

Technical Specification

**Transport and Main Roads Specifications
MRTS272 Shotcrete for Aboveground Applications**

November 2020

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1 Introduction

This Technical Specification applies to the supply and installation of shotcrete. It is intended for fibre-reinforced and conventional steel bar or steel mesh reinforced wet-mix shotcrete. It is not intended for overhead applications, for tunnelling, or for other underground Works. Typical applications include:

- slab-on-ground drainage
- slope stabilisation
- abutment protection, and
- retaining wall elements where the shotcrete is not the primary structural element (for example, between cast-in-place piles).

The aim of this Technical Specification is to achieve finished shotcrete of the required strength, durability and appearance. It describes the materials, supply, application, finishing, curing and measurement of shotcrete.

All concrete for shotcrete work shall be manufactured and supplied in accordance with the requirements of AS 1379 *Specification and supply of concrete*, where covered by its scope, MRTS70 *Concrete* and the additional requirements of this Technical Specification.

Where the application is covered by MRTS03 *Drainage, Retaining Structures and Protective Treatments* (for example, sprayed concrete paving), the requirements of that Technical Specification shall also be met.

This Technical Specification shall be read in conjunction with MRTS01 *Introduction to Technical Specifications* and other Technical Specifications as appropriate.

This Technical Specification forms part of the Transport and Main Roads Specifications Manual.

This Technical Specification draws upon and references MRTS70 *Concrete* extensively. A knowledge of MRTS70 *Concrete* is critical for correct application of this Technical Specification. For tunnelling or underground shotcrete work, a project-specific Specification is required until MRTS275 *Concrete for Underground Tunnel Applications* is published.

1.1 Registered products and suppliers

The requirements for the construction of shotcrete elements include the use of registered products and suppliers. For information regarding these products and suppliers, refer to the department's website at <https://www.tmr.qld.gov.au/business-industry/Business-with-us/Approved-products-and-suppliers> or email TMRStructuralMaterials@tmr.qld.gov.au.

2 Definition of terms

The terms and symbols used in this Technical Specification shall be as defined in Clause 2 of MRTS01 *Introduction to Technical Specifications*, MRTS70 *Concrete* and in Table 2 below.

Table 2 – Definition of terms

Term	Definition
as-supplied concrete	Concrete delivered to Site in a transit mixer, prior to spraying. Samples are taken from the transit mixer chute.
batch	One load or charge of a mixing plant or transit mixer.
Lot	<p>An identifiable quantity of shotcrete from which samples are taken, and about which decisions are made on the basis of tests carried out on specimen cylinders made from samples and/or cores taken from the lot. A lot shall consist of batches of shotcrete of the same strength grade, produced and placed in an essentially uniform and continuous manner during a day's production.</p> <p>A lot may be further defined by individual product Technical Specifications.</p>
nozzle	Attachment at the end of delivery hose from which the shotcrete is projected.
overspray	Shotcrete material that is not intercepted by the receiving surface.
panel	A distinct section of the area for shotcreting (usually not less than 10 m in length)
rebound	Shotcrete material that bounces off the receiving surface.
shotcrete	<p>Shotcrete (generic): Concrete projected onto a surface at high velocity.</p> <p>Wet-mix Shotcrete: Shotcrete in which cement, aggregate and water are first mixed together before introduction of concrete into the delivery hose. Admixtures may be mixed in with the concrete or injected at the nozzle.</p>
shotcrete mix	<p>Base Mix: Concrete designed, tested and supplied independent from the shotcreting process, equipment and personnel.</p> <p>Shotcrete Mix: The base mix after it is applied to the Works or Test Panels.</p>
sample	A portion of fresh shotcrete drawn from a batch and from which specimen cylinders are made, or core samples taken, or test panels sprayed.
sloughing	Detachment or falling away of fresh shotcrete.
registered	<p>Pre-qualified product or supplier in accordance with departmental Registration Schemes:</p> <ul style="list-style-type: none"> • <i>Registration Scheme: Suppliers and Products for Bridges and Other Structures</i> • <i>Product Index for Bridges and Other Structures</i> • <i>Construction Materials Testing Supplier Registration Scheme</i> • <i>Quarry Registration System.</i> <p>Registration for certain products and suppliers is a prerequisite for approval, not a substitute.</p>

3 Referenced documents

Table 3 lists documents referenced in this Technical Specification.

Table 3 – Referenced documents

Reference	Title
AS 1012.9	<i>Methods of testing concrete, Method 9: Compressive strength tests – Concrete, mortar and grout specimens</i>
AS 1012.12.2	<i>Methods of testing concrete: Determination of mass per unit volume of hardened concrete – Water displacement method</i>
AS 1012.14	<i>Methods of testing concrete, Method 14: Method for securing and testing cores from hardened concrete for compressive strength and mass per unit volume</i>
AS 1379	<i>Specification and supply of concrete</i>
AS 1478.1	<i>Chemical admixtures for concrete, mortar and grout, Part 1: Admixtures for concrete</i>
AS 3600	<i>Concrete structures</i>
AS 3610.1	<i>Formwork for concrete, Part 1: Specifications</i>
AS 5100.5	<i>Bridge design Part 5: Concrete</i>
AS/NZS 4680	<i>Hot-dip galvanized (zinc) coatings on fabricated ferrous articles</i>
Design Criteria	<i>Design Criteria for Bridges and Other Structures</i>
MRTS01	<i>Introduction to Technical Specifications</i>
MRTS03	<i>Drainage, Retaining Structures and Protective Treatments</i>
MRTS50	<i>Specific Quality System Requirements</i>
MRTS70	<i>Concrete</i>
MRTS71	<i>Reinforcing Steel</i>
MRTS71A	<i>Stainless Steel Reinforcing</i>
MRTS273	<i>Fibre-reinforced Concrete</i>
MRTS275	<i>Concrete for Underground Tunnel Applications (not yet published)</i>
SCM-P-015	<i>Registration Scheme: Suppliers and Products for Bridges and Other Structures</i>

4 Standard test methods

The standard test methods stated in Table 4 shall be used in this Technical Specification.

Further details of test numbers and test descriptions are given in Clause 4 of MRTS01 *Introduction to Technical Specifications*.

All tests for the purposes of compliance, including sampling, are to be performed and reported by a NATA-accredited laboratory, whose scope of accreditation encompasses the test method used. Laboratories must also be registered with the department via the Construction Materials Testing Supplier Registration System (CMT-SRS).

Table 4 – Standard test methods

Property to be Tested	Method No.
Concrete compressive strength	AS 1012.9
Concrete density	AS 1012.12.2
Core sampling and compressive strength of core samples	AS 1012.14

4.1 Testing of cores

The compressive strength of cores shall be corrected (following AS 1012.14) for:

- a) core L / d ratio
- b) damage due to drilling, and
- c) horizontal drilling.

The application of these correction factors shall be noted on the test report.

Cores shall be dry conditioned in accordance with AS 1012.14 unless noted otherwise on the Drawings.

For example, a 100 mm diameter core from a 150 mm thick upright panel would be corrected as follows: $x_{corrected} = x \times 0.96 \times 1.06 \times 1.07 = 1.089x$

5 Quality system requirements

5.1 Hold Points, Witness Points and Milestones

General requirements for Hold Points, Witness Points and Milestones are specified in Clause 5.2 of MRTS01 *Introduction to Technical Specifications*.

The Hold Points, Witness Points and Milestones applicable to this Technical Specification are summarised in Table 5.1.

Table 5.1 – Hold Points, Witness Points and Milestones

Clause	Hold Point	Witness Point	Milestone
7	1. Construction procedures		Submission of procedures and mix designs (5 weeks)
9		1. Shotcrete trial placement 2. Coring of trial	
9.2	2. Approval to place shotcrete		
14		3. Shotcrete placement	
16	3. Rectification of defects		

5.2 Construction procedures

The Contractor shall prepare and submit, to the Administrator, documented procedures for construction processes in accordance with the quality system requirements of the Contract. These processes are listed in Table 5.2.

Table 5.2 – Construction procedures

Clause	Procedure
7	Shotcreting

5.3 Conformance requirements

The conformance requirements which apply to lots of work covered by this Technical Specification are summarised in Table 5.3.

Table 5.3 - Conformance requirements

Clause	Conformance requirement
11	Concrete strength, density
14	Dimensions and levels

6 Materials

Concrete designated on the Drawings as 'special-class' shall comply with Clauses 7 through 10 of MRTS70 *Concrete* and this Technical Specification.

Concrete designated on the Drawings as 'normal-class' shall comply with Clauses 17.2 through 17.5 of MRTS70 *Concrete* and this Technical Specification.

Reinforcing steel and its use shall comply with MRTS71 *Reinforcing Steel* or MRTS71A *Stainless Steel Reinforcing* as specified. Where galvanised reinforcing steel is specified, reinforcing steel shall be hot-dip galvanised in accordance with AS/NZS 4680.

6.1 Concrete

In addition to the requirements of MRTS70 *Concrete*, the following requirements apply to shotcrete.

The nominated slump of the concrete mix shall be between 60 mm and 180 mm.

For special-class shotcrete, chemical admixtures included in the mix or injected at the nozzle, designated special purpose in accordance with AS 1478.1, are permissible without Director (Structures Construction Materials) approval. Such admixtures shall be registered by Transport and Main Roads specifically to this Technical Specification. Admixtures included in the concrete mix or injected at the nozzle shall have a proven and necessary purpose. Corrosion inhibitors and internal curing admixtures are not permitted in either normal or special-class concrete.

6.2 Fibres

Where noted on the Drawings, fibres shall be included in the base concrete mix. Fibres, the design and specification of the fibres, and their use shall conform to MRTS273 *Fibre-reinforced Concrete*.

Fibres may be used as a replacement for conventional reinforcement where indicated or approved by the Designer.

Fibre types and dosages shall be as nominated on the Drawings and shall not result in balling, pumpability or sprayability issues with the shotcrete.

Toughness and residual flexural strength are tested on as-sprayed samples during concrete mix trials. Flexural strength is tested on as supplied concrete during trials and production. See Clause 9 and MRTS273 *Fibre-reinforced Concrete*.

7 Proposed construction procedures

No less than 5 weeks prior to construction, the Contractor shall submit proposed procedures for approval by the Administrator. **Milestone**

These procedures shall include details of:

- a) concrete batching and supply, as per Clause 10 of MRTS70 *Concrete*
- b) surface preparation
- c) equipment
- d) placement and fixing of reinforcement
- e) spraying
- f) finishing and curing
- g) concrete mix design, and
- h) nominated nozzle operators.

The concrete trial (Clause 9) shall not proceed until the above have been approved by the Administrator. **Hold Point 1**

The *Recommended Practice: Shotcreting in Australia* (Concrete Institute of Australia, 2010) provides guidance on materials and methods to take into consideration when preparing these procedures.

8 Equipment

Equipment shall be capable of producing a continuous uninterrupted stream of shotcrete. Equipment shall be capable of maximising compaction and quality while minimising rebound and overspray.

Dispensing devices for admixtures added at the nozzle shall be mechanically regulated, and calibrated.

9 Trial mix

No less than four weeks prior to construction, a trial shall be undertaken for each concrete mix and nozzle operator, in the presence of the Administrator. **Witness Point 1** The trial shall use the

proposed procedures to create test panels, measuring at least 750 mm x 750 mm across, with thickness the greater of 150 mm and the design thickness.

Moulds for test panels shall be fabricated from rigid, non-water absorbent material. Appropriate measures shall be taken to avoid entrapment of rebound in the mould. Steel reinforcement, if included in the Drawings, shall be incorporated in the test panel. A suitable lifting anchor shall also be incorporated into the panel to assist with movement and transport. Moulds shall be positioned at an angle representative of the project surface to the shotcrete.

From the same batch of concrete used for the test panels, a minimum of four concrete cylinders shall be cast. One cylinder shall be tested for compressive strength at seven days, and a matched pair at 28 days, in accordance with AS 1012.9. Density of cylinders shall be measured in accordance with AS 1012.12.2.

At least 24 hours after spraying, four cores shall be taken from the test panel in accordance with AS 1012.14. **Witness Point 2** One core shall be tested for compressive strength at seven days, and a matched pair at 28 days. Density of cores shall be measured in accordance with AS 1012.12.2.

The relative strength and density of the cores compared to the cylinders shall be reported.

Documented evidence of trials, including test reports and photographs, performed on previous projects using the same concrete mix, spraying equipment and applicator may be accepted in lieu of project-specific trials, at the discretion of the Administrator.

Sets of four samples are taken, in line with MRTS70 *Concrete*, to maintain a spare, in case of underperformance at early age or testing failures. The spare can be discarded once 28 day testing is completed.

9.1 Fibre-reinforced shotcrete

For fibre-reinforced shotcrete, additional test panels of the appropriate thickness and shape for the desired test(s) shall be sprayed from the concrete batch and cut (if necessary) from the sample panel at least 24 hours after spraying. The number of required specimens shall be in accordance with MRTS273 *Fibre-reinforced Concrete*.

Flexural strength, and/or residual flexural strength and/or toughness (whichever is specified) shall be measured from samples from the as-sprayed concrete. Indirect tensile tests shall be conducted on cylinders made from as-supplied concrete.

9.2 Conformance

The concrete mix and proposed procedures shall be approved if:

- a) 28 day sample compressive strength (cylinders) equals or exceeds $0.5 (f'_c + f'_t)$
- b) 28 day sample compressive strength (cores) exceeds f'_c . (see Clause 4.1)
- c) density of core exceeds 98% of the density of cylinders
- d) 28 day sample flexural strength and/or residual flexural strength and/or toughness exceed requirements, if specified by the Designer
- e) visual examination of cores, core holes and rear panel face reveals hard, dense concrete without voids or honeycombing

- f) unmoulded finish of panel meets requirements of Drawings, and
- g) requirements of MRTS70 *Concrete* regarding the concrete mix are met (see Clause 15.1 of MRTS70 *Concrete*).

Construction Works shall not commence until approval has been granted by the Administrator.

Hold Point 2

Early provisional approval may be granted from seven day results for the above tests at the discretion of the Administrator.

Early provisional approval would be particularly suitable where previous performance of the concrete mix, spraying equipment and of nozzle operators was known separately.

10 Environmental limits for concreting applications

Environmental and temperature limits shall apply as per Clause 13 of MRTS70 *Concrete*.

11 Surface preparation

Surfaces shall be adequately prepared to receive and adhere shotcrete. Moisture condition and surface profile of the substrate shall be managed to prevent slippage, non-adherence and loss of water from the shotcrete. Water shall not be flowing across the surface or seeping excessively from the surface to be shotcreted.

Loose surfaces (including soil, earth and gravel) shall be compacted and trimmed to the required line and grade. Rigid surfaces (including rock and concrete) shall be free from loose material, dust and any films that may interfere with the bond (for example, oils).

Where shotcrete is used for rehabilitation of an existing concrete element, the substrate shall be broken back to sound concrete and any exposed reinforcement treated with a zinc-rich primer. The existing concrete surface shall be dampened prior to shotcreting.

If shotcrete is to be applied to a metal surface, the surface shall be prepared in accordance with the Drawings.

Surfaces adjacent to the area to be shotcreted shall be protected if required from any adhering shotcrete or, alternatively, shotcrete shall be removed from these surfaces after spraying.

12 Acceptance and rejection of plastic concrete

Concrete shall be delivered, tested and accepted / rejected prior to spraying in accordance with Clause 11 of MRTS70 *Concrete*.

13 Acceptance and rejection of hardened concrete

Hardened concrete shall be sampled, tested and accepted / rejected as follows.

13.1 As-supplied special-class concrete

Special-class concrete shall be sampled in accordance with MRTS70 *Concrete*. Concrete shall be tested and assessed in accordance with MRTS70 *Concrete*. Shotcrete is exempt from the over-strength (1.4 x f_c) provision of MRTS70 *Concrete* (Clause 12.5(c)).

For fibre-reinforced concrete (see MRTS273 *Fibre-reinforced Concrete*), indirect tensile testings shall be conducted on the as-supplied concrete.

13.2 As-supplied normal-class concrete

Normal-class concrete shall be sampled, tested and assessed prior to spraying in accordance with Clause 17.7 of MRTS70 *Concrete* on a project assessment basis.

For fibre-reinforced concrete (see MRTS273 *Fibre-reinforced Concrete*), indirect tensile testings shall be conducted on the as-supplied concrete.

13.3 As-sprayed concrete

Samples shall be cored from applied shotcrete at the frequencies listed in Table 13.3, with a minimum of one sample per day. Each sample shall consist of a minimum of three cores and represent a single batch of concrete from which cylinders have also been taken. Care shall be taken to avoid damage to any steel reinforcement or fixtures.

Cores taken prior to 28 days shall be stored in standard laboratory conditions (see AS 1012.8.1).

Table 13.3 – Testing frequency

Lot area (m ²)	Number of samples
≤ 125	1
125–300	2
301–500	3
≥ 500	4

The 28 day compressive strength of the concrete cores shall be determined in accordance with Clause 12.3 of MRTS70 *Concrete* and Clause 4.1 of this Technical Specification.

Correction factors are applied to specimen results prior to averaging.

Concrete in the lot shall be rejected if:

- a) any sample strength is less than 0.9 times the specified characteristic strength, or
- b) the density of the cores is less than 95% of the corresponding cylinders.

The relative strength of the cores compared to the as-supplied concrete shall be reported and compared to the ratio calculated from the trial mix.

Core holes shall be repaired using either a registered repair mortar with a characteristic strength exceeding that of the shotcrete or additional shotcrete of the original mix.

14 Placement

The Contractor shall ensure equipment, procedures and personnel are adequate to produce shotcrete which is dense, homogenous, without segregation of aggregate or fibres, and without sloughing, collapsing, excessive rebound or other visible imperfections.

Shotcrete shall be sprayed at a regulated rate, in a steady uninterrupted manner. **Witness Point 3**
The distance between the receiving surface and the nozzle, and the angle of approach shall be

maintained within the parameters of the approved construction procedure and that used during the trial. The maximum angle used shall be 30° from perpendicular.

Shotcrete shall be applied in successive layers not exceeding 75 mm in thickness to the design thickness, ensuring adequate adhesion to the substrate or previously applied layers. The time delay between layers shall be sufficient to prevent sloughing or collapsing of the applied shotcrete or the previous layer. Shotcrete shall be applied continuously between joints which shall be prepared to prevent feathering.

Any shotcrete that has sagged, slumped, or is loose, porous, or uncompacted shall be removed from the Site and not incorporated into the Works. Likewise, rebound material shall be removed. If lack of adhesion or compaction persist, shotcreting shall cease until the cause has been identified and rectified. **Nonconformance**

14.1 Monitoring shotcrete thickness

Probes or depth pins shall be used during application of the shotcrete to enable monitoring of shotcrete thickness. Alternative methods for monitoring of the shotcrete thickness may be proposed for approval by the Administrator.

14.2 Surface finish

Unless specified otherwise, all completed shotcrete surfaces shall have an undisturbed natural finish as applied from the nozzle, or a screeded finish acceptable to the Administrator to line and level. Where a smooth finish is required, it shall meet the requirements of a Class 3 finish to AS 3610.1. Other finishes if specified, shall be approved by the Administrator. Screeding rails or guides if used are to be removed from the finished Works and any damage associated with removal to be repaired to a standard acceptable to the Administrator.

Cracks shall not exceed 0.3 mm in width, 500 mm in length, or one linear metre per square metre of shotcrete.

Tolerances for a smooth or screeded finish shall be in accordance with MRTS70 *Concrete* if applicable.

14.3 Construction joints

Specified construction joints shall comply with MRTS70 *Concrete* and the Drawings. Unless otherwise specified, steel reinforcement shall be continuous through the construction joint and such reinforcement shall be galvanised.

Unplanned joints shall be treated as directed by the Administrator.

14.4 Curing

Shotcrete shall be cured using curing compounds or water in accordance with Clause 15.11 of MRTS70 *Concrete*. Curing compounds shall not be used when additional layers of shotcrete or concrete are to be applied.

15 Dimensional 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 shall be as per either the Drawings, MRTS03 *Drainage, Retaining Structures and Protective Treatments* or MRTS70 *Concrete*, in that order of precedence. The tolerance on thickness shall be as shown on the

Drawings and, if not shown on these Drawings, shall be no less than the indicated thickness or as directed by the Administrator.

16 Defects and rectification

Where shotcrete does not comply with the requirements listed in this Technical Specification, the unit or lot may, at the discretion of the Administrator, be rejected and replaced or undergo rectification.

This work shall be at the Contractor's expense.

The method of rectification shall be approved by the Administrator. **Hold Point 3**

