 g and with a limit of performance within the range of 0.0005 g.
4.2 Drying oven of suitable capacity, having a temperature of 105 to 110°C and complying with AS 1289.0.
4.3 Furnace, capable of maintaining temperature up to 800°C.
4.4 Hotplate, capable of maintaining a temperature of 150-200°C.
4.5 Steam bath.
4.6 Volumetric flasks, of 100 mL capacity.
4.7 Measuring cylinders of 25 mL, 50 mL and 100 mL capacity.
4.8 Pipettes, of 10 mL capacity, graduated in 0.1 mL divisions.
4.9 Pasteur pipettes.
4.10 Pipette filler.
4.11 Glass filter funnels.
4.12 Beakers, of 400 mL and 600 mL capacity.
4.13 Watch glasses of approximately 100 mm in diameter.
4.14 Desiccator, containing silica gel desiccant or equivalent.
4.15 Crucibles, silica or platinum crucibles with lids.
4.16 Crucible tongs.
4.17 Container, approximately 350 mL capacity, plastic and sealed with an airtight lid.
4.18 Storage bottles (amber glass), of 250 mL capacity.
5 **Reagents**

All reagents are analytical reagent grade and the following are required (Notes 11.1 and 11.2):

5.1 **Ammonia solution, dilute:**
   - Dilute 25 mL of concentrated ammonia solution with distilled water (or equivalent) and make up to the mark in a 50 mL measuring cylinder.

5.2 **Hydrochloric acid, concentrated (31-32% w/w).**

5.3 **Hydrochloric acid, dilute:**
   - Using a graduated pipette, add 1 mL of concentrated hydrochloric acid to 90 mL of distilled water (or equivalent) in a 100 mL measuring cylinder and make up to 100 mL with distilled water (or equivalent).

5.4 **Methyl red indicator solution:**
   - Dissolve 0.1 g of methyl red indicator in distilled water (or equivalent) and make up to 100 mL with distilled water (or equivalent).

5.5 **Barium chloride solution:**
   - Dissolve 10 g of barium chloride in distilled water (or equivalent).
   - Transfer the solution to a 100 mL volumetric flask and make up to the mark with distilled water (or equivalent).

5.6 **Silver nitrate solution (Note 11.3):**
   - Dissolve 1 g of silver nitrate in distilled water (or equivalent).
   - Transfer the solution to a 100 mL volumetric flask and made up to the mark with distilled water (or equivalent).
   - Transfer the solution to a 250 mL amber glass storage bottle and store in a dark cupboard.

6 **Materials**

The following materials are required:

6.1 **Distilled water or equivalent (for example, reverse osmosis water).**

6.2 **Filter papers, Whatman No. 1, 40 and 542 or equivalent.**

7 **Sample preparation**

The sample shall be prepared as follows:

7.1 Crush the sample to obtain a representative subsample passing 0.150 mm fine screening sieve as detailed in Test Method Q101F.

7.2 Dry the subsample in an oven maintained at 105-110°C and allow to cool to room temperature.

7.3 Store the oven dried subsample in a sealed container.
8 Procedure

The procedure shall be performed as follows in duplicate:

8.1 Weigh a sample portion expected to be equivalent to about 1 g of cement into a 400 mL beaker and record the mass to the nearest 0.0001 g ($m_1$) (Note 11.4).

8.2 Disperse the sample by adding 25 mL of distilled water (or equivalent) and 10 mL of concentrated hydrochloric acid. If effervescence is evident, a watch glass may be placed over the top of the beaker.

8.3 Add 50 mL of hot distilled water (or equivalent) to the beaker, cover with the watch glass and boil the contents for 5 to 10 minutes on the hotplate.

8.4 Filter the solution through a Whatman No. 40 (or equivalent) filter paper, collecting the filtrate in a 600 mL beaker.

8.5 Wash the insoluble residue on the filter paper with 3 or 4 portions of 20 mL of hot dilute hydrochloric acid. Collect the washings in the 600 mL beaker containing the filtrate. Discard the remaining insoluble residue.

8.6 Heat the filtrate and the washings to boiling and add 5 drops of methyl red indicator solution using a pasteur pipette. Neutralise the solution by adding dropwise dilute ammonia solution until a colour change of from pink to yellow is observed.

8.7 Filter the solution through a Whatman No. 1 (or equivalent) filter paper, collecting the filtrate in a 400 mL beaker.

8.8 Wash the precipitate with 3 or 4 portions of 10 to 15 mL of hot distilled water (or equivalent). Collect the washings in the 400 mL beaker containing the filtrate. Discard this precipitate.

8.9 Add 1 mL of concentrated hydrochloric acid using a graduated pipette and pipette filler.

8.10 Place the beaker and contents on the hotplate and heat to boiling.

8.11 Remove the beaker from the hotplate and place on the steam bath to maintain gentle boiling of the contents.

8.12 Add barium chloride solution dropwise to the contents, ensuring that no interruption to the boiling occurs and until precipitation appears complete.

8.13 Remove the beaker from the steam bath and allow the precipitate to settle. Add a few drops of barium chloride solution to the clear supernatant liquid to ensure complete precipitation of barium sulfate has occurred.

8.14 If precipitation is incomplete, add additional barium chloride solution and return the beaker to the steam bath for 1 hour. Repeat Steps 8.12 to 8.14.

8.15 Once precipitation is complete, allow the beaker and contents to cool to room temperature and filter the contents carefully through a Whatman No. 542 (or equivalent) filter paper, ensuring that all of the precipitate is transferred from the beaker to the filter paper.

8.16 Wash the precipitate several times with portions of approximately 30 mL of boiling distilled water (or equivalent) until the washings are chloride free (Note 11.5). Discard the filtered solution.

8.17 Heat a crucible for approximately 30 minutes in the furnace at 600-800°C, cool to room temperature in a desiccator and weigh, recording the mass to the nearest 0.0001 g.
8.18 Repeat Step 8.17 until constant mass is attained. Record the mass of the final weighing to the nearest 0.0001 g ($m_1$).

8.19 Carefully transfer the filter paper containing the precipitate to the crucible and dry at approximately 100°C in the furnace.

8.20 Place the lid onto the crucible and gradually increase the temperature of the furnace to about 250°C over approximately 1 hour. Increase the temperature of the furnace further to 600 - 800°C and hold at this temperature for 1 hour.

8.21 Remove the crucible from the furnace, cool to room temperature in the desiccator and weigh to the nearest 0.0001 g.

8.22 Heat the crucible at 600 - 800°C for 15 to 20 minutes and repeat Step 8.20.

8.23 Repeat Step 8.22 until constant mass is attained. Record the mass of the final weighing to the nearest 0.0001 g ($m_3$).

9 Calculations

Calculations shall be as follows:

9.1 Calculate the sulfate content for each run of the procedure, to the nearest 0.1% using the relevant calculation as follows:

$$\text{SO}_4^{2-} = \frac{41.2(m_3 - m_2)}{m_1}$$

where $\text{SO}_4^{2-}$ = sulfate content expressed as $\text{SO}_4^{2-}$ (%)  
$m_1$ = mass of sample (g)  
$m_2$ = mass of crucible (g)  
$m_3$ = mass of crucible and residue (g)

$$\text{SO}_3 = \frac{34.3(m_3 - m_2)}{m_1}$$

where $\text{SO}_3$ = sulfate content expressed as $\text{SO}_3$(%)  
$m_1$ = mass of sample (g)  
$m_2$ = mass of crucible (g)  
$m_3$ = mass of crucible and residue (g)

9.2 Calculate the average of the two results and record as the sulfate content of the sample to the nearest 0.1%.

10 Reporting

Report the sulfate content expressed as $\text{SO}_4^{2-}$ or $\text{SO}_3$ to the nearest 0.1%.
11 Notes on method

11.1 Before handling chemicals and preparing reagents, the operator should consult the relevant SDS.

11.2 Unless otherwise indicated, all reagents are to conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.

11.3 Silver nitrate should be handled carefully to avoid any spillage of the solution which readily leaves black stains on bench tops and so on. Should staining occur, it can be removed using a reagent prepared by dissolving 75 g of each of thiourea and citric acid in 1 L of distilled water (or equivalent). This reagent is stable indefinitely.

11.4 Generally for hardened concrete, a 5 g sample approximates 1 g of cement.

11.5 To ensure the washings are free from chlorides, approximately 10 mL of the washings are acidified with 3 drops of concentrated nitric acid and silver nitrate is added dropwise. If a white precipitate or cloudiness forms, further washing of the precipitate with boiling distilled water are carried out until the addition of silver nitrate produces no white discoloration.
Test Method Q457B: Chloride content of hardened concrete - Mohr titration

1 Source
This method was developed in-house and is based on the procedures described in A Text-Book of Quantitative Inorganic Analysis including Elementary Instrumental Analysis (3rd Ed.) - Arthur Vogel: Section III, 23 - Standardisation of the Silver Nitrate Solution: Part A - with Potassium Chromate as Indicator. The Mohr Titration (contained within page 259 of this edition).

2 Scope
This method describes the procedure for determining the chloride content of hardened concrete. Chloride content is determined by acid extraction and titrimetric analysis of the extract for chloride ions using standardised silver nitrate.

3 Apparatus
The following apparatus is required:

3.1 Balances:
   a) balance of suitable capacity, readable to 0.1 g and with a limit of performance within the range of ± 0.5 g
   b) balance of suitable capacity, readable to 0.01 g and with a limit of performance within the range of ± 0.05 g, and
   c) balance of suitable capacity, readable to 0.0001 g and with a limit of performance within the range of ± 0.0005 g.

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

3.3 Furnace, capable of maintaining a temperature of 250°C.

3.4 Steam bath.

3.5 Volumetric flasks, of 100 mL, 250 mL and 1000 mL capacity.

3.6 Measuring cylinder (graduated) of 250 mL capacity.

3.7 Pipettes:
   3.7.1 Bulb type of 10 mL, 25 mL and 50 mL capacity.
   3.7.2 Graduated type of 1 mL capacity (graduated in 0.1 mL divisions).
   3.7.3 Pasteur pipettes.

3.8 Pipette filler.

3.9 Burette, of 50 mL capacity graduated in 0.1 mL divisions.

3.10 Filter funnels (glass).

3.11 Beakers, of 250 mL, 400 mL and 600 mL capacity.

3.12 Magnetic stirrer and stirring bar.

3.13 Desiccator, containing silica gel desiccant (or equivalent).

3.14 Storage bottles, of 100 mL and 250 mL, and one of 1000 mL capacity (amber glass).
3.15 pH meter or pH indicator paper.
3.16 Conical flasks, of 125 mL capacity.

4 Reagents

All reagents are analytical reagent grade and the following are required (Notes 11.1 and 11.2).

4.1 Standard sodium chloride solution.
   - Heat sodium chloride in a furnace maintained at 250°C for 2 hours and then cool in a desiccator.
   - Dissolve 1.6485 ± 0.0001 g of dry sodium chloride in distilled water (or equivalent).
   - Transfer the solution to a 1000 mL volumetric flask and make up to the mark with distilled water (or equivalent) (1 mL of this solution equals 1 mg of chloride).

4.2 Silver nitrate solution.
   - Dissolve 4.8 g of silver nitrate in distilled water (or equivalent).
   - Transfer the solution to a 1000 mL volumetric flask and make up to the mark with distilled water (or equivalent).
   - Transfer the solution to a 1000 mL amber glass storage bottle and store in a dark cupboard (Note 11.3).

4.3 Potassium chromate indicator solution.
   - Dissolve 5 g of potassium chromate in 80 mL of distilled water (or equivalent).
   - While stirring, add dropwise the silver nitrate solution until a permanent red precipitate is produced.
   - Filter the solution and dilute the filtrate by making up to the mark in a 100 mL volumetric flask with distilled water (or equivalent). Transfer the indicator solution to a 100 mL storage bottle.

4.4 Sulfuric acid solution.
   - Add 0.5 mL of concentrated sulfuric acid by means of a 1 mL graduated pipette to 180 mL of distilled water (or equivalent) in a measuring cylinder.
   - Transfer the solution to a 250 mL storage bottle.

4.5 Sodium carbonate solution.
   - Dissolve 1.1 g of sodium carbonate in 200 mL of distilled water (or equivalent) and transfer to a 250 mL storage bottle.

4.6 Phenolphthalein indicator solution.
   - Dissolve 0.5 g of phenolphthalein in 50 mL of 95% ethanol and then slowly add 50 mL of distilled water (or equivalent) with constant stirring.
   - Filter the solution and transfer to a 100 mL storage bottle.

4.7 Sodium hydroxide solution.
   - Dissolve 5.1 g of sodium hydroxide in distilled water (or equivalent).
   - Transfer the solution to a 250 mL volumetric flask and make up to the mark with distilled water (or equivalent).
4.8 Nitric acid, concentrated.

5 Materials
The following materials are required:

5.1 Distilled water or equivalent (for example, reverse osmosis water).
5.2 Filter paper, Whatman No 1 or equivalent.

6 Standardisation of silver nitrate solution
The standardisation shall be performed as follows:

6.1 Perform Steps 6.2 to 6.5 in triplicate.
6.2 Pipette a 25 mL aliquot of standard sodium chloride solution into a 125 mL conical flask.
6.3 Add 1 mL of potassium chromate indicator solution to the flask by pasteur pipette.
6.4 Stir the solution using a magnetic stirring bar and titrate with silver nitrate solution to the first permanent red-brown colour change.
6.5 Record the titre value to the nearest 0.1 mL.
6.6 Calculate the average of the three titre determinations and record it as the molarity of the silver nitrate solution to the nearest 0.01.

7 Sample preparation
The sample shall be prepared as follows:

7.1 Crush the sample of hardened concrete to obtain a representative subsample of 750 g passing 0.150 mm sieve as detailed in Test Method Q101F.
7.2 Dry the subsample at 105 to 110°C and then allow to cool to room temperature.
7.3 Store the oven dried sample in a sealed container.

8 Procedure
The following procedure shall be performed in duplicate:

8.1 Weigh a portion of the sample to be equivalent to about 2 g of cement into a 250 mL beaker and record the mass to the nearest 0.0001 g (m) (Note 11.4).
8.2 Disperse the sample with 25 mL of distilled water (or equivalent) and 10 mL of concentrated nitric acid. Add 50 mL of hot distilled water (or equivalent) and place the beaker on a steam bath for 10 to 15 minutes.
8.3 Filter the solution and transfer all the material to the filter paper using a minimum quantity of distilled water (or equivalent). Wash the material retained on the filter paper with three 50 mL portions of distilled water (or equivalent). Collect the filtrate and washings in a 600 mL beaker. Discard the insoluble residue.
8.4 Adjust the pH of the filtrate to a value of 8.2 using the sodium hydroxide solution (Note 11.5).
8.5 If necessary, place the beaker on a steam bath and reduce the volume to approximately 250 mL.
8.6 Filter the solution into a 400 mL beaker. Transfer all of the precipitate to the filter paper from the 600 mL beaker using distilled water (or equivalent).
8.7 Wash the precipitate with three 10 mL portions of distilled water (or equivalent) and collect the washings in the 400 mL beaker containing the filtrate. Discard the insoluble residue.

8.8 Cool the filtrate to room temperature and add 2 mL of potassium chromate indicator.

8.9 Stir the solution using a magnetic stirring bar and titrate with silver nitrate solution to the first permanent red-brown colour change. For lengthy titrations, add additional 1 mL increments of potassium chromate indicator for every 10-15 mL of silver nitrate solution used.

8.10 Record the volume of the silver nitrate solution to the nearest 0.1 mL (V_t).

8.11 Carry out a blank determination using approximately 250 mL of distilled water (or equivalent).

8.12 Record the volume of silver nitrate solution to the nearest 0.1 mL (V_b).

9 Calculations
Calculations shall be as follows:

9.1 Calculate the chloride content for each run of the procedure to the nearest 1 part per million (ppm) as follows:

\[
C = \frac{25000(V_t - V_b)}{V_m}
\]

where

- \(C\) = chloride content of sample (ppm)
- \(V_t\) = volume of silver nitrate solution titrated against the sample extract (mL)
- \(V_b\) = volume of silver nitrate solution titrated against the blank (mL)
- \(V\) = average volume of silver nitrate solution titrated during standardisation (mL)
- \(m\) = mass of sample portion (g)

9.2 Calculate and record the average of the two results as the chloride content of the sample to the nearest 1 ppm.

10 Reporting
Report the chloride content of the sample to the nearest 10 ppm.

11 Notes on method
11.1 Before handling chemicals and preparing reagents, the operator should consult the relevant SDS.

11.2 Unless otherwise indicated, all reagents are to conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.

11.3 Silver nitrate should be handled carefully to avoid any spillage of the solution which readily leaves black stains on bench tops and so on. Should staining occur, it can be removed using a reagent prepared by dissolving 75 g of each of thiourea and citric acid in 1 L of distilled water. This reagent is stable indefinitely.

11.4 Generally for hardened concrete, approximately 10 g of sample is equivalent to approximately 2 g of cement.
11.5 Sulfuric acid solution may be used if the pH of the solution goes above 8.2.
Test Method Q460A: Compressive stress and recovery of preformed joint filler

1 Source
This method is based on ASTM D545-84: Preformed expansion joint fillers for concrete construction (non-extruding and resilient types) Section 7.2: Recovery and compression, with only minor variations.

2 Scope
This method describes the procedure for determining, under specified conditions, both the stress required to compress preformed joint filler to a set strain level, and then the recovery of the filler material once the compressive force has been removed.

3 Apparatus
The following apparatus is required:

3.1 Compression testing machine, at least Class A as defined in AS 2193, with a moveable lower platen which travels at a uniform vertical rate of 1.3 mm/minute when measured loaded.

3.2 Compression platens, having machined parallel bearing surfaces at least 12.5 mm thick and of sufficient area to provide at least 10 mm clearance between the edge of the specimen and any edge of the platen.

3.3 Vertical displacement measuring system, to allow the measurement of the vertical displacement at the centre of the specimen. The system can use a dial gauge complying with the requirements of AS 2103, which has a scale interval of 0.01 mm and a minimum range of 30 mm, or a displacement transducer or any equivalent system of at least equal performance.

3.4 Force application assembly, incorporating a spherical seat.

3.5 Glass beaker, or similar heat resistant container having a capacity of approximately 5 L (Note 7.1).

3.6 Hotplate, with temperature control capable of maintaining a temperature of at least 110°C (Note 7.1).

4 Procedure
The procedure shall be as follows:

4.1 Sample Preparation
4.1.1 For self-expanding cork joint fillers only, boil a 120 mm x 120 mm sample for 1 hour (using the glass beaker and hot plate) and air dry for 24 hours.

4.1.2 Cut a test specimen, 100 mm square (tolerance ± 0.5 mm), from the preformed joint filler such that each edge is freshly cut.

4.2 Testing
4.2.1 Locate the lower and upper compression platens centrally on the lower platen of the testing machine. Place the displacement measuring system above the centre of the upper platen and record the dial gauge reading (\(d_1\)).

4.2.2 Raise the upper platen by hand and locate the test specimen centrally between the platens. Record the dial gauge reading (\(d_2\)).
4.2.3 Using the force application assembly, apply and record the maximum force \( F \) necessary to compress the specimen to 50 per cent of its original thickness (Note 7.2).

4.2.4 Immediately remove the force from the specimen and allow it to recover for 30 minutes with the upper platen, the displacement measuring system and the load application assembly in place.

4.2.5 Repeat Steps 4.2.3 and 4.2.4 applying sufficient force to again achieve a compression of 50 per cent of the original thickness.

4.2.6 Compress the test specimen a third time by repeating Step 4.2.5.

4.2.7 Immediately remove the force, disassemble the testing apparatus and allow the specimen to recover unrestrained for 24 hours.

4.2.8 At the end of the recovery period, locate the lower and upper compression platens on a flat surface such as the lower platen of the testing machine. Place the displacement measuring system above the centre of the upper platen and record the dial gauge reading \( d_4 \).

4.2.9 Raise the upper platen by hand and locate the recovered test specimen centrally between the platens. Record the dial gauge reading \( d_4 \).

5  Calculations

Calculate shall be as follows:

5.1 Calculate the applied stress \( S \) as follows:

\[
S = \frac{F}{A}
\]

where

- \( S \) = applied stress (MPa)
- \( F \) = force required to achieve 50% thickness (N)
- \( A \) = area of test specimen (mm\(^2\)) (taken as 10,000 mm\(^2\))

5.2 Calculate the percentage recovery \( R \) as follows:

\[
R = \frac{100(d_4 - d_3)}{d_2 - d_1}
\]

where

- \( R \) = recovery (%)
- \( d_4 \) = dial gauge reading for upper platen with recovered specimen (mm)
- \( d_3 \) = dial gauge reading for upper platen after testing (mm)
- \( d_2 \) = dial gauge reading for upper platen with untested specimen (mm)
- \( d_1 \) = dial gauge reading for upper platen before testing (mm)

6  Reporting

The following shall be reported:

6.1 Applied stress to the nearest 0.1 MPa.

6.2 Percentage recovery to the nearest 0.5%.
7 Notes on method

7.1 The glass beaker and hotplate are only required when a self-expanding cork joint filler is to be tested.

7.2 The dial gauge reading corresponding to 50 per cent compression is calculated as follows:

\[ d_{50} = d_1 + \frac{(d_2 - d_1)}{2} \]

where
- \( d_{50} \) = dial gauge or transducer reading corresponding to 50% compression (mm)
- \( d_1 \) = dial gauge reading for upper platen before testing (mm)
- \( d_2 \) = dial gauge reading for upper platen with untested specimen (mm)
Test Method Q460B: Extrusion of preformed joint filler

1 Source
This method is based on ASTM D545-84: Preformed expansion joint fillers for concrete construction (non-extruding and resilient types), Section 7.3: Extrusion, with only minor variations.

2 Scope
This method describes the procedure for determining the extrusion of preformed joint filler when subjected to a compressive force under specified conditions.

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

The following apparatus is required:

3.1 Compression testing machine, at least Class A as defined in AS 2193, with a moveable lower platen which travels at a uniform vertical rate of 1.3 mm/minute when measured loaded.

3.2 Metal mould with a base of 100 mm x 100 mm, a thickness of 11 mm, and three sides which are at least 50 mm high and 5 mm thick (Note 7.1).

3.3 Compression platen, having machined parallel bearing surfaces 100 mm x 100 mm and at least 5 mm thick (Note 7.1).

3.4 Vertical displacement measuring system, to allow the measurement of the vertical displacement at the centre of the specimen. The system can use a dial gauge complying with the requirements of AS 2103, which has a scale interval of 0.01 mm and a minimum range of 30 mm, or a displacement transducer of at least equal performance.

3.5 Force application assembly, incorporating a spherical seat.

3.6 Horizontal displacement measuring system, to allow the measurement of the horizontal displacement of the specimens. The system can use a dial gauge complying with the requirements of AS 2103, which has a scale interval of 0.01 mm and a minimum range of 10 mm, and is fitted with a disk shaped contact and mounted on a stand, or other suitable assembly to allow the horizontal displacement of the specimen to be measured.

3.7 Glass beaker, or similar heat resistant container having a capacity of approximately 5 L (Note 7.2).

3.8 Hotplate, with temperature control capable of maintaining a temperature of at least 110°C (Note 7.2).

4 Procedure
The procedure shall be as follows:

4.1 Sample preparation

4.1.1 For self-expanding cork joint fillers only, boil a 120 mm x 120 mm sample for 1 hour (using the glass beaker and hot plate) and air dry for 24 hours.

4.1.2 Cut a test specimen, 100 mm square (tolerance ± 0.5 mm), from the preformed joint filler such that each edge is freshly cut.
4.2 Testing

4.2.1 Locate the mould and compression platen centrally on the lower platen of the testing machine. Place the vertical measuring system above the centre of the compression platen and record the dial gauge reading ($d_1$).

4.2.2 Remove the compression platen and place the specimen in the mould. Replace the platen and align it such that it is flush with the open side of the mould and is centrally located between the adjacent sides. Record the dial gauge reading ($d_2$).

4.2.3 Locate the horizontal measuring system such that the contact is touching the free edge of the specimen. Record the dial gauge reading ($d_3$).

4.2.4 Using the load application assembly, apply and record the force necessary to compress the specimen to 50 per cent of its original thickness (Note 7.3).

4.2.5 Immediately read and record the reading ($d_4$) of the dial gauge in the horizontal system being used to measure extrusion of the specimen.

5 Calculations

Calculate the extrusion as follows:

$$E = d_3 - d_4$$

where

- $E$ = extrusion (mm)
- $d_3$ = dial gauge reading before compression (mm)
- $d_4$ = dial gauge reading after compression (mm)

6 Reporting

Report the extrusion to the nearest 0.01 mm.

7 Notes on method

7.1 The compression platen is required to fit firmly into the mould without binding with any side.

7.2 The glass beaker and hotplate are only required when a self-expanding cork joint filler is to be tested.

7.3 The dial gauge reading corresponding to 50 per cent compression is calculated as follows:

$$d_{50} = d_1 + \frac{(d_2 - d_1)}{2}$$

where

- $d_{50}$ = dial gauge or transducer reading corresponding to 50% compression (mm)
- $d_1$ = dial gauge reading for upper platen before testing (mm)
- $d_2$ = dial gauge reading for upper platen with untested specimen (mm)
**Table 1 – Working tolerances for apparatus**

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<th>Value</th>
<th>Tolerance</th>
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Test Method Q460C: Expansion of preformed self-expanding joint filler

1 Source
This method is based on ASTM D545-84: Preformed expansion joint fillers for concrete construction (non-extruding and resilient types), Section 7.1: Expansion in boiling water, with only minor variations.

2 Scope
This method describes the procedure for determining the expansion of self-expanding joint filler in boiling water.

3 Apparatus
The following apparatus is required:

3.1 Glass beaker, or similar heat resistant container having a capacity of approximately 5 L.
3.2 Hotplate, with temperature control capable of maintaining a temperature of at least 110°C.
3.3 Digital calliper, with a resolution of at least 0.1 mm and complying with AS 1984.

4 Procedure
The procedure shall be as follows:

4.1 Sample preparation
Cut two test specimens, 114 mm square (tolerance ± 2.5 mm), from the self-expanding joint filler such that each edge is freshly cut.

4.2 Testing
4.2.1 Measure and record the average initial thickness of each test specimen to the nearest 0.1 mm ($t_1$).

4.2.2 Half fill the beaker with water and bring to the boil.

4.2.3 Immerse one of the specimens in the boiling water for 1 hour.

4.2.4 At the end of this period, remove the specimen and allow it to cool at room temperature for 15 minutes.

4.2.5 Measure and record the average thickness of the specimen to the nearest 0.1 mm ($t_2$).

4.2.6 Repeat Steps 4.2.2 to 4.2.5 for the second specimen.
5 Calculations

Calculations shall be as follows:

5.1 Calculate the percentage expansion for each specimen as follows:

\[ E = \frac{100(t_2 - t_1)}{t_1} \]

where  
- \( E \)  = expansion (%)  
- \( t_2 \)  = average final thickness of specimen (mm)  
- \( t_1 \)  = average initial thickness of specimen (mm)

5.2 Calculate the expansion as the average expansion for the two specimens.

6 Reporting

Report the expansion of the self-expanding joint filler to the nearest 1%.
Test Method Q460D: Accelerated weathering of preformed joint filler

1 Source
This method is based on ASTM D545-67: Preformed expansion joint fillers for concrete construction (non-extruding and resilient types), with only minor variations.

2 Scope
This method describes the procedure for determining the weathering resistance of joint filler materials.

3 Apparatus
The following apparatus is required:
3.1 Drying oven, capable of maintaining a temperature of 75 ± 1°C.
3.2 Cabinet, capable of maintaining a temperature between -10°C and -20°C.
3.3 Water bath, capable of maintaining a temperature between 20°C and 40°C.
3.4 Metal test container, at least 100 mm deep and 120 mm in diameter.
3.5 Glass beaker, or similar heat resistant container having a capacity of approximately 5 L (Note 6.1).
3.6 Hotplate, with temperature control capable of maintaining a temperature of at least 110°C (Note 6.1).
3.7 Clamps, for holding the test specimens in the metal test container.

4 Procedure
The procedure shall be as follows:

4.1 Sample preparation
4.1.1 For self-expanding cork joint fillers only, boil a 120 mm x 120 mm sample for 1 hour (using the glass beaker and hot plate) and air dry for 24 hours.
4.1.2 Cut a test specimen, 100 mm square (tolerance ± 0.5 mm), from the preformed joint filler such that each edge is freshly cut.

4.2 Testing
4.2.1 Place the two test specimens in the oven for a period of 7 days.
4.2.2 At the end of this period, remove the specimens and immerse them in a partly filled beaker of water at room temperature for 24 hours.
4.2.3 Place the specimens on edge in the metal test container and clamp them securely in position such that they are not in contact with each other.
4.2.4 Partly fill the container with water to a depth of 50 mm (half the depth of the specimens), then place the container in the cabinet until the water has frozen.
4.2.5 Remove the container from the cabinet and partly immerse the container in the water bath until the ice in the test container has completely melted.
4.2.6 Repeat Steps 4.2.4 to 4.2.5 until 10 cycles have been completed.
4.2.7 At the completion of the last cycle, remove the specimens from the container and allow them to stand at room temperature for 48 hours.

4.2.8 Examine each specimen and record details of any evidence of disintegration.

5 Reporting

Report any evidence of disintegration of each specimen.

6 Notes on method

6.1 The glass beaker and hotplate are only required when a self-expanding cork joint filler is to be tested.
Test Method Q460E: Resistance to heat degradation of closed cell foam joint filler

1 Source

This method applies the principles of RMS Test Method T1154: Resistance to heat degradation of closed cell foam joint filler. It differs from this method in that details for the making and curing of the mortar blocks are included.

2 Scope

This method describes the procedure for determining the resistance of closed cell foam joint filler to degradation from contact with hot poured joint sealant when using these materials together in a formed joint system.

3 Apparatus

The following apparatus is required:

3.1 Mortar moulds, 50 mm x 50 mm and 25 mm thick.
3.2 Glass plate, at least 150 mm x 150 mm.
3.3 Masking tape, 25 mm wide.
3.4 Scalpel, or similar sharp cutting tool.
3.5 Heating container and lid, made of metal with a diameter of approximately 100 mm, a depth of approximately 150 mm and a maximum wall thickness of 1 mm. The lid must have access holes for a thermometer and a mechanical stirrer.
3.6 Mechanical stirrer and stand.
3.7 Thermometer, a partial or total immersion thermometer or other suitable temperature measuring device having a temperature range of at least 0°C–300°C and graduated to 5°C or less with an uncertainty of no more than 5°C.
3.8 Oil bath, containing silicone oil or an oil with a flash point in excess of 285°C, equipped with a mechanical stirrer.
3.9 Ruler, with a scale interval of 0.5 mm.
3.10 Trowel, made of steel with a blade approximately 100 mm–150 mm long.
3.11 Tamper, made of a rubber compound with a Shore A hardness of 80 ± 10 or of seasoned hardwood which has been immersed in paraffin wax at 200°C for 15 minutes. The tamper shall have a rectangular face, 13 mm x 25 mm, which is at right angles to the length of the tamper. A convenient tamper length is 125 mm to 150 mm.

4 Materials

The following materials are required:

4.1 Mould oil, a light oil such as Caltex Mould Oil 20 (Notes 7.1 and 7.2).
4.2 Hot poured joint sealant (Note 7.1).
4.3 Release agent, for example, Potash soap (Note 7.1).
4.4 General purpose cement (GP).
4.5 Sand.
4.6 Water.
4.7 Masking tape.

5 Procedure

The procedure shall be as follows:

5.1 Preparation of cement mortar test blocks

5.1.1 Lightly oil two moulds, base plates and covers.
5.1.2 Mix 1 part of GP cement with 1.5 parts of sand by mass, adding sufficient water to the mixture to produce a consistency suitable for tamping. Mix the mortar for approximately 3 minutes.
5.1.3 Fill both the moulds in two equal layers, compacting each layer fully using the tamper.
5.1.4 Strike off the excess mortar and smooth the surface using the trowel, then place the covers on the moulds.
5.1.5 Undertake initial curing and standard moist curing as detailed in AS 1012.8, Clause 1.9.
5.1.6 At the completion of at least 7 days standard moist curing, surface dry the mortar blocks so they are ready for the application of the release agent.

5.2 Preparation of hot poured joint sealing compound

5.2.1 Heat the oil bath with the heating container fixed into position until the oil temperature is in the range 190°C - 220°C.
5.2.2 Melt approximately 250 g of hot poured joint sealant by placing of approximately 50 g pieces of the compound in the heating container at approximately 30 second intervals.
5.2.3 Place the lid on the container and insert the thermometer and mechanical stirrer.
5.2.4 Commence mixing the joint sealant and continue heating until its temperature is 190°C.

5.3 Sample preparation

5.3.1 Cut a test specimen 50 mm long and 25 mm wide from a sample of closed cell foam filler.

5.4 Testing

5.4.1 Apply release agent to one 50 mm square face of each cement mortar block.
5.4.2 Place the cement blocks on the glass plate such that the coated surfaces are facing each other in the vertical plane and are separated by at least the thickness of the specimen. Locate the test specimen centrally between the blocks such that a face formed by its 50 mm length and thickness is in contact with the glass plate.
5.4.3 Apply sufficient pressure to the mortar blocks to ensure there is intimate contact between the blocks and the foam filler. Wrap masking tape around the blocks and the foam filler to form a reservoir 25 mm deep, 50 mm long and having a width equal to the thickness of the specimen.
5.4.4 Rapidly fill the reservoir with hot poured sealant and allow the mould to stand for 24 hours at 16°C to 25°C.
5.4.5 Remove the filler and sealant from the mould.
5.4.6 Place the filler/sealant combination on a flat surface and cut through the two compounds along a line at right angles to the filler/sealer interface.
5.4.7 Measure the amount of penetration of the sealant into the filler to the nearest 0.5 mm at a number of locations along the interface.

6 Reporting

Report the average depth of penetration to the nearest 1 mm as the resistance to heat degradation.

7 Notes on method

7.1 Before handling oil, release agent or joint sealant, the operator should consult the relevant SDS.

7.2 Other mould oils such at Shellmould P5, Reochem Mould Oil 20 and Caltex Mould Oil 222 have also been found to be suitable.
Test Method Q460F: Resistance to disintegration of preformed cork joint filler

1 Source

This method is based on ASTM D545-84: *Preformed expansion joint fillers for concrete construction (non-extruding and resilient types)*, Section 7.4: *Boiling in hydrochloric acid, with only minor variations*.

2 Scope

This method describes the procedure for assessing the effectiveness of the bonding materials in preformed cork joint fillers used to bond the granulated particles of natural cork.

3 Apparatus

The following apparatus is required:

3.1 Glass beaker, having a capacity of at least 5 L (Note 7.1).

3.2 Fume cabinet.

3.3 Hotplate, with temperature control capable of maintaining a temperature of at least 110ºC (Note 7.1).

4 Reagent

The following reagent is required:

4.1 Hydrochloric acid, 12.4M (concentrated) (Note 7.2).

5 Procedure

The procedure shall be as follows:

5.1 Sample preparation

5.1.1 For self-expanding cork joint fillers only, boil a 120 mm x 120 mm sample for 1 hour (using the glass beaker and hot plate) and air dry for 24 hours.

5.1.2 Cut a test specimen, 100 mm square (tolerance ± 0.5 mm), from the preformed joint filler such that each edge is freshly cut.

5.2 Testing

5.2.1 Half fill the beaker with hydrochloric acid and bring the acid to the boil using a hotplate located in a fume cabinet with the fume cabinet extraction system operating.

5.2.2 Immerse the specimen in the boiling hydrochloric acid for 1 hour.

5.2.3 Remove the specimen from the beaker and wash the specimen under running water.

5.2.4 Examine the test specimen and note any signs of disintegration, delamination, porosity or dislodged particles of cork.

5.2.5 Use the fingers to test for friability, lack of resiliency and resistance to abrasion by rubbing.

6 Reporting

Report any defects, ignoring discolouration and slight swelling.
7 Notes on method

7.1 The glass beaker and hotplate are only required when a self-expanding cork joint filler is to be tested.

7.2 Before handling concentrated hydrochloric acid, the operator should consult the relevant SDS.
Test Method Q461: Durability of sealant

1 Source

This method is based on RMS Test Method T1192-1992: Adhesion of sealant, and RMS Test Method T1193-1991: Accelerated aging of cured sealant, with only minor variations.

2 Scope

This method describes the procedure to assess the durability of sealant bonded to a substrate when tested for adhesion and cohesion. The method is applicable to sealant used to seal sawn joints in concrete pavements.

3 Apparatus

The following apparatus is required:

3.1 Oven, capable of maintaining a temperature of 70 ± 3°C within all of the working space or a defined area of sufficient size to accommodate the test specimen assembly.

3.2 Refrigerated cabinet, capable of maintaining a temperature of 0 ± 3°C.

3.3 Water bath, capable of maintaining a temperature of 35 ± 1°C and of sufficient size to allow immersion of the test specimen assembly to a depth of at least 20 mm below the surface.

3.4 Cabinet, capable of maintaining a temperature of 23 ± 2°C.

3.5 Testing machine, capable of applying tensile and compressive forces at a rate of travel of 10 mm/minute.

3.6 Mould, made from non-absorbent material that will not react with concrete and be able to cast a concrete prism, 50 mm x 140 mm and about 200 mm long.

3.7 Saw, diamond tipped masonry saw.

3.8 Spacer blocks, made from non-absorbent material with machined surfaces 13 mm x 20 mm x 31 mm.

3.9 Backing foam, 15 mm thick.

3.10 Clamps, for example G clamps or quick release clamps.

3.11 Tension and compression testing jig, as shown in Figure 1.

3.12 Digital calliper, with a resolution of at least 0.1 mm and complying with AS 1984.

3.13 Vertical displacement measuring system, to measure the extension and compression of the moulded sealant. The system can use a dial gauge complying with the requirements of AS 2103 with a scale interval of 0.01 mm and a minimum travel of 25 mm, or a displacement transducer of at least equal performance.

4 Materials

The following materials are required:

4.1 Release agent, for example, Potash Soap.

4.2 Concrete.

4.3 Paper towel.
5 Procedure

The procedure shall be as follows:

5.1 Preparation of concrete blocks

5.1.1 Mould a concrete prism using at least 40 MPa concrete and allow it to cure for at least 28 days as detailed in AS 1012.8.1.

5.1.2 Cut 6 concrete blocks from the prism using the masonry saw, such that each block has 2 flat cut faces, 50 mm x 140 mm, and is approximately 25 mm thick.

5.1.3 Condition the blocks using one of the following methods:
   a) dry blocks: allow the blocks to dry at room temperature for 7 days after cutting
   b) dry abraded blocks: allow the blocks to dry at room temperature for 7 days after cutting, then blast one flat surface (the bonding face) on each block with grit abrasive, or
   c) saturated surface-dry blocks: immerse the blocks in water at room temperature for 2 hours, then remove the blocks and blot them dry with folded paper towel to remove surface water.

5.2 Moulding of sealant

Mould 3 specimens of sealant as detailed below:

5.2.1 Apply the release agent to a 13 mm x 31 mm surface of each spacer block, that is, the face that will contact the sealant.

5.2.2 Cut a strip from the 15 mm thick backing foam, 100 mm x 19 mm (tolerance ± 0.5 mm). Apply release agent to the 100 mm x 15 mm face that will contact the sealant.

5.2.3 Assemble the concrete blocks, spacer blocks and foam using the clamps to hold the components in place such that a formed cavity 100 mm long, 13 mm wide and 12 mm deep between the blocks after compressing the foam to a thickness of 13 mm. Refer to Figure 2.

5.2.4 Prepare the sealant according to the manufacturer's instructions and fill the cavity with sealant to the top of the spacer blocks.

5.2.5 Allow the sealant to cure for 7 days at 23 ± 2°C before removing the spacer blocks and backing foam.

5.3 Aging

Age the 3 specimens of sealant as detailed below:

5.3.1 Air cure the test specimen assemblies in the oven for 72 hours at 70 ± 3°C.

5.3.2 Air cure the test specimen assemblies in the refrigerated cabinet for 24 hours at 0 ± 3°C.

5.3.3 Submerge the test specimen assemblies in the water bath and cure for 48 hours at 35 ± 1°C.

5.3.4 Air cure the test specimen assemblies for 24 hours at 23 ± 2°C.

5.4 Testing

5.4.1 Measure the distance between the faces of the concrete blocks for one of the test specimen assemblies by taking at least three measurements along the top surface of the sealant and three measurements along the bottom surface.

5.4.2 Place the test specimen assembly in the testing jig and secure the concrete blocks firmly in the jaws.
5.4.3 Attach the testing jig to the testing machine maintaining the distance between the blocks as measured in Step 5.4.1.

5.4.4 Cycle the sealant specimen through 100 cycles of 70 per cent extension and 50 per cent compression as measured by the displacement measuring system (Note 7.2).

5.4.5 During the extension and compression cycles, monitor the specimen for cohesion failure or adhesion failure as follows:
   a) cohesion Failure - assess the extent of any cracking of the specimen during compression using a fine wire such as a straightened paper clip to probe the depth of any crack. Where the degree of failure is equal to or greater than 10 percent of the cross-sectional area of the specimen, record the specimen as a fail, or
   b) adhesion Failure - assess the extent of any debonding at both sealant/concrete block interfaces. Again, use a fine wire such as a straightened paper clip to probe the extent of any debonding. Where the degree of failure at either interface equal to or greater than 10 percent of the cross-sectional area of the specimen, record the specimen as a fail.

5.4.6 Repeat Steps 5.4.1 to 5.4.5 for the remaining two test specimen assemblies. If no more than one specimen fails the test, the sealant is acceptable. Otherwise the sealant is unacceptable.

6 Reporting

Report the durability of the sealant as either acceptable or unacceptable.

7 Notes on method

7.1 Before handling release agent or concrete, the operator should consult the relevant SDS.

7.2 The extension and compression are determined from the specimen width measured in Step 5.4.1.
Figure 1 – Testing jig

LEGEND

- Concrete Block
- Sealant

METAL SPACER

STEEL JAWS

4 SCREWS AT EACH END
Figure 2 – Test specimen assembly
Test Method Q462: Resistance of vulcanised rubber to the absorption of oil

1 **Source**

This method is based on ASTM D471-96: *Rubber property – Effects of liquids*, Section 10: *Procedure for change in mass*, with only minor variations.

2 **Scope**

This method describes the procedure for determining the resistance of vulcanized rubber to absorption and consequent swelling when immersed in a standard oil.

3 **Apparatus**

The following apparatus is required:

3.1 Balance of suitable capacity, having a resolution of at least 0.0001 g and with a limit of performance within the range of ± 0.0005 g.

3.2 Test tube, having a diameter of 38 mm and a length of 300 mm fitted with a stopper.

3.3 Frame, for holding the test specimens in the test tube, for example, a wire frame with a horizontal arm.

3.4 Water bath, capable of maintaining a temperature of 50 ± 2ºC.

3.5 Petri dish.

4 **Materials**

The following materials are required:

4.1 Standard oil, IRM 903 (Note 8.1).

4.2 Acetone (Note 8.1).

5 **Procedure**

The procedure shall be as follows:

5.1 **Sample Preparation**

5.1.1 Cut three test specimens from the rubber sample, 25 mm x 50 mm (tolerance ± 0.5 mm) with a thickness of 2.0 ± 0.1 mm. Test samples with a thickness less than specified as received. Buff the samples with a thickness above the upper tolerance to a thickness of 2.0 ± 0.1 mm.

5.1.2 Drill a small hole in each specimen near one end to allow the suspension of the specimens in the test tube.

5.2 **Testing**

5.2.1 Determine the mass of each test specimen (m₁).

5.2.2 Pour 100 mL of oil into the test tube.

5.2.3 Suspend the test specimens from the frame and immerse the specimens in the oil.

5.2.4 Stopper the test tube and place the test tube in the water bath for 22 hours at 50ºC.

5.2.5 At the end of the immersion period, remove the specimens from the oil and allow them to cool in a container of clean oil at room temperature for 30 to 60 minutes.
5.2.6 After cooling, dip each specimen in turn in acetone, blot lightly with filter paper and place immediately in a petri dish of known mass ($m_1$).

5.2.7 Determine the mass of each specimen and petri dish ($m_3$).

6 Calculations

Calculations shall be as follows:

6.1 Calculate the gain in mass for each specimen as a percentage of its original mass as follows:

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

where $M$ = gain in mass (%)
$m_3$ = mass of oil soaked specimen and petri dish (g)
$m_2$ = mass of petri dish (g)
$m_1$ = mass of untested specimen (g)

7 Reporting

Report the average mass gain as the oil absorption to the nearest 0.5%.

8 Notes on method

8.1 Before handling oil or acetone, the operator should consult the relevant SDS.
Test Method Q463A: High temperature recovery of preformed polychloroprene elastomeric joint seals

1 **Source**

This method is based on RMS T1161: *High temperature recovery of polychloroprene elastomeric joint seals for bridge structures*, with only minor variations.

2 **Scope**

This method describes the procedure for determining the high temperature recovery of compressed polychloroprene elastomeric seals used for bridge structures.

3 **Apparatus**

The following apparatus is required:

3.1 Digital calliper, with a resolution of at least 0.2 mm and complying with AS 1984.

3.2 Compression plates, 125 mm x 200 mm, at least 5 mm thick and chrome plated or otherwise protected from corrosion. The plates shall be drilled at each corner and fitted with 10 mm diameter bolts and nuts.

3.3 Oven, capable of maintaining a temperature of 100 ± 1ºC.

3.4 Room, capable of maintaining a temperature of 23 ± 2ºC.

4 **Procedure**

The procedure shall be as follows:

4.1 **Sample Preparation**

Cut a test specimen 125 mm long from the joint seal.

4.2 **Testing**

4.2.1 Measure and record the width \( w_1 \) of the test specimen at the centre of the top surface of the seal, that is, the face to be exposed to traffic. Mark the position where the measurement was made.

4.2.2 Place the test specimen centrally between the compression plates such that the top surface is at right angles to the plates and the longitudinal axis of the specimen is parallel to the longitudinal axes of the compression plates.

4.2.3 Compress the joint seal uniformly between the compression plates by tightening the nuts on the bolts, ensuring that the top surface of the seal folds inwards towards the centre of the specimen. Continue until the specimen has been compressed to 50 per cent of its original thickness.

4.2.4 Place the compressed specimen in the oven for 72 hours.

4.2.5 At the end of the 72 hour period, remove the specimen from the oven, unclamp the compression plates and allow the specimen to recover at 23ºC for 1 hour.

4.2.6 Immediately measure the recovered width \( w_2 \) of the marked centre position of the specimen.
5 Calculations

Calculate the percentage recovery as follows:

\[ R = \frac{w_2}{w_1} \times 100 \]

where

- \( R \) = high temperature recovery (\%)
- \( w_2 \) = recovered specimen width (mm)
- \( w_1 \) = original specimen width (mm)

6 Reporting

Report the high temperature recovery to the nearest 0.5\%.
Test Method Q463B: Low temperature recovery of preformed polychloroprene elastomeric joint seals

1 Source
This method is based on RMS T1160: Low temperature recovery of polychloroprene elastomeric joint seals for bridge structures, with only minor variations.

2 Scope
This method describes the procedure for determining the low temperature recovery of compressed polychloroprene elastomeric seals used for bridge structures.

3 Apparatus
The following apparatus is required:

3.1 Digital calliper, with a resolution of at least 0.2 mm and complying with AS 1984.

3.2 Compression plates, 125 mm x 200 mm, at least 5 mm thick and chrome plated or otherwise protected from corrosion. The plates shall be drilled at each corner and fitted with 10 mm diameter bolts and nuts.

3.3 Refrigerated cabinet, capable of maintaining both a temperature of –10 ± 1°C and a temperature of –29 ± 1°C.

4 Procedure
The procedure shall be as follows:

4.1 Sample preparation
4.1.1 Cut two test specimens, each 125 mm long, from the joint seal.

4.2 Testing
4.2.1 Measure and record the width \( w_1 \) of one of the test specimens at the centre of the top surface of the seal, that is the face to be exposed to traffic. Mark the position where the measurement was made.

4.2.2 Place the test specimen centrally between the compression plates such that the top surface is at right angles to the plates and the longitudinal axis of the specimen is parallel to the longitudinal axes of the compression plates.

4.2.3 Compress the joint seal uniformly between the compression plates by tightening the nuts on the bolts, ensuring that the top surface of the seal folds inwards towards the centre of the specimen. Continue until the specimen has been compressed to 50 per cent of its original width.

4.2.4 Place the compressed specimen in the refrigerated cabinet and maintain it at a temperature of -10 ± 1°C for 72 hours.

4.2.5 At the end of the 72 hour period, unclamp the specimen and allow it to recover in the cabinet at -10 ± 1°C for 1 hour.

4.2.6 Immediately measure the recovered width \( w_2 \) at the marked centre position on the specimen.
4.2.7 Repeat Steps 4.2.1 to 4.2.3 for the second specimen but recording the original measured width as $w_3$.

4.2.8 Place the compressed specimen in the refrigerated cabinet and maintain it at a temperature of $-29 \pm 1^\circ C$ for 22 hours.

4.2.9 At the end of the 22 hour period, unclamp the specimen and allow it to recover in the cabinet at $-29 \pm 1^\circ C$ for 1 hour.

4.2.10 Immediately measure the recovered width of the marked centre position on the specimen $(w_4)$.

5 Calculations

Calculations shall be as follows:

5.1 Calculate the percentage recovery at $-10^\circ C$ as follows:

$$R_{-10} = \frac{w_2}{w_1} \times 100$$

where $R_{-10} = \text{recovery at test temperature } -10^\circ C \text{ (%) }$

$w_2 = \text{recovered specimen width (mm)}$

$w_1 = \text{original specimen width (mm)}$

5.2 Calculate the percentage recovery at $-29^\circ C$ as follows:

$$R_{-29} = \frac{w_4}{w_3} \times 100$$

where $R_{-29} = \text{recovery at test temperature } -29^\circ C \text{ (%) }$

$w_4 = \text{recovered specimen width (mm)}$

$w_3 = \text{original specimen width (mm)}$

6 Reporting

Report the low temperature recoveries at the test temperatures of $-10^\circ C$ and $-29^\circ C$ to the nearest 0.5%.
Test Method Q470: Coefficient of thermal expansion of concrete

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

2 Scope
This method describes the procedure for determining the coefficient of thermal expansion of concrete prisms when measured over a temperature range of -10°C to 45°C.

3 Apparatus
The following apparatus is required:

3.1 Thermocouple and indicator, Type T thermocouple and an indicator with a minimum range of -15°C to 50°C, readable to at least 0.1°C and with an uncertainty of no more than 0.1°C.

3.2 Drying room, as detailed in AS 1012.13 Section 5.

3.3 Length Comparator, as detailed in AS 1012.13 Section 5.

3.4 Drying oven, capable of maintaining a temperature of 45°C to 50°C.

3.5 Refrigerated cabinet, capable of maintaining a temperature of approximately -10°C.

4 Procedure
The procedure shall be as follows:

4.1 Moulding and Curing
4.1.1 Cast three concrete prisms, 100 mm x 100 mm x 250 mm as detailed in AS 1012.8.4 Sections 5 and 6 with a Type T thermocouple cast into the centre of one prism.

4.1.2 At the completion of initial curing, demould the specimens and moist cure them at 27 ± 2°C for 7 days as detailed in AS 1012.8.4.

4.1.3 At the completion of standard moist curing, place the specimens in the drying room for 21 days.

4.1.4 At the completion of the drying period, measure each specimen using the comparator and note the reading together with the specimen temperature.

4.2 Conditioning
4.2.1 Place each prism in a separate plastic bag such that the air gap is reduced to a minimum and seal each bag, but allowing the thermocouple wires to protrude.

4.2.2 Place the prisms in the oven and monitor the temperature of the instrumented prism until it reaches an equilibrium (Note 7.1).

4.2.3 When an equilibrium is reached, remove the prisms one at a time from the oven, remove the plastic bag and measure and note the length ($L_1$), together with the specimen temperature ($T_1$).

4.2.4 Reseal each prism in its plastic bag as detailed in Step 4.2.1, place the specimens in the refrigerated cabinet and leave for at least 12 hours.
4.2.5 Remove the prisms one at a time from the cabinet, remove the plastic bag, and measure and note the length \( l_2 \) of each, together with the specimen temperature \( T_2 \) of the instrumented prism.

4.2.6 Reseal each prism in its plastic bag as detailed in Step 4.2.1, place the specimens in the drying room and leave for at least 12 hours.

4.2.7 Remove each prism from its bag in turn and measure and note its length together with the temperature of the instrumented prism. Return the prisms to their plastic bags and seal.

4.3 Testing

4.3.1 At the completion of the conditioning cycle, repeat Steps 4.2.2 to 4.2.5 but recording the values of \( l \) and \( T \) for use in the calculations below.

5 Calculations

5.1 Calculate the coefficient of thermal expansion as follows:

\[
\alpha = \frac{10^6 (l_1 - l_2)}{L(T_1 - T_2)} - \alpha^i
\]

where  
\( \alpha \) = coefficient of thermal expansion (\( \mu\varepsilon/\degree C \))

\( \alpha^i \) = coefficient of thermal expansion of the gauge studs (\( \mu\varepsilon/\degree C \)) taken as 9 \( \mu\varepsilon/\degree C \)

\( l_1 \) = specimen length at temperature \( T_1 \) (mm)

\( l_2 \) = specimen length at temperature \( T_2 \) (mm)

\( L \) = gauge length (mm) taken as 250 mm

\( T_1 \) = temperature of specimen after storage in the oven (\(^\circ\)C)

\( T_2 \) = temperature of specimen after storage in the refrigerated cabinet (\(^\circ\)C)

6 Reporting

Report the coefficient of thermal expansion to the nearest 10 \( \mu\varepsilon/\degree C \).

7 Notes on method

7.1 An equilibrium should be reached in 6 hours.
Test Method Q471: Making, curing and testing moulded concrete specimens - field simulated curing

1 Source
This method is based on RMS Test method T367: Field simulated curing and testing of moulded concrete specimens, with only minor variations.

2 Scope
This method describes the procedure to mould specimens of base course concrete and simulate the curing of these specimens in the field prior to determining compressive strength.

3 Apparatus
The following apparatus is required:
3.1 Spray bottle.
3.2 Shovel.
3.3 Steel rule or tape measure.
3.4 Thermometer, maximum and minimum reading thermometer or other suitable temperature measuring device, having a range of at least 0 - 50°C and graduated to 1°C or less with an uncertainty of no more than 1°C.
3.5 Vacuum desiccator.
3.6 Vacuum pump.

4 Materials
The following materials are required:
4.1 Concrete curing compound.
4.2 Bedding material such as sand or gravel.

5 Procedure
The procedure shall be as follows:

5.1 Sampling and moulding
5.1.1 Select the batch to be sampled within the lot under consideration using Random Sampling: Selection of Location – Interval (unless otherwise specified) as detailed in Test Method Q050.
5.1.2 Sample a batch of concrete which is to be incorporated into the works as detailed in Test Method AS 1012.1.
5.1.3 Mould test specimens as detailed in Test Method AS 1012.8.1 except that the mould covers are not to be fitted at the completion of moulding.

5.2 Simulated curing
5.2.1 After moulding and the disappearance of bleed water, spray the top surface of the specimens with a curing compound, using the same type and application rate as used in the works.
5.2.2 Cure the specimens either adjacent to the concrete pavement which is represented or at the place of specimen moulding. The location must duplicate the conditions of temperature,
moisture and wind to which the pavement is subjected, and the specimens must not be subjected to any artificial curing conditions nor protected from any natural ambient conditions. The top surfaces of the specimens are to be left exposed to ambient conditions unless the pavement is afforded cover and protection, in which case such protective treatment is to be duplicated in all regards for the specimens.

5.2.3 Within 6 hours of moulding, bed the specimens in bedding material to a level of 5 ± 5 mm below the top of the specimens. Extend the bedding to a horizontal distance of not less than 300 mm beyond the mould edge and grade the surface away from the specimen at not less than 2 percent such that water drains away. The bedding must not be treated in any way which is likely to provide artificially favourable curing conditions (Note 8.1).

5.2.4 Specimens are to remain undisturbed for a period as directed by the Principal. During this time, record details of weather conditions including daily maximum and minimum temperatures.

5.3 Preconditioning

5.3.1 At the completion of the simulated curing, remove the specimens from the bedding material. Immediately cover the trowelled surfaces using mould covers or, for previously demoulded specimens, plastic bags. Transport the specimens to the laboratory such that they are not damaged in transit nor subjected to any artificial temperature conditions.

5.3.2 Demould or remove specimens from their plastic bags and wet-condition each specimen using one of the following methods:

   a) immerse the specimens in water at 27 ± 2°C for 24 ± 4 hours, or
   b) vacuum saturate the specimens by immersing in water in a desiccator and applying a partial vacuum of 13 kPa or less absolute pressure for 3 hours (Note 8.2).

5.4 Testing

5.4.1 At the completion of wet-conditioning, assess the specimens for acceptance as detailed in AS 1012.9, Section 4.

5.4.2 Determine the saturated surface-dry density of each specimen as detailed in Test Method Q473.

5.4.3 Cap the specimens and determine their unconfined compressive strength as detailed in AS 1012.9, Sections 5 to 8.

6 Calculations

Undertake calculations as detailed in Test Method Q473 and AS 1012.9.

7 Reporting

The following shall be reported:

7.1 The density, compressive strength and general information as detailed in Test Method Q473 and AS 1012.9.

7.2 Duration of field simulated curing.

7.3 The daily maximum and minimum temperatures, together with details of daily weather conditions.

7.4 Wet conditioning method used.
7.5 Details of the concrete lot that the test results represent.

8 Notes on method

8.1 The specimens can remain in their moulds during the entire simulation period. Alternatively, they may be demoulded after 18 hours of curing provided the specimens are tightly wrapped in a dry water tight plastic bag while leaving the trowelled surface exposed and then returned to the sand/gravel bedding within 30 minutes of demoulding. During this time, maintain the specimens in a constant condition of moisture at ambient temperature.

8.2 A partial vacuum of 13 kPa absolute pressure is approximately equivalent to a -88 kPa reading on a vacuum gauge at sea level.
Test Method Q473: Density of hardened concrete - water displacement

1 Source
This method combines the principles of RMS Test Method T368 – *Draft: Dressing of voids in concrete specimens and adjustment for embedded steel*, and of AS 1012.12.2: *Determination of mass per unit volume of hardened concrete – Water displacement method*, with only minor variations.

2 Scope
This method describes the procedure for the determination of the density of hardened concrete using a water displacement method. The method allows for testing of moulded and cored specimens for concrete pavements, but may be also applicable to other situations. The method provides for the inclusion of surface voids in the calculation of density and for the adjustment of the measured value for any embedded reinforcing steel, and is applicable to specimens having a diameter of 100 mm or larger.

3 Apparatus
The following apparatus is required:

3.1 Balance of suitable capacity, with a resolution of 1 g, with a limit of performance within the range of ± 5 g and capable of below balance weighing.

3.2 Balance bench, equipped with a hole for below balance weighing.

3.3 Thermometer, total immersion or other suitable temperature measuring device having a temperature range which includes the test temperature, and graduated to 1°C or less with an uncertainty of no more than 1.0°C.

3.4 Water container, fitted with an overflow and of suitable dimensions to allow the complete immersion of the sample without contacting any part of the container.

3.5 Attachment, a non-absorbent device to suspend the concrete specimen, for example nylon or wire loop or wire support frame.

3.6 Basket, wire basket of suitable mesh and capacity to hold any reinforcing steel.

3.7 Calliper, with a resolution not exceeding 0.1 mm and complying with AS 1984 or JIS B 7507.

3.8 Steel rule.

3.9 Putty knife or scraper.

3.10 Absorbent cloth.

3.11 Masonry or diamond saw for trimming specimens.

4 Materials
The following material is required:

4.1 Filler, which is non-absorbent and mechanically stable to allow easy shaping, yet able to retain its shape during handling and immersion, for example plasticine or wax (Note 9.1).

5 Cored Specimens
The procedure for cored specimens shall be as follows:
5.1 **Dressing of voids**

5.1.1 Pre-condition the specimen using the wet conditioning procedure as detailed in AS 1012.14.

5.1.2 Remove the surplus water from the surface of the wet conditioned specimen using an absorbent cloth and continue drying until the surface appears just damp.

5.1.3 Determine the mass of the specimen \( m_1 \).

5.1.4 Examine the specimen to identify which voids, if any, meet the criteria for filling as follows:
   a) voids with a maximum dimension less than 5 mm need not be filled
   b) voids with a maximum dimension between 5 and 15 mm are filled if there are more than 10 on the surface, or
   c) voids with a maximum dimension greater than 15 mm are filled.

5.1.5 For a specimen containing reinforcing steel embedded in the surface which can be removed without damaging the specimen, remove the steel and fill any air voids adjoining the resultant cavity with filler (Note 9.2).

5.1.6 Remove any non-concrete materials such as bitumen using a scraper.

5.1.7 Where required, remove surface texture and fractured surfaces using a masonry saw. The removal of concrete is limited to a maximum of 10 mm from each end.

5.1.8 Fill any surface voids which require filling by shaping the filler to match the specimen’s contour as if complete compaction had been achieved (Note 9.3).

5.2 Determine the average diameter \( D \) of the test specimen to the nearest 0.1 mm from two diameters measured at right angles to each other.

5.3 Determine the height \( h \) of the test specimen to the nearest 1 mm.

5.4 **Conditioning of specimens**

5.4.1 Immerse the specimen in water at a temperature of 23 ± 2°C for approximately 1 hour.

5.4.2 Remove the specimen from the water, remove surplus water from its surface using an absorbent cloth and continue drying until the surface appears just damp.

5.4.3 Determine the mass of the specimen and filler in the saturated surface dry condition \( m_2 \).

5.5 **Density measurement**

5.5.1 Place the container directly below the hole in the balance bench, fill it with water until water escapes from the overflow and allow the excess water to run to waste.

5.5.2 When water has ceased dripping from the overflow, fit the attachment to the balance, allow the remainder of the attachment to be immersed in the water container, and zero the balance.

5.5.3 Using the attachment, suspend the specimen from the balance and gently lower it into the water container until completely immersed, taking care to ensure that the suspended specimen hangs free of the sides and bottom of the container.

5.5.4 Add additional water if necessary until water escapes from the overflow, and allow the excess water to run to waste.

5.5.5 When water has ceased dripping from the overflow, determine the mass of the immersed specimen and filler \( m_3 \).
5.5.6 Record the temperature of the water in the container to the nearest 1°C \( (t_1) \).

5.6 **Adjustment for reinforcing steel**

5.6.1 Remove the specimen from the container and, for a specimen containing embedded reinforcing steel, remove this by breaking the concrete.

5.6.2 Determine the mass of the reinforcing steel \( (m_r) \).

5.6.3 Suspend the wire basket below the balance and add additional water if necessary until water escapes from the overflow, and allow the excess water to run to waste.

5.6.4 Zero the balance.

5.6.5 Remove the wire basket and place any steel in the basket.

5.6.6 Suspend the wire basket and steel from the balance and completely immerse them in the water.

5.6.7 Agitate the wire basket to remove any entrapped air.

5.6.8 Add additional water if necessary until water escapes from the overflow, and allow the excess water to run to waste.

5.6.9 When water has ceased dripping from the overflow, determine the mass of the immersed reinforcing steel \( (m_r) \).

5.6.10 Record the temperature of the water in the container to the nearest 1°C \( (t_2) \).

6 **Moulded specimens**

The procedure for moulded specimens shall be as follows:

6.1 **Conditioning of specimens**

6.1.1 Immerse the specimen in water at a temperature of 23 ± 2°C for approximately 1 hour.

6.1.2 Remove the specimen from the water, remove surplus water from its surface using an absorbent cloth and continue drying until the surface appears just damp.

6.1.3 Determine the mass of the specimen \( (m_6) \).

6.2 **Density measurement**

6.2.1 Place the container directly below the hole in the balance bench, fill it with water until water escapes from the overflow and allow the excess water to run to waste.

6.2.2 When water has ceased dripping from the overflow, fit the attachment to the balance, allow the remainder of the attachment to be immersed in the water container, and zero the balance.

6.2.3 Using the attachment, suspend the specimen from the balance and gently lower it into the water container until completely immersed, taking care to ensure that the suspended specimen hangs free of the sides and bottom of the container.

6.2.4 Add additional water if necessary until water escapes from the overflow, and allow the excess water to run to waste.

6.2.5 When water has ceased dripping from the overflow, determine the mass of the immersed specimen and filler \( (m_7) \).

6.2.6 Record the temperature of the water in the container to the nearest 1°C \( (t_3) \).
7 Calculations

Calculations shall be as follows:

7.1 Calculate the compacted density of concrete for the core specimen as follows:

\[ \rho_c = \frac{m_1 - m_3}{m_2 - m_3 \cdot \rho_{w1} - m_4 - m_5 \cdot \rho_{w2}} \]

where
- \( \rho_c \) = compacted density of concrete (t/m\(^3\))
- \( \rho_{w1} \) = density of water at test temperature \( t_1 \) (t/m\(^3\)) (Table 1)
- \( \rho_{w2} \) = density of water at test temperature \( t_2 \) (t/m\(^3\)) (Table 1)
- \( m_1 \) = mass of saturated surface-dry specimen (g)
- \( m_2 \) = mass of moist specimen and filler (g)
- \( m_3 \) = mass of fully immersed specimen and filler (g)
- \( m_4 \) = mass of reinforcing steel (g)
- \( m_5 \) = mass of fully immersed reinforcing steel (g)

7.2 Calculate the reference density of concrete from the moulded specimen as follows:

\[ RD_c = \frac{m_6}{m_7 - \rho_{w3}} \]

where
- \( RD_c \) = reference density of concrete (t/m\(^3\))
- \( \rho_{w3} \) = density of water at test temperature \( t_3 \) (t/m\(^3\)) (Table 1)
- \( m_6 \) = mass of saturated surface-dry specimen (g)
- \( m_7 \) = mass of fully immersed specimen (g)

8 Reporting

The following shall be reported:

8.1 Description of test specimen providing information on:

8.1.1 Specimen type, that is, moulded specimen or core.
8.1.2 Moisture condition when tested, that is, saturated surface-dry.
8.1.3 Presence or not of reinforcing steel and, when present, whether steel was removed before or after testing.
8.1.4 Trimming of any fractured core surface.

8.2 For moulded specimens:

8.2.1 Reference density of concrete to the nearest 0.01 t/m\(^3\).

8.3 For core specimens:
8.3.1 Compacted density of the concrete to the nearest 0.01 t/m³.
8.3.2 Specimen diameter to the nearest 0.1 mm.
8.3.3 Specimen height to the nearest 1 mm.

9 Notes on method
9.1 Before handling any filler, the operator should consult the relevant SDS.
9.2 Do not fill the cavity left by the steel itself or any imprints from deformation patterns on the steel bar.
9.3 If voids are to be filled in a fractured surface at the bottom of a core, it is acceptable to trim the face by saw-cutting, provided there will be no significant change to the density of the specimen due to the removal of poorly compacted concrete.

Table 1 – Density of Water

<table>
<thead>
<tr>
<th>Temperature (ºC)</th>
<th>Density (t/m³)</th>
<th>Temperature (ºC)</th>
<th>Density (t/m³)</th>
<th>Temperature (ºC)</th>
<th>Density (t/m³)</th>
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Test Method Q474: Dowel pull-out test

1 Source
This method is based on a RMS Test Method T366: Dowel pull-out test, with only minor variations.

2 Scope
This method describes the procedure for the determination of the suitability of dowel debonder coatings, by measuring the tensile strength of the bond developed when a coated steel dowel is embedded in concrete. The method is applicable to steel dowels used in concrete road pavements for load transfer across joints.

3 Apparatus
The following apparatus is required:

3.1 Concrete cylinder moulds, having a diameter between 145 mm and 155 mm and capable of moulding specimens that are right cylinders having height between 1.95 and 2.05 times the average diameter of the specimen.

3.2 Internal vibrator, having a vibrating element that operates at a frequency of at least 115 Hz, a minimum diameter of 15 mm, a maximum diameter of 30 mm and is powered by a 240 volt, 50 Hz electric motor with a minimum rating of 1500 watts.

3.3 Scoop and wooden float.

3.4 Digital calliper, with a resolution of at least 0.1 mm and complying with the requirements of AS 1984.

3.5 Steel rule, with a scale interval of 0.5 mm.

3.6 Testing machine, capable of applying a tensile force at a constant rate of 0.5 mm per minute and complying with the requirements of AS 2193, Class C.

3.7 Vertical displacement measurement system, to measure the vertical displacement of the dowel bar. The system can use a dial gauge complying with the requirements of AS 2103 with a scale interval of 0.01 mm and a minimum travel of 10 mm, or a displacement transducer of at least equal performance.

4 Procedure
The procedure shall be as follows:

4.1 Sampling

4.1.1 Sample fresh concrete from the works or mix concrete in the laboratory complying with the relevant specification requirements, as detailed in AS 1012.1 or AS 1012.2 as appropriate.

4.2 Moulding and curing

Mould and cure two test specimens as follows:

4.2.1 Half fill each mould with concrete and insert a dowel which has been treated with the debonder coating. Locate the dowel centrally into the mould so that it touches the bottom of the mould.
4.2.2 Compact the concrete by inserting the vibrator element in at least two locations, approximately at the quarter points of one diameter, ensuring that the element does not come in contact with the sides or base of the mould.

4.2.3 After inserting the element, continue compacting the concrete until the surface becomes relatively smooth in appearance, and substantial air bubbles cease breaking the surface. Do not unduly prolong the vibration beyond this point. At this time, slowly extract the vibrator element over a period of 3 seconds or more.

4.2.4 Complete the filling of each mould by placing sufficient concrete in the last layer to overfill the mould when compacted.

4.2.5 Compact the second layer as detailed in Steps 4.2.2 and 4.2.3, inserting the vibrator to a depth which just penetrates the first layer (Note 7.1)

4.2.6 Strike off and smooth the surface of the concrete using the wooden float.

4.2.7 Cure the concrete cylinders for 7 days as detailed in AS 1012.8 Section 1.9, except that after initial curing, test specimens are not demoulded before being placed under standard moist-curing conditions.

4.3 Testing

4.3.1 At the completion of the 7 days curing, demould the test specimens and remove the debonding coating from the exposed part of the dowels.

4.3.2 For each specimen, measure the dowel diameter ($d$) to the nearest 0.1 mm and concrete specimen height ($l$) to the nearest 0.5 mm by averaging readings taken from a number of locations.

4.3.3 Position a test specimen in the testing machine and locate the displacement measuring system such that the movement of the dowel relative to the concrete can be measured.

4.3.4 Apply force to the specimen until a dowel displacement of at least 0.25 mm is achieved.

4.3.5 Record the maximum applied force ($P$) to the nearest 10 kN.

4.3.6 Repeat Steps 4.3.3 to 4.3.5 for the second specimen.

5 Calculation

Calculations shall be as follows:

5.1 Calculate the bond strength for each specimen as follows:

$$S = \frac{P}{\pi dl}$$

where

$S$ = bond strength (MPa)

$P$ = maximum applied force (kN)

$d$ = dowel diameter (mm)

$l$ = dowel embedded length (mm)

5.2 Calculate the average bond strength to the nearest 0.1 MPa.
6 **Reporting**

The following shall be reported:

6.1 Type of debonder coating used and the method of application.

6.2 Nominal diameter of dowels under test (mm)

6.3 Average bond strength to the nearest 0.1 MPa.

7 **Notes on method**

7.1 If, after partial compaction of the layer, it is apparent that the mould will not be completely filled, add additional concrete and then complete compaction.
Test Method Q475: Tie bar pull-out test

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

2 Scope
This method describes a field procedure for the determination of the tensile strength of the bond developed between a tie bar and the concrete into which it is embedded. This method is applicable to tie bars used at construction joints and sawn joints in concrete road pavements.

3 Apparatus
The following apparatus is required:

3.1 Hollow ram jack, capable of applying a tensile force at a constant rate of 10 mm per minute and having a force indicator which complies with the requirements of AS 2193, Class C.
3.2 Clamping mechanism, to allow load transfer from the jack to the tie bar.
3.3 Steel shims, of appropriate size for the jack, for example 150 mm x 25 mm x 1 mm.
3.4 Digital calliper, with a resolution of at least 0.1 mm and complying with the requirements of AS 1984.
3.5 Steel rule, with a scale interval of 0.5 mm.

4 Procedure
The procedure shall be as follows:

4.1 Ensure that the pavement edge which is adjacent to the tie bar and which will come into contact with the jack is free of concrete projections.
4.2 For the tie-bar of nominal length \( l_1 \), measure the exposed length \( l_2 \) to the nearest 1 mm and the tie bar diameter \( d \) to the nearest 0.1 mm by averaging readings taken from a number of locations.
4.3 Position the jack on the tie bar using any necessary supports to ensure that the base of the jack makes uniform contact with the pavement edge and the jack is centrally located about the bar using the necessary supports (Note 7.1).
4.4 Attach the clamping mechanism to the tie bar and apply a tensile force to the bar at a rate of 10 mm per minute.
4.5 Continue applying the force to the bar until a displacement of 5–10 mm relative to the pavement edge is achieved. Record the maximum force \( P \) to the nearest 10 kN.
5 Calculation

Calculate the bond strength as follows:

\[ S = \frac{P}{\pi d(l_1 - l_2)} \]

where

- \( S \) = bond strength (MPa)
- \( P \) = maximum applied force (kN)
- \( d \) = average tie bar diameter (mm)
- \( l_1 \) = nominal tie bar length (mm)
- \( l_2 \) = average tie bar exposed length (mm)

6 Reporting

The following shall be reported:

6.1 The nominal diameter and bonded length of the tie bar (mm).
6.2 The age of the concrete at the time of testing (days).
6.3 The bond strength to the nearest 0.1 MPa.

7 Notes on method

7.1 Where irregularities in the shape of the pavement edge will not allow the jack to act parallel to the tie bar, use steel shims to pack the base of the jack.
Test Method Q477: Foreign materials content of recycled crushed concrete

1 Source
This method is based on RMS Test Method T276: Foreign Materials Content of Recycled Crushed Concrete. It differs from this method by providing for the identification of two additional foreign material types.

2 Scope
This test method sets out the procedure for the determination of the foreign materials content in a sample of recycled crushed concrete.

3 Apparatus
The following apparatus is required:

3.1 Sieve, 4.75 mm complying with ISO 3310.
3.2 Sieve brush.
3.3 Drying oven of suitable capacity, having a temperature of 45 - 50°C and complying with AS 1289.0.
3.4 A metal mixing and quartering tray.
3.5 Mixing apparatus such as a trowel and quartering tools.
3.6 Sample dividers (optional).
3.7 Balance of suitable capacity, having a resolution of at least 0.1 g and with a limit of performance within the range of ± 0.5 g.
3.8 Suitable metal dishes.

4 Procedure
The procedure shall be as follows:

4.1 Prepare a bulk sample as detailed in Section 5 of Test Method Q101 to produce a representative test portion of about 6000 g.
4.2 Place the test portion in the oven and dry to a constant mass (Note 7.1).
4.3 Allow the test portion to cool to ambient temperature and determine the mass of the test portion (m_1).
4.4 Sieve the test portion by hand through the 4.75 mm sieve, ensuring that the sieve is not overloaded (Refer to Table 1) and using a lateral and vertical motion accompanied by a slight jarring action to keep the material moving over the sieve. Continue sieving until no more than 1 per cent by mass of residue passes the sieve during a further 1 minute of continuous hand sieving.
4.5 Sort and separate by hand all foreign material retained on the 4.75 mm sieve, and classify it in accordance with Table 2.
4.6 Determine the mass of each foreign material type retained on the 4.75 mm sieve (m_i).
5 Calculations

Calculations shall be as follows:

5.1 Calculate the percentage of each foreign material type as follows:

\[ F_i = \frac{m_i}{m_t} \times 100 \]

where

- \( F_i \) = percentage of each foreign material type retained on the 4.75 mm sieve (%)
- \( m_i \) = mass of each foreign material type (g)
- \( m_t \) = mass of test portion (g)

6 Reporting

Report the percentage of each foreign material type retained on the 4.75 mm sieve to the nearest 0.1%.

7 Notes on method

7.1 A test portion is considered to have reached a constant mass when the difference between successive weighings, after a further 4 hours drying at 45 - 50°C, is not more than 1 percent of the total of the previous moisture losses.

Table 1 – Recommended maximum sieve loading

<table>
<thead>
<tr>
<th>AS sieve (mm)</th>
<th>Maximum loading (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>200 mm diameter</td>
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<tr>
<td>4.75</td>
<td></td>
</tr>
<tr>
<td></td>
<td>200</td>
</tr>
</tbody>
</table>

Table 2 – Classification of foreign material types

<table>
<thead>
<tr>
<th>Foreign material type</th>
<th>Material retained</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Brick and glass</td>
</tr>
<tr>
<td>2</td>
<td>Metal, ceramics and slag (other than blast furnace slag)</td>
</tr>
<tr>
<td>3</td>
<td>Plaster, clay lumps and other friable material</td>
</tr>
<tr>
<td>4</td>
<td>Rubber, plastic, bitumen (not part of asphalt), paper, cloth, paint, wood and other vegetable matter</td>
</tr>
<tr>
<td>5</td>
<td>Asphalt</td>
</tr>
</tbody>
</table>
Test Method Q480: Relaxation of prestressing and posttensioning material

Perform the test in accordance with AS 4672.1-2007 Appendix B: Isothermal relaxation test, but with the following changes, as detailed below. The purpose of these changes:

a) addressing deficiencies in the published standard
b) restricting testing options permitted under AS 4672.1-2007 rather than altering the procedure
c) defining how to determine relaxation at both 1000 hours and 10,000 days.

Sub-clause B5 (a)
In the first line, delete “60%, 70% or”.

Sub-clause B5
Replace Clause (e) with:

“Continue the test for 330 ± 24 h and, without halting the test, perform an extrapolation to 1000 h and 10,000 days using Method 2 of Clause B8. The test may be finalised at this point if:

i) the relaxation at 10 000 days is outside the range of 4.20%-5.80% inclusive, and
ii) the regression coefficient is greater than or equal to 0.98.

If these conditions are not met, the test must continue in accordance with Clause (f).”

Add Clause (f):

“Continue the test to 1000 hours, and perform an extrapolation to 10,000 days using Method 2 of Clause B8, and using all data from 8 hours to 1000 hours. If the regression coefficient is less than 0.98, the 10,000 day relaxation value is not to be accepted. Reasons for the regression coefficient being less than 0.98 shall be investigated and reported.”

Add the following to below Clause (f):

“All data points shall be recorded, and a reading that appears anomalous shall be investigated, and if valid reasons are found, such information shall be recorded on the test report.”

Sub-clause B6 (a)
Add “and 10,000 days” after “1000 h”.

Sub-clause B8
In the first sentence, replace “160” with “330 ± 24” in both instances.

Replace the third sentence with “The regression shall be performed using Method 2.”

Replace the first sentence under Method 2 with:

“To extrapolate to 1000 h or 10,000 days, a regression shall be performed on the available data from 8 hours onwards using the following equation:”

Sub-clause B9 (d)
After the first “1000 h” add “and 10,000 days” and replace “at least 160” with “330 ± 24”.

Sub-clause B9 (f)
Replace “either Equation B7 (1) or B7 (2)” with “Equation B7 (2)”. 

Sub-clause B9 (g)

Replace with "Reference to this Standard Appendix, AS 4672.1, as modified by Q480".
Test Method Q482: Relative compaction of concrete

1 Source

This method applies the principles of Roads and Maritime Services QA Specification R83: Concrete pavement base. It varies from this specification by allowing the use of a nuclear gauge to determine the compacted density of the concrete.

2 Scope

This method describes the procedure for determining the relative compaction of concrete. It is determined as the ratio of the core density and the reference density values for the concrete expressed as a percentage.

3 Procedure

The procedure shall be as follows:

3.1 Select test locations within the lot under consideration using Random Stratified Sampling: Selection of Location – Available Area (unless otherwise specified) as detailed in Test Method Q050. The locations should be chosen to exclude joints and, where applicable, steel reinforcement or tie bars (located with the aid of a metal detector or similarly appropriate device).

3.2 Compacted density of concrete by coring

3.2.1 Extract 75 – 100 mm diameter cores from the full depth of the concrete base as detailed in AS 1012.14.

3.2.2 Place the cores in either:
   a) a tank of lime-saturated water, or
   b) individual sealed plastic bags to prevent moisture loss and shaded to reduce temperature extremes.

3.2.3 Determine the compacted density of the concrete \( \rho_c \) as detailed in Test Method Q473 and record the value to the nearest 0.01 t/m\(^3\).

3.3 Compacted density of concrete by nuclear gauge

3.3.1 Determine the compacted density of the concrete \( \rho_c \) in accordance with Test Method Q484 and record the value to the nearest 0.01 t/m\(^3\).

3.4 For each lot determine the assigned reference density of the concrete \( \text{LRD}_c \) in accordance with Test Method Q483 and record the value to the nearest 0.01 t/m\(^3\).
4 Calculations

Calculations shall be as follows:

4.1 Calculate the relative compaction to the nearest 0.1% as follows:

\[ RC_c = \frac{100\rho_c}{LRD_c} \]

where

- \( RC_c \) = relative compaction of concrete (%)
- \( \rho_c \) = compacted density of concrete (t/m\(^3\))
- \( LRD_c \) = assigned reference density of concrete (t/m\(^3\))

4.2 Where a number of tests have been performed on a lot, calculate the minimum characteristic value of relative compaction as detailed in Test Method Q020.

5 Reporting

The following shall be reported:

5.1 Report the relative compaction of concrete to the nearest 0.1%.

5.2 If required, report the minimum characteristic value of relative compaction as detailed in Test Method Q020.
Test Method Q483: Assignment of reference density for concrete

1 Source

This method applies the principles of Roads and Maritime Services QA Specification R83: Concrete pavement base to the assignment of a reference density for a concrete lot. It varies in using all available tests in each lot to establish a reference density.

2 Scope

This method sets out the procedure for assigning a reference value of density for a concrete lot and is applicable only to concrete pavements.

3 Procedure

The procedure shall be as follows:

3.1 Obtain all pairs of specimens sampled, manufactured and cured for the determination of the 28 day compressive strength of concrete and remove from curing at 7 days.

3.2 Test each specimen separately and determine the density as detailed in Test Method Q473.

3.3 Return each specimen to the curing environment at the completion of testing and no longer than 1 hour after their removal.

4 Calculations

Calculations shall be as follows:

4.1 For each pair of specimens calculate the mean density and if the difference in density between the pair of specimens is greater than 10% of the mean density of the pair, exclude the lower density from further calculations.

4.2 Using the remaining specimens calculate the mean of the density values. This value is the assigned reference density of the concrete lot \( (LRD_c) \).

5 Reporting

The following shall be reported:

5.1 The assigned reference density to the nearest 0.01 t/m³.

5.2 Identification of the nominated mix or trial section.

5.3 Identification of the lot.

6 Notes on method

Plot control charts of the progressively assigned values to assess whether there is drift in the values being used.
Test Method Q484: Compacted density of concrete - nuclear gauge

This test shall be performed in accordance with Test Method N06: *Compacted Density of Concrete* contained within the department's *Nuclear Gauge Testing Manual*. 
Test Method Q485: Carbonation depth of concrete

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

2 Scope
This method describes a procedure for determining the depth of carbonation in concrete using phenolphthalein indicator solution.

3 Definitions
For the purpose of this method, the following definitions shall apply:
Carbonation is the term referring collectively to a number of natural processes causing neutralisation of concrete. The most significant process occurs when carbon dioxide in the atmosphere reacts with calcium hydroxide in the cement in the presence of moisture forming calcium carbonate. This results in a reduction in pH of the concrete and an increased potential for corrosion of steel reinforcement.

4 Apparatus
The following apparatus is required:
4.1 Spray bottle or paint brush.
4.2 Steel rule with 1 mm graduations.
4.3 Compression testing machine and Brazil jig (optional).

5 Reagents
The following reagents are required:
5.1 Phenolphthalein indicator solution (Note 8.1).
   • Dissolve 1 g of phenolphthalein and 50 ml of ethanol in 50 ml of distilled water (use proportionally larger quantities if necessary).

6 Procedure
The procedure shall be as follows:
6.1 Obtain a concrete core and determine its length (Note 8.2).
6.2 Place the specimen so that, in the case of a cylindrical specimen, it is resting on its side between the platens of the corresponding testing machine (that is, in a manner similar to that used in the Brazil or splitting test).
6.3 Apply a force without shock until the specimen fails diametrically. The objective is to cause a single fracture plane.
6.4 Remove the pieces of the specimen from the testing machine and place them so as to enable the reagent to be sprayed on the newly exposed surfaces of the specimen.
6.5 Ensure the newly exposed surfaces are dry. Paint or spray the newly exposed surfaces uniformly with the indicator solution. Areas of the newly exposed surfaces not subjected to carbonation will turn purple. Areas where carbonation of the concrete has occurred will not change colour.

6.6 Measure the depth of carbonation at three points to the nearest 1 mm, from the original external surface of the specimen to the border between the carbonated and un-carbonated areas (Note 8.2).

6.7 Calculate the average of the three depths and record as the depth of carbonation to the nearest 1 mm.

7 Reporting

The following shall be reported:

7.1 Identification of the specimen.

7.2 Carbonation depth or range of depths, to the nearest 1 mm.

7.3 Length of the specimen to the nearest 1 mm.

8 Notes on method

8.1 Before handling phenolphthalein indicator solution, the operator should consult the relevant Safety Data Sheet (SDS).

8.2 Samples other than concrete cores may be tested.

8.3 It will be evident from an inspection of the specimen, that one or more of the external surfaces formed part of the external surfaces of the structure from which the specimen was removed. It is from these surfaces that measurements of carbonation depth should be made. If the border between the two areas is approximately parallel to the outer surface record the average depth of carbonation. If the border is very uneven or diverges from the outer surface record the range of depths observed.