

TRANSPORT FOR NSW (TfNSW)

QA SPECIFICATION R68

SHOTCRETE WORK WITHOUT STEEL FIBRES

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REVISION REGISTER

Ed/Rev Number	Clause Number	Description of Revision	Authorised By	Date
Ed 1/Rev 0		First issue	GM, IC	20.04.09
Ed 1/Rev 1	4.1	Procedures for controlling water seepage at freshly placed shotcrete added.	GM, IC	08.02.10
	4.2	Preparation of earth surface revised, with inclusion of alternative option to prevent excessive absorption of water by earth surface.		
	5.5	Requirement for minimum cover depth amended.		
	7.3	Nozzle operator requirements included. Prohibition on use of rebound into works.		
	8.5	Reference to Clause 7.2 inserted for thickness.		
	8.5.1	Requirement to identify reinforcement locations prior to coring added in first paragraph.		
	Annexure R68/L1	Table L1, Clause 6.3 – Test Method reference corrected to Clause 3.5.		
	Annexure R68/L2.2	Core diameter added in first paragraph. In third paragraph, “a” inserted, “concrete” replaced with “shotcrete” and repair of core holes to leave no visible cracks added.		
Ed 1/Rev 2	1.2.4	Previous Clause 1.3. Subsequent clauses renumbered.	GM, IC W Stalder	01.08.11
	2.3.1	New sub-clause heading “General” added.		
	2.3.2	New sub-clause “Corrosion Inhibitors” added.		
Ed 1/Rev 3	2.2	Requirement for taking of initial 5 kg cement sample deleted.	GM, CB	22.01.16
	2.7	Heat accelerated curing and corresponding sulfate limit deleted.		

Ed/Rev Number	Clause Number	Description of Revision	Authorised By	Date
	Table R68.3 Annex A, A1.3 Annex B	Maximum acid-soluble chloride ion contents for unreinforced concrete, prestressed concrete and grout deleted. Durability provisions replaced by curing regimes. Pay item P1 introduced.		
Ed 1/Rev 4	Global	References to “Roads and Maritime Services” or “RMS” changed to “Transport for NSW” or “TfNSW” respectively.	DCS	22.06.20

GUIDE NOTES

(Not Part of Contract Document)

Using Specification R68

TfNSW R68 is a QA specification and the use of QA specifications requires the implementation of a quality management system by the Contractor that meets the quality system requirements specified in TfNSW Q. To comply with the intention of Government policy as well as TfNSW R68, shotcrete works constructed using TfNSW R68 require adequate surveillance and audit by the Principal.

Edition 1

The specification is based on TfNSW B82 Ed 2/Rev 3 and TfNSW B80 Ed 5/Rev 5, but with the requirements relating to steel fibres, including performance parameters relating to steel fibres, omitted.

The Specification is intended for shotcrete reinforced with conventional steel reinforcing bars and/or mesh.



Transport
for NSW

QA SPECIFICATION R68

SHOTCRETE WORK WITHOUT STEEL FIBRES

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VERSION FOR: DATE:

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FOREWORD

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REVISIONS TO PREVIOUS VERSION

This document has been revised from Specification TfNSW R68 Edition 1 Revision 3.

All revisions to the previous version (other than minor editorial and project specific changes) are indicated by a vertical line in the margin as shown here, except when it is a new edition and the text has been extensively rewritten.

PROJECT SPECIFIC CHANGES

Any project specific changes are indicated in the following manner:

- (a) Text which is additional to the base document and which is included in the Specification is shown in bold italics e.g. ***Additional Text***.
- (b) Text which has been deleted from the base document and which is not included in the Specification is shown struck out e.g. ~~Deleted Text~~.

TfNSW QA SPECIFICATION R68

SHOTCRETE WORK WITHOUT STEEL FIBRES

1 GENERAL

1.1 SCOPE

This Specification sets out the requirements for the supply and application of structural shotcrete.

Shotcrete supplied and applied under this Specification must be conventionally reinforced wet-mix shotcrete not containing steel fibres.

The scope of this Specification does not include provisions for the structural design of the shotcrete, the supply and installation of rock bolts or the supply and installation of waterproofing and drainage elements.

1.2 STRUCTURE OF THE SPECIFICATION

This Specification includes a series of annexures that detail additional requirements.

1.2.1 Project Specific Requirements

Project specific details of work are shown in Annexure R68/A.

1.2.2 (Not Used)

1.2.3 Schedules of HOLD POINTS and Identified Records

The schedules in Annexure R68/C list the **HOLD POINTS** that must be observed. Refer to Specification TfNSW Q for the definition of **HOLD POINTS**.

The records listed in Annexure R68/C are **Identified Records** for the purposes of TfNSW Q Annexure Q/E.

1.2.4 Planning Documents

The PROJECT QUALITY PLAN must include each of the documents and requirements listed in Annexure R68/D and must be implemented.

In all cases where this Specification refers to the manufacturer's recommendations, these must be included in the PROJECT QUALITY PLAN.

1.2.5 Testing Procedures

The Inspection and Test Plan must nominate the proposed testing frequency to verify conformity of the item and it must not be less than that specified in Annexure R68/L. Where a minimum frequency is not specified, nominate an appropriate frequency.

The Principal may conditionally agree to your proposal to reduce the specified minimum frequency of testing. The proposal must be supported by a statistical analysis verifying consistent process

capability and product characteristics. The Principal may vary or restore the specified minimum frequency of testing, either selectively or permanently, at any time.

1.2.6 Referenced Documents

Unless specified otherwise, the applicable issue of a referenced document, other than a TfNSW Specification, must be the issue current at the date one week before the closing date for tenders, or where no issue is current at that date, the most recent issue.

Standards, specifications and test methods are referred to in abbreviated form (e.g. AS 2350). For convenience, the full titles are given in Annexure R68/M.

1.3 DEFINITIONS

The terms “you” and “your” mean “the Contractor” and “the Contractor’s” respectively.

The following definitions apply to this Specification:

- (a) **Cement:** Material conforming to Specification TfNSW 3211 Clause 6. It comprises cements, blended cements supplementary and other cementitious materials.
- (b) **Concrete:** A thoroughly mixed combination of cement, aggregates and water, with or without the addition of chemical admixtures or other materials, all of which separately and when combined comply with the requirements of this Specification.
- (c) **Cover:** The distance between the outside of the reinforcement and the nearest permanent surface of the shotcrete, or between the outside of the reinforcement and the nearest point on the receiving surface.
- (d) **Curing:** The control of temperature and moisture in the concrete until the concrete has developed required properties.
 - (i) **Sealed Curing:** Curing at ambient temperature in which the concrete surface is sealed by at least two coats of a curing compound conforming to this Specification.
 - (ii) **Standard Moist Curing:** Standard Moist Curing as defined in AS 1012, Part 8.
 - (iii) **Wet Curing:** Curing at ambient temperature in which the concrete surface is effectively covered with water or placed in a fog room/chamber with a relative humidity exceeding 98 %.
- (e) **Exposure Classification:** The exposure classification for the surface of a member as determined in Clause 5.4.3 SAA HB77.
- (f) **Nozzle:** Attachment at end of delivery hose from which shotcrete is projected.
- (g) **Overspray:** Shotcrete material that is not intercepted by the receiving surface.
- (h) **Panel:** A distinct section of the area for shotcreting (usually not less than 10m in length).
- (i) **Rebound:** Shotcrete material that bounces off the receiving surface.
- (j) **Shotcrete:**
 - (i) **Shotcrete (generic):** Concrete projected onto a surface at high velocity.
 - (ii) **Wet-mix Shotcrete:** Shotcrete in which cement, aggregate, and water are first mixed together before introduction as concrete into the delivery hose.
- (k) **Shotcrete Mix:**
 - (i) **Base Mix:** Concrete designed, tested and supplied independent from the shotcreting process, equipment and personnel.

- (ii) **Shotcrete Mix:** The base mix after it is applied to the Works, or to Test Panels.
- (l) **Sloughing:** Detachment or falling away of fresh shotcrete.
- (m) **Water/Cement Ratio (w/c):** The ratio, by mass, of total free water, including water contained in admixture solutions, to total cement including all supplementary cementitious materials, in the concrete mix.

2 MATERIALS FOR CONCRETE

2.1 GENERAL

Materials for concrete must comply with Section 2 of AS 1379 and with the additional requirements of Clause 2 of this Specification.

2.2 CEMENT

Cement used in the Works must be Shrinkage Limited Type SL or General Purpose Blended cement Type GB conforming to this Specification and TfNSW 3211.

Blending of cement must be achieved either at the cement manufacturer's facilities and/or at the concrete batching plant, unless otherwise specified.

Supplementary cementitious materials (SCM) such as Fly Ash, Slag and Amorphous Silica and their proportions must conform to TfNSW 3211.

2.3 ADMIXTURES

2.3.1 General

Chemical admixtures, including corrosion inhibitors, and their use must conform to AS 1478.1. Admixtures must not contain calcium chloride. Where two or more admixtures are proposed for incorporation into a concrete mix, get their compatibility certified by the manufacturers. Submit details of the requirements for storage, preparation and mixing the admixtures.

Dispense accelerators and other admixtures that are added to concrete at the nozzle or at the delivery hose by calibrated mechanical means at dosage rates not exceeding the maximum recommended by the manufacturer.

Hydration control admixtures that suspend the hydration of shotcrete until the addition of the activator must not cause a decrease in concrete strength with age.

2.3.2 Corrosion Inhibitors

Corrosion inhibitors must contain a minimum of 30% of calcium nitrite solids. Where retarders additional to those already present in the corrosion inhibitor admixture are used to further modify the acceleration characteristics of the admixture, they must be added to the concrete before or with the admixture.

Where corrosion inhibitors are specified, the admixture application rate must be such that the concrete contains a minimum of 9 kg of calcium nitrite solids per cubic metre.

2.4 AGGREGATES

2.4.1 General

All aggregates used in the works must comply with AS 2758.1.

The combined grading of all coarse and fine aggregates in the base mix must be in accordance with Table R68.1

The Principal may approve the use of a particle size distribution outside the specified limits if evidence is provided that shotcrete made with this particle size distribution meets all other requirements of this Specification both in the fresh and hardened state. Supply additional evidence of acceptable performance for segregation, bleeding, plastic shrinkage and finishing properties.

Table R68.1 - Combined Coarse and Fine Aggregate Grading Requirements

Sieve aperture	Mass of sample passing, percent
13.2 mm	100
9.5 mm	90 – 100
6.7 mm	–
4.75 mm	70 – 85
2.36 mm	50 – 70
1.18 mm	35 – 55
600 µm	20 – 40
300 µm	8 – 20
150 µm	2 – 10

2.4.2 Additional Requirements for Coarse Aggregate

Do not use lightweight coarse aggregate.

Only use coarse aggregate with maximum nominal size of 10 mm.

Limit water absorption to a maximum of 2.5% except for slag aggregate where the maximum limit is 6%.

Use wet strength and wet/dry strength variation tests for aggregate durability assessment in accordance with AS 2758.1 with ‘duplicate testing’ being carried out in accordance with AS 1141.22.

2.4.3 Additional Requirements for Fine Aggregate

Limit water absorption to a maximum of 2.5%.

Any manufactured sand used as a fine aggregate must be crushed from rock from which is produced aggregate conforming to the requirements of Clause 2.4, and must be non-plastic when tested in accordance with AS 1289.3.

The requirements of Clause 8.2.2 of AS 2758.1 do not apply for manufactured sand. The water absorption of the combined fine aggregate must not exceed 2.5%

2.5 ALKALI-AGGREGATE REACTION (AAR)

2.5.1 Alkali - Reactive Materials

All aggregate used in the concrete to be incorporated into the Works must be:

- (a) petrographically examined in accordance with Clause 2.5.2; and
- (b) assessed and classified for AAR using the accelerated mortar bar test method in accordance with Test Method TfNSW T363.

2.5.2 Petrographic Examination

Petrographic examination must be in accordance with ASTM C295.

Aggregates containing obviously reactive components may be eliminated without further testing. Obviously reactive components include:

- (a) Opaline material;
- (b) Unstable silica minerals such as moderate amounts of tridymite and cristobalite; or
- (c) Sheared rock containing moderate amounts of strained quartz and microcrystalline quartz.

Do not rely on petrographic examination alone to determine that an aggregate is non-reactive. Testing of the aggregate to Test Method TfNSW T363 is also required.

2.5.3 Actions Required for Control of AAR

For aggregates classified as non-reactive by TfNSW T363, no action for control of potential AAR is required.

Where any of the aggregates in a mix are classified as slowly reactive or reactive by TfNSW T363, actions required for control of potential AAR in the concrete must be in accordance with Table R68.2.

Blended cements used for control of potential AAR must be in accordance with TfNSW 3211.

Aggregates classified as reactive by Test Method TfNSW T364 in a particular concrete mix design must not be used. Use alternative aggregates and/or alternative concrete mix designs that conform to this Specification.

**Table R68.2 - Actions Required for Control of Potential AAR
Based on TfNSW T363 Testing**

Mortar bar expansion (%) in 1M NaOH (80°C) at 21 days		Actions Required
Coarse aggregate	Fine aggregate	
≥ 0.10, < 0.40	≥ 0.15, < 0.45	Use blended cement
≥ 0.40	≥ 0.45	Use an alternative aggregate; or Use blended cement and assess aggregate reactivity in the concrete mix using TfNSW T364

2.6 FIBRES

2.6.1 Synthetic Fibres

Include synthetic fibres in the shotcrete mix to mitigate the effects of explosive spalling of shotcrete when subjected to high intensity hydrocarbon-fuelled fires. Add between 1 and 2 kg/m³ of fine micro polypropylene monofilament fibres to the concrete.

The Principal may approve the use of other synthetic fibres if evidence is provided that the proposed fibres will give equivalent or better fire behaviour.

2.7 SOLUBLE SALTS

Determine the chloride ion content by testing ground samples of hardened concrete in accordance with AS 1012.20.

Take the samples from a minimum 1.2 kg portion of the hardened concrete. Crush and grind the 1.2 kg of hardened concrete to a maximum size of 150 microns and then oven dry at 110°C ± 5°C for a minimum of one hour before taking the samples for analysis.

Analyse five (5) randomly selected samples of 20 ± 0.1 grams of the ground concrete for chloride ion content.

Use the Volhard method calibrated against a concrete with known chloride content for the tests. Modify the procedure of AS 1012.20 and use standard solutions for the analysis that bracket the expected chloride ion concentration.

Report the chloride ion content of each of the five samples and calculate and report the average chloride content and the standard deviation of the five samples.

The average mass of acid-soluble chloride ion per unit volume of concrete as placed must not exceed the values given in Table R68.3.

The sulfate content of concrete as placed, determined by calculation and expressed as the percentage by mass of acid-soluble SO₃ to cement, must not be greater than 5.0%.

Table R68.3 - Maximum Values of Acid-Soluble Chloride-Ion Content in Concrete

Exposure Classification *	Maximum acid-soluble chloride ion content for Reinforced Concrete (kg/m ³)
A	0.8
B1	0.4
B2	0.3
C	0.3
U	In accordance with Annexure R68/A

Note: Chloride ion content may be expressed in percentage weight of oven dried concrete. (0.1 kg/m³ ion content is approximately equivalent to 0.0042% by weight of oven dried concrete)

* For information on exposure classifications, see AS 5100.5.

3 DESIGN OF SHOTCRETE MIX

3.1 GENERAL

Base the design and trial of the shotcrete mix on the anticipated conditions which will prevail on site so that, under these conditions and with the nominated application method and nozzle operators, the shotcrete meets all the requirements of this Specification.

Carry out the design of the shotcrete mix in two stages:

- (i) First stage: design of a base mix; and
- (ii) Second stage: trial of the shotcrete mix.

Where the shotcrete mix, during its trial stage, is found to require significant alteration to the base mix exceeding the variations specified in Clause 3.9, design and trial a modified base mix and assess for conformity.

Test results must be the average of a minimum of two specimens, unless specified otherwise in the applicable test method.

3.2 BASE MIX

3.2.1 Target Compressive Strength for Mix Design

Design the base mix to achieve a target strength $f_{c,md}$ such that:

$$f_{c,md} \geq f_{c,min} + M_{control}$$

where $M_{control}$ is the margin nominated for variations in strength as defined in Clause 6.1 and $f_{c,min}$ is the specified minimum 28 day compressive strength as stated on the Drawings, or elsewhere in the Specification.

Unless specified otherwise on the Drawings, or approved by the Principal, the target strength $f_{c,md}$ must not exceed 45 MPa.

3.2.2 Proportioning for Durability

For the exposure classifications specified on the Drawings, the minimum cement content and maximum water/cement ratio of the base mix must be in accordance with Table R68.4.

Table R68.4 - Minimum Cement Content and Maximum Water/Cement Ratio

Exposure classification	Minimum cement content (kg/m ³)	Maximum water/cement ratio (by mass)
A	320	0.45
B1	320	0.45
B2	370	0.40
C	420	0.40
U	In accordance with Annexure R68/A Clause A1	

3.2.3 Trial Base Mix, Sampling and Testing

Prepare a trial base mix in accordance with AS 1012.2 using:

- (a) the proposed materials and mix proportions;
- (b) all admixtures including nozzle-added admixtures added at the highest dosages proposed by you; and
- (c) the proposed fibres at proposed dosage.

Batch the trial base mix at the highest water/cement ratio conforming to the allowable slump range which must allow for batching tolerances specified for the nominated base mix.

Carry out sampling and testing for:

- (i) slump;
- (ii) shrinkage;
- (iii) density; and
- (iv) compressive strength.

3.3 SLUMP

Unless specified otherwise on the Drawings, or approved by the Principal, the base mix must have a slump between 75 mm and 120 mm.

3.4 SHRINKAGE

Prepare and measure shrinkage of specimens from the base mix in accordance with AS 1012.13.

Shrinkage of the specimens after either 3 or 8 week's drying must conform to Table R68.5. Where no exposure classification is stated on the Drawings or elsewhere in the Specification, apply exposure classification B1.

Table R68.5 - Maximum Shrinkage Strain of the Nominated Base Mix Specimens

Exposure Classification	Maximum shrinkage strain, micro strain	
	Drying period	
	3 weeks	8 weeks
A	680	900
B1, B2	560	800
C	530	700
U	In accordance with Annexure R68/A	

3.5 DENSITY OF HARDENED CONCRETE

The density, at 28 days, of hardened concrete included in the Works, determined in accordance with AS 1012.12 on representative samples cut from the Works in accordance with AS 1012.14, must not be less than 98% of:

- (a) that of the corresponding samples taken from the transit mixer in accordance with AS 1012.8.1; and
- (b) the nominated base mix.

Core diameters of less than 75 mm are acceptable.

3.6 COMPRESSIVE STRENGTH

Unless specified otherwise on the Drawings, the 28 day compressive strength of concrete determined in accordance with Annexure R68/L Clause L2 must not be less than 32 MPa.

3.7 PERMEABILITY

For the exposure classifications specified on the Drawings, the maximum permeability penetration depth, determined in accordance with DIN 1048, of shotcrete included in the Works must be in accordance with Table R68.6.

Table R68.6 - Permeability Requirements – Penetration Depth

Exposure classification	Maximum Penetration Depth (mm)
A	30
B1	30
B2	25
C	25
U	In accordance with Annexure R68/A

3.8 NOMINATED SHOTCRETE MIX

3.8.1 General

Submit to the Principal details of each nominated shotcrete mix, together with a certificate stating that the nominated shotcrete mix, its constituents, the proposed application and the proposed curing regime meet the requirements of this Specification.

HOLD POINT

Process Held: Use of each nominated shotcrete mix in the Works.

Submission Details: All details from Clause 3.2 to Clause 3.7 inclusive and certification, at least 5 working days prior to the proposed usage of each shotcrete mix.

Release of Hold Point: The Principal will consider the submitted documents and may carry out surveillance and audits, prior to authorising the release of the Hold Point.

3.8.2 Submission Details for Base Mix

(a) Material Constituents

- (i) Source;
- (ii) Current test results not more than 12 months old providing evidence of conformity to Clause 2; and in particular
- (iii) Method of controlling alkali-aggregate reaction specified in Clause 2.5.

(b) Mix Design

- (i) Constituent quantities;
- (ii) Trial mix water/cement ratio and corresponding nominated water/cement ratio;
- (iii) Condition of constituents used in the mix design e.g. moisture condition of aggregates;
- (iv) $f_{c,min}$ (refer Clause 3.2.1);
- (v) Slump of the trial base mix and corresponding nominated slump; and
- (vi) Maximum time for shotcrete application, where hydration-control admixtures are used.

(c) Batching, Mixing and Transport

- (i) Methods;
- (ii) Level of control and accuracy of batching;
- (iii) Level of control and accuracy of determination of the aggregate moisture content;
- (iv) Method of determination of $M_{control}$; and
- (v) Minimum mixing time.

(e) Test Results of Hardened Concrete

- (i) 28 day compressive strength in accordance with AS 1012.9;
- (ii) Shrinkage in accordance with AS 1012.13; and
- (iii) Sulfate and chloride ion contents in accordance with Clause 2.7.

(f) Trial mix “Report”: in accordance with AS 1012.2.

3.8.3 Submission Details for Shotcrete Mix

(a) Test Panel Construction

- (i) Number and sizes of Test Panels;
- (ii) Base mix used in each Test Panel;
- (iii) Type and dosages of nozzle-added admixtures;
- (iv) Required and actual thickness;
- (v) Description of finished product;
- (vi) Description of internal cut surfaces; and
- (vii) Degree of control required to achieve uniform shotcrete without excessive rebound, sloughing, partial or total collapsing during shotcreting.

(b) Hardened Shotcrete Characteristics

Test reports for:

- (i) Compressive strength;
- (ii) Density; and
- (iii) Permeability.

3.8.4 Submission Details for Application Method and Curing Regime

(a) Application Method

- (i) Procedures for shotcreting;
- (ii) Equipment used for shotcreting;
- (iii) Position of shotcreting; and
- (iv) Names and experience of nozzle operators.

(b) Curing regime

- (i) Method and duration of curing; and
- (ii) Anticipated minimum ambient temperatures during the curing period.

If you propose to vary the curing regime, submit a new nominated base mix in accordance with Clause 3.11, unless otherwise approved by the Principal.

3.9 VARIATION TO NOMINATED MIXES

The quantities of the constituents in a nominated mix may be varied to improve the quality of the concrete. Variations to the quantities of constituents in the nominated mix must not exceed the following:

- (a) Cement: 3% by mass of each constituent;
- (b) Aggregates: 5% by mass of each constituent;
- (c) Water: 3% by mass and/or volume of water.

Notify the Principal in writing and submit written details of such variations to a nominated mix before commencing production with the varied quantities.

Notwithstanding the above provisions, the varied mix must:

- (i) not have a water/cement ratio exceeding that nominated for the concrete mix (refer to Clause 3.8);
- (ii) conform to the requirements of Clause 3.2.2 for minimum cement content and maximum water/cement ratio; and
- (iii) conform to the requirements of TfNSW 3211 for the range of SCM in Blended cement.

If you wish to vary the quantities of the constituents in excess of the above amounts, or wish to change the type or source of supply of any constituent, or vary the curing regime, submit a new nominated mix for approval in accordance with Clause 3.2.2, unless approved otherwise by the Principal.

3.10 COLOURING OF SHOTCRETE

Where required by the Principal, colour the shotcrete to blend the work with the surrounding slopes. The medium used must provide a permanent colour to the shotcrete.

The medium may be either:

- (i) a pigment, included in the shotcrete mix; or
- (ii) a coating, applied to the shotcrete.

At least seven working days prior to the application of the shotcrete, supply details of the proposed method, the medium to be used to colour the shotcrete, and examples of the proposed colour scheme to the Principal for approval.

3.11 TRIAL OF SHOTCRETE MIX

Prior to commencing construction, construct Test Panels using each proposed base mix, including any colouring as required, and for each nominated nozzle operator. Apply shotcrete normal to the surface of horizontal and vertical Test Panels. The Test Panels must be at least 750 mm x 750 mm, constructed to the same thickness as the Works, or 150 mm, whichever is the greater. Where reinforcement in the form of steel fabric or bars is used, provide the same reinforcement in at least half of the panel.

Carry out sampling and testing for compressive strength, density, and permeability.

Note: Where it is shown that same materials, mix designs, equipment, procedures and personnel have given satisfactory results in similar works, the Principal may exercise his discretion and accept the first shotcrete placed in the Works as the Test Panel.

3.12 ASSESSMENT FOR CONFORMITY

Assess the nominated shotcrete mix for conformity including assessment of the base mix, the curing regime and application method based on:

- (a) the average result, for slump and shrinkage of specimens sampled from the trial mix;
- (b) the average result, for compressive strength and permeability of specimens cut from Test Panels;
- (c) the average result for concrete density and relative concrete density;
- (d) thickness of panels, quality of its external surfaces and internal cut surfaces; and
- (e) the degree of control required to achieve dense and homogeneous shotcrete without segregation, sloughing, collapsing, excessive rebound or other visible imperfections.

4 SURFACE PREPARATION

HOLD POINT

Process Held:	Surface preparation.
Submission Details:	Notification of each intention to commence surface preparation with details of the method to be used at least two working days prior to commencing. Request to Principal for direction on the need for pressure grouting.
Release of Hold Point	The Principal will consider the submitted documents and may carry out surveillance and audits, prior to direction on pressure grouting and authorising the release of the Hold Point.

4.1 GENERAL

Prepare all surfaces to be shotcreted prior to application of shotcrete.

Prevent wash-out of freshly placed shotcrete due to water seepage by using conduits to channel the water away. On completion of shotcreting, plug the conduits using flash setting cement.

4.2 EARTH SURFACES

Prior to shotcreting, compact and trim the earth surface to line and grade to enable the designed shotcrete thickness to be achieved. Remove all loose soil or other material from the trimmed surface.

Prevent excessive absorption of mixing water from the shotcrete by:

- (a) Prewetting all earth surfaces to be shotcreted but keep the surface free of free water; or
- (b) Installing a moisture barrier system to stop the movement of moisture from the newly placed shotcrete into the earth. When sheet materials are used, prevent wrinkling or folding to stop voids being formed behind the moisture barrier. Take extra care in the sequence of application or apply a flashcoat to prevent shotcrete slippage.

4.3 ROCK SURFACES

Clear all rock surfaces to be shotcreted of loose material, debris, chips, mud, dirt, or other foreign matter prior to shotcreting.

Include the costs of preparing and clearing surfaces in the prices generally for shotcreting work.

After the loose material has been removed, wash the surface as required with a high-pressure air / water jet or by other means.

After the above preparation is carried out, pre-wet the rock surface prior to the application of shotcrete.

Remove any excess free water by blowing with oil-free dry compressed air.

4.4 CONCRETE SURFACES

Clear existing concrete surfaces to be shotcreted of any spalled, cracked, deteriorated, loose, unsound and/or chemically contaminated concrete until a sound and uncontaminated concrete is reached.

Where shotcrete is to be placed against a smooth concrete surface, roughen the surface by mechanical methods.

After the above preparation is carried out, pre-wet the concrete surface prior to the application of shotcrete.

Remove any excess free water by blowing with oil-free dry compressed air.

5 SUPPLY AND FIXING OF STEEL REINFORCEMENT AND EMBEDMENTS

5.1 QUALITY MANAGEMENT SYSTEM

The reinforcement material supplier must be certified by the Australian Certification Authority for Reinforcing Steels (ACRS) for the supply of reinforcement material.

The reinforcement fabricator must be certified by ACRS for fabricating reinforcement and implement and maintain a quality management system in accordance with AS/NZS ISO 9001, as a means of ensuring that the product conforms to the Specification requirements.

5.2 MATERIALS

5.2.1 Reinforcement

Reinforcement must be deformed bars or welded wire fabric except that plain bars or wire may be used for fitments (a fitment is a unit of reinforcement commonly known as a tie, stirrup, ligature or helix). All reinforcement must conform to AS/NZS 4671.

5.2.2 Protective Coatings

Unless specified otherwise, do not use reinforcement with a protective coating, including epoxy coating.

5.3 STORAGE

Support reinforcement above the surface of the ground, and protect it from damage and from deterioration due to exposure.

5.4 SURFACE CONDITION

At the time concrete is placed, the surface condition of reinforcement must be such as not to impair its bond to the concrete or its performance in the member.

5.5 PLACING AND FIXING OF REINFORCEMENT AND EMBEDMENTS

Support reinforcement and hold clear of surface to be shotcreted with the cover as stated on the Drawings. Where no cover is shown on the Drawings, maintain a minimum cover of 30 mm unless specified otherwise.

5.6 EMBEDMENTS FOR DRAINAGE

Relieve water pressure behind the completed Works by installation of a permanent pressure-relief drainage system where stated on the Drawings, or directed by the Principal.

6 SUPPLY AND DELIVERY OF CONCRETE

6.1 GENERAL

Produce and deliver concrete to the site of the Works in accordance with the requirements of AS 1379 and the additional requirements of this Specification.

Classify all concrete for use in the Works as Special Class and designate "S" in accordance with Clause 1.6.4 of AS 1379. Nominate the method of production assessment relevant to the plant in accordance with the criteria of AS 1379.

Nominate a margin for strength which is consistent with the nominated method of production assessment under which the plant operates. This margin for strength, referred to in this Specification as M_{control} , is the measure of the level of control for the nominated plant producing the nominated mix.

Dispose of water, contaminants, debris, excess concrete and other materials from concrete supply operations in accordance with Specification TfNSW G36.

6.2 MOISTURE CONTENT OF AGGREGATES

Determine the moisture content of the fine and coarse aggregates prior to concrete production for the day and whenever conditions change, either by a moisture meter or by other equivalent devices or methods. Make corrections to the mass of all aggregates and the volume of water used in the mix commensurate with the moisture content determined.

6.3 ADDITIONAL REQUIREMENTS FOR MIXING

6.3.1 Equipment

Do not use continuous mixers.

6.3.2 Discharging of Mixer

Discharge the entire contents of the mixer before charging it with a new batch.

6.3.3 Maximum Mixing Time

Where by reason of delay it is necessary to hold a batch in the mixer, mixing may be continued, for a maximum of ten successive minutes, except for split drum mixers where the maximum must be five minutes.

For longer periods, the batch may be held in the mixer and turned over at regular intervals, subject to the time limits specified for incorporation of the concrete into the work not being exceeded.

6.3.4 Delivery

Transport concrete produced at a remote central batching plant to the point of discharge by truck-mounted drum mixers conforming to the requirements of AS 1379 and this Specification. On completion of batching, continuously agitate the concrete until it is thoroughly mixed. On completion of mixing, continuously agitate the concrete until it is fully discharged. The agitation speed and duration to achieve thorough mixing must be as specified by the manufacturer of the equipment.

6.3.5 Period for Completion of Discharge

Place the shotcrete within 1.5 hours from the addition of the cement to the aggregates, unless hydration-control admixtures are used.

Do not incorporate concrete into the Works if its slump is outside the specified limits.

6.4 SLUMP

Check the slump of the concrete in accordance with AS 1379 except that the frequency of sampling must be in accordance with Annexure R68/L.

If the measured slump is not within the specified limits, immediately make one repeat test from another portion of the same sample. If the value obtained from the repeat test falls within the specified limits, the concrete represented by the sample is deemed to conform; otherwise reject it.

Check and record the slump of the concrete within 30 minutes of adding cement to the aggregate. Also check and record the slump immediately prior to discharge when the actual haul time exceeds 45 minutes and/or when water is added to a mixed batch.

6.5 ADDITION OF WATER TO A MIXED BATCH

You may add water to a mixed batch of concrete prior to the commencement of discharge subject to the following:

- (a) Less than 45 minutes have elapsed since cement was added to the aggregate;
- (b) Immediately after the addition of any water, operate the mixing mechanism at mixing speed for a time equivalent to at least 30 revolutions of the mechanism, and for such additional time as may be necessary to re-establish uniformity of the mix;
- (c) The total quantity of water added is not more than 9 kg/m^3 and is such that the nominated water/cement ratio is not exceeded;
- (d) The quantity of water added is measured and recorded;
- (e) The slump is checked after the water has been added.

Once discharge of a batch has commenced, do not add further water to that batch.

6.6 TEMPERATURE AT POINT OF DELIVERY

Do not use concrete if its temperature at any time up to the time of discharge from transport vehicles is less than 10°C or more than 32°C.

7 APPLICATION OF SHOTCRETE

7.1 EQUIPMENT

The type and capacity of the proposed shotcrete equipment must have performance records of successful application.

Equipment must be capable of allowing the shotcrete to leave the nozzle in a continuous uninterrupted stream. Equipment must be capable of maximising compaction and quality while minimising rebound and overspray.

Dispensing devices for admixtures added at the nozzle must be mechanically regulated and have calibrated meters.

7.2 PROVISION FOR MONITORING SHOTCRETE THICKNESS

Utilise probes during application of shotcrete to enable monitoring of shotcrete thickness. You may propose alternative methods for the approval of the Principal for the monitoring of shotcrete thickness whilst shotcrete is being applied.

7.3 SHOTCRETING

HOLD POINT

Process Held:	Each application of shotcrete in the Works.
Submission Details:	At least 2 working days prior, give notice of each intention to shotcrete. At least 4 working hours prior to the proposed commencement of application (unless otherwise allowed by the Principal), submit a Certificate of Conformity in respect of surface preparation, reinforcement and embedments. Verification checklists and other details showing conformity with this Specification must accompany this certificate.
Release of Hold Point:	The Principal will consider the submitted documents and may carry out surveillance and audit, prior to authorising the release of the Hold Point.

The procedure, equipment and personnel involved in shotcreting must produce an end product which is dense, homogeneous, without segregation of aggregate or fibres, and without sloughing, collapsing, excessive rebound or other visible imperfections.

Use the same nozzle operator for the works as used for the production of conforming test panels as specified in Clause 3.11.

Apply shotcrete in successive layers not exceeding 75 mm in thickness and with adequate adhesion to the surface or previous layers of shotcrete to prevent sagging or slumping. Unless approved otherwise, complete the shotcreting to a whole panel (preferably not less than 10 m in length) prior to shotcreting the next panel.

Stop shotcreting in situations which may adversely affect the end product. Before shotcreting is resumed, prepare the hardened concrete surface in accordance with Clause 4.4.

Remove shotcrete that is segregated, loose, porous or uncompacted otherwise prior to the application of additional shotcrete. Do not incorporate rebound into the works.

Regulate the concrete pump to evenly deliver the wet mix shotcrete at the rate required for the particular shotcrete application.

The shotcrete must emerge from the nozzle in a steady, uninterrupted flow. Where the flow becomes intermittent for any reason, direct it away from the Work until it becomes constant.

The distance of manually held nozzles from the receiving surface must be between 0.5 m and 1.0 m. Hold the nozzle perpendicular to the receiving surface except that where necessary use an angle of 0° to 30° to the perpendicular.

Where a succeeding layer is to cover a layer of shotcrete, sharply taper the first layer at joints and do not feather the tapered joints. Prepare the first layer in accordance with Clause 4.4 and then place the second layer on the tapered surface.

Do not apply curing compounds and bond breaking materials to surfaces that will be covered by an additional layer of shotcrete.

For vertical and near vertical surfaces of a tunnel lining, commence application of shotcrete at the bottom of the surface with the full thickness applied before applying any shotcrete to overhead surfaces.

7.4 SURFACE FINISH

Unless specified otherwise, all completed shotcrete surfaces must be the undisturbed natural finish as applied from nozzle. Where specified on the Drawings, or as directed by the Principal, steel float the shotcrete surface.

7.5 TOLERANCES

The maximum variation in alignment, grade, and dimensions of the structures from the established alignment, grade and dimensions (excluding thickness) shown on the Drawings must be ± 50 mm, unless specified otherwise on the Drawings. The tolerance in thickness must be as shown on the Drawings.

7.6 TEMPERATURE AND RAIN

Unless adequate protection is provided, do not place shotcrete during rain or when rain appears imminent.

Do not apply shotcrete when the air temperature in the shade is below 5°C or above 38°C unless special precautions, approved by the Principal, are taken.

Any shotcrete which is exposed to rain, other precipitation or dripping water within the period from application to curing must be deemed nonconforming.

7.7 PLACING OUTSIDE DAYLIGHT HOURS

Do not place shotcrete outside daylight hours or underground unless adequate lighting is provided.

8 CURING

8.1 GENERAL

Cure all shotcrete surfaces by one, or more, of the following methods,

- (a) wet curing, in accordance with Clause 8.2;
- (b) use of curing compounds, in accordance with Clause 8.3; and/or
- (c) using internal curing admixtures in accordance with Clause 8.3.1.

For all types of curing regimes, maintain the concrete surface at a temperature not less than 5°C throughout the curing period.

8.2 WET CURING

Apply wet curing to surfaces immediately after the completion of the application and finishing operations.

You may cover shotcrete by canvas, hessian or plastic sheets or other suitable materials provided it is kept continually wet. Water used for curing must conform to AS 1379.

8.3 CURING COMPOUNDS

Do not use spray-on curing compounds when additional layers of shotcrete or surface materials are to be applied to a shotcrete surface.

Curing compounds must conform to the requirements of AS 3799 for the classes and types specified in Table R68.8. Do not expose any curing compound remains on any shotcrete surface to view within a period of six (6) months after the date of application of the compound.

Table R68.8 - Classes and Types of Curing Compounds

Description of curing compound	Class (to AS 3799)	Type (to AS 3799)
Wax-based compounds (Wax emulsion)	A	1-D
Resin-based compounds (Hydrocarbon resin)	B	
Water-borne compounds	Z	

The curing compound supplier must implement and maintain a quality management system in accordance with AS/NZS ISO 9001, as a means of ensuring that the product conforms to the Specification requirements.

For each curing compound proposed for use in the Works, provide the Principal a Certificate of Conformity from the supplier, supported by test certificates from a laboratory with appropriate NATA registration, certifying that the curing compound conforms to this Specification.

This Certificate of Conformity must relate only to the formulation on which the tests were made and must be valid for not more than three years from the date of issue. The test certificates must report the non-volatile content, the efficiency index and the density and must provide a reference for the infrared spectrum as determined in accordance with Test Method TfNSW T1005.

For each batch delivered, provide to the Principal a Certificate of Uniformity from the supplier, supported by uniformity testing on both non-volatile content and density in accordance with AS 3799 Clause 3.2, and on viscosity in accordance with AS 3799 Clause 3.1.5. Additionally, provide an infrared spectrum and it must match the above mentioned reference infrared spectrum. The Certificate of Uniformity must state that the same formulation has been used for the batch as is represented by the Certificate of Conformity.

Sample and test at a rate of not less than one test per 3000 litres, or part thereof, supplied.

Apply the curing compound by a pressurised sprayer to give a uniform cover. The sprayer must incorporate a device for continuous agitation and mixing of the compound in its container during spraying.

Apply the curing compound using a fine spray at the rate stated on the certificate of conformity, or at a rate of 0.2 litres/m² per coat, whichever is the greater. Check the application rate by calculating the amount of curing compound falling on felt mats, each approximately 0.25 m² in area, placed on the concrete surface.

Apply two coats at the full rate.

The time between the first and second coat must be in accordance with the manufacturer's recommendation, or on the basis of a trial application.

Apply the curing compound to surfaces immediately after completion of all finishing operations.

Maintain the curing membrane intact after its initial application, for a minimum period of seven days. Make good any damage to the curing membrane due to your or others' activities by respraying of the affected areas.

8.3.1 Internal Curing Admixtures

Use internal curing admixtures in accordance with Clause 2.3. The admixture must not cause a decrease in concrete strength with age.

8.4 SHOTCRETE CRACKING

At the end of the curing period, the shotcrete must have no cracks of width greater than 0.15 mm, measured at the shotcrete surface. Where such cracks exist, identify them as nonconforming and seal them by an approved method to the satisfaction of the Principal.

8.5 QUALITY OF SHOTCRETE

Sample and test the shotcrete for conformity with this Specification and the Drawings during the progress of the work in accordance with Annexure R68/L for:

- (a) thickness (Clause 7.2);

- (b) compressive strength (Clause 3.6);
- (c) permeability (Clause 3.7); and
- (d) density (Clause 3.5).

Sample and test production Test Panels constructed with the Works in accordance with Clause 3.12 and, where specified in Annexure R68/L, from the completed Works.

8.5.1 Thickness and Visual Inspection

Determine the shotcrete thickness by taking core specimens of 25 mm diameter in randomly located positions within a representative area in accordance with Annexure R68/L. Prior to coring, locate the steel reinforcement positions using a cover meter, to prevent cutting the steel during coring.

Where production Test Panels are used for this purpose, saw each Test Panel into four parts for examination and evaluation of the internal cut surfaces, as well as the external surfaces, and total thickness.

In addition to the above requirement, visual inspection of all completed shotcrete work must ensure conformity with compaction and finish requirements.

ANNEXURE R68/A – PROJECT SPECIFIC REQUIREMENTS

Refer to Clause 1.2.1.

A1 MEMBERS IN EXPOSURE CLASSIFICATION U

A1.1 General

Shotcrete members in exposure classification U must conform to this Specification for the *Base Exposure Classification* and the additional requirements contained in this Annexure.

A1.2 Base Exposure Classification

The *Base Exposure Classification*, *Nature of Exposure* and *shotcrete isolation* requirements are contained in Table R68/A.1 or as specified on the Drawings.

Shotcrete quality, cover and other durability requirements for the *Base Exposure Classification* must conform to those specified for the corresponding exposure classification of AS 5100.5.

Where full isolation of shotcrete surface from the aggressive environment is mandatory, include details of the proposed isolation method with the shotcrete mix design submission.

Table R68/A.1

Parameters	Project Specific
<u>Base Exposure Classification:</u> ❶ B1 ❷ B2 ❸ C	
<u>Nature of Exposure:</u> ❶ Acid sulfate soil ❷ Soft or running water ❸ Others	
<u>Full Isolation of Shotcrete Surface from Aggressive Environment :</u> ❶ Not required ❷ Optional ❸ Mandatory	

A1.3 Additional Requirements

Cement:

Aggregate:

Admixtures:

Curing Regime:

Others:

ANNEXURE R68/B – MEASUREMENT AND PAYMENT

Payment will be made for all costs associated with completing the work detailed in this Specification in accordance with the following Pay Items.

Where no specific pay items are provided for a particular item of work, the costs associated with that item of work are deemed to be included in the rates and prices generally for the Work Under the Contract.

Unless specified otherwise, a lump sum price for any of these items will not be accepted.

Pay Item R68P1 – Supply and Placing of Shotcrete

The unit of measurement is per square metre of surface covered by the full thickness of shotcrete, as shown on the Drawings or directed by the Principal.

The schedule rate must include all materials and work associated with the surface preparation, supply and fixing of reinforcement, supply, application, curing of shotcrete and the costs of testing where such costs are not paid under Primary Testing..

ANNEXURE R68/C – SCHEDULES OF HOLD POINTS AND IDENTIFIED RECORDS

Refer to Clause 1.2.3.

C1 SCHEDULE OF HOLD POINTS

Clause	Description
3.8.1	Submission of nominated shotcrete mix details and certification.
4	Submission of method of surface preparation and a notice of intention to commence surface preparation. Request to Principal for direction on need for pressure grouting.
7.3	Submission of Certificate of Conformity in respect of surface preparation, reinforcement and embedments and notice of intention to commence shotcreting.

C2 SCHEDULE OF IDENTIFIED RECORDS

The records listed below are Identified Records for the purposes of TfNSW Q Annexure Q/E.

Clause	Description of Identified Record
2.3	Details of the effect of hydration control admixtures.
4 & 5	Certificate of Conformity of surface preparation, reinforcement and embedments.
8.3	Certificate of Conformity of curing compound.
8.3.1	Details of the effect of internal curing admixtures.

ANNEXURE R68/D – PLANNING DOCUMENTS

Refer to Clause 1.2.4.

The following documents are a summary of documents that must be included in the PROJECT QUALITY PLAN. Review the requirements of this Specification and others included in the Contract to determine additional documentation requirements.

The information to be submitted as part of the PROJECT QUALITY PLAN must include the following:-

- (a) Details of the methods to be used in determining the effect of hydration control admixtures on the properties of shotcrete in the Works over time (refer to Clause 2.3);
- (b) Technical Procedures in accordance with TfNSW Q for the surface preparation processes in Clause 4. Include details of the personnel required to carry out the operations together with proof of their relevant training and experience;
- (c) Technical Procedures in accordance with TfNSW Q for the shotcreting processes in Clause 7. Include details of the nozzle operators and other personnel required to carry out the operations together with proof of their relevant training and experience.

ANNEXURES R68/E TO R68/K – (NOT USED)

ANNEXURE R68/L – TESTING PROCEDURES

Refer to Clause 1.2.5.

L1 MINIMUM FREQUENCY OF TESTING

Clause	Property Tested	Test Method	Minimum Frequency of Testing
Supply and Delivery of Concrete			
2.4.1	Combined particle size distribution of coarse and fine aggregates - deviation from nominated particle size distribution	AS 1141.11.1	One per week
3.3	Slump	AS 1012.3.1	One per batch of concrete
Production of Test Panels			
3.11	Construction of production Test Panels	Clause 3.11	As required by the Principal
Thickness and Visual Inspection			
8.5.1	<u>From production Test Panels</u> Frequency of sawing	Clause 8.5.1	Each production Test Panel
	<u>From the Works</u> Frequency of drilling	Clause 8.5.1	Random core for each 50 m ² or part thereof
Determination of 28 Day Compressive Strength, Density and Relative Density			
3.5 & 3.6	<u>From concrete supply</u> Frequency of moulding specimens and testing.	AS 1012.8.1 and AS 1012.9	One pair per 25 m ³ or part thereof
	<u>From the Works</u> Frequency of drilling test specimens	AS 1012.14	One pair per one day's production
Determination of Permeability			
3.7	<u>From the Works</u> Frequency of drilling test specimens	AS 1012.14 DIN 1048	One pair per one day's production

L2 COMPRESSIVE STRENGTH

L2.1 Moulding of Samples

Mould concrete specimens in standard cylinders in accordance with the requirements and procedure of AS 1012.8.1 using rodding only.

L2.2 Specimens Cut from the Works (Cores)

When permitted by the Principal, cut 75 mm diameter core specimens by means of a core drill, wet-condition and test in accordance with AS 1012.14. Adjust the corrected (for length to diameter ratio) strength so determined for age by dividing the result by the factors shown in Table R68/L.1.

Do not test cores containing reinforcement but cut replacement cores at new locations.

Clean and restore core holes using a concrete mix designed to produce the same shotcrete quality as the material from which the core was cut. Design the repair concrete mix, and place the concrete in such a manner, so as to produce no shrinkage or no visible cracks. The surface of the restored hole must be similar to the surrounding surface in texture and colour.

L2.3 Testing

The compressive strength of the concrete represented by a pair of specimens made and cured in accordance with AS 1012.8.1 and tested in accordance with AS 1012.9, is the average strength of the two specimens unless the two results differ by more than 10% of their average, in which case take the higher result as the strength of the concrete.

L2.4 Adjustment for Age of Specimen

Should any specimen be tested more than 28 days after moulding, the equivalent 28 day strength is the test strength divided by the age factor given in Table R68/L.1. Age adjustment factors are given for concrete made with Portland cement and Blended cement. For intermediate ages, determine the factor on a pro-rata basis.

Table R68/L.1 - Factors for Age of Specimens

Age of specimen at time of test (days)	Age factor	
	Portland cement	Blended cement
28	1.00	1.00
56	1.08	1.19
112	1.14	1.33
224	1.22	1.42
365 or greater	1.25	1.45

ANNEXURE R68/M – REFERENCED DOCUMENTS

Refer to Clause 1.2.6.

TfNSW Specifications

TfNSW G36	Environmental Protection
TfNSW Q	Quality Management System
TfNSW 3211	Cements, Binders and Fillers

TfNSW Test Methods

TfNSW T363	Accelerated Mortar Bar Test for AAR Assessment
TfNSW T364	Concrete Prism Test for AAR Assessment
TfNSW T1005	Quantitative Analysis Using the Infrared Spectrophotometer

Australian Standards

AS 1012	Methods of testing concrete
AS 1012.2	Method 2: Preparing concrete mixes in the laboratory
AS 1012.3.1	Method 3.1: Determination of properties related to the consistency of concrete – Slump test
AS 1012.8.1	Method 8.1: Method for making and curing concrete – Compression and indirect tensile test specimens
AS 1012.9	Method 9: Compressive strength test – Concrete, mortar and grout specimens
AS 1012.13	Method 13: Determination of the drying shrinkage of concrete for samples prepared in the field or in the laboratory
AS 1012.14	Method 14: Method for securing and testing cores from hardened concrete for compressive strength
AS 1012.20	Method 20: Determination of chloride and sulfate in hardened concrete and concrete aggregates
AS 1141	Methods for sampling and testing aggregates
AS 1141.11.1	Method 11.1: Particle size distribution – Sieving method
AS 1141.22	Method 22: Wet/dry strength variation
AS 1289.3	Methods of testing soils for engineering purposes – Soil classification tests
AS 1379	Specification and supply of concrete
AS 1478.1	Chemical admixtures for concrete, mortar and Grout – Admixtures for concrete
AS 2349	Method of sampling Portland and blended cements
AS 2758.1	Aggregates and rock for engineering purposes – Concrete aggregates
AS 3799	Liquid membrane – forming curing compounds for concrete
AS/NZS 4671	Steel reinforcing materials
AS 5100.5	Bridge design – Concrete

AS/NZS ISO 9001 Quality management systems – requirements

ASTM Standards

ASTM C 295 Standard Practice for Petrographic Examination of Aggregates for Concrete

DIN Standards

DIN 1048 Part 5 Testing Methods for Concrete – Permeability