

Appendix A

Reference Specification

The purpose of this appendix is to provide an end-product or performance-type specification for sprayed concrete, applicable to both new construction and to repair and strengthening work.

It has been prepared on the same basis as the CIA companion Recommended Practice *Reference Specification for Concrete Work* (October 1980), in that it has been made as comprehensive as possible and includes suitable technical clauses. As such, it can generally be considered a reference specification and may be modified to produce a more detailed specification for specific projects.

As this specification is intended to form only part of the documents comprising a contract, it should be supported by drawings describing the work, bills of quantities, etc.

A1 General

A1.1 Scope

This specification covers the requirements for materials, proportioning and application of sprayed concrete.

A1.2 Definitions

For the purposes of this specification the following definitions shall apply:

Sprayed Concrete - a mixture of cement, aggregate and water projected at high velocity from a nozzle into place, to produce a dense, homogeneous mass.

Gunitite - sprayed concrete in which the maximum aggregate size is less than 10 mm

Shotcrete - sprayed concrete in which the maximum aggregate size is 10 mm or greater.

Dry-mix Process - that in which a mixture of cement and aggregate (weight-or volume-batched) thoroughly mixed 'dry' and fed into a purpose-made machine, wherein the mixture is pressurised, metered into a dry air stream and conveyed through hoses or pipes to a nozzle, where water (as a spray) is introduced to hydrate the mix, which is projected without interruption into place.

Wet-mix Process - that in which a mixture of cement and aggregate (weight-hatched) mixed with water at site or in mixer trucks prior to being conveyed through a pipeline to a nozzle, where air is injected and the mix projected without interruption into place.

Flash Coat - sprayed concrete applied as a thin layer protecting, priming or finishing the surface.

Layer - all material that, having passed through the nozzle, does not conform to the

above definition of sprayed concrete.

Nozzle - the attachment at the end of the hose from which the material is discharged at high velocity. *Nozzleman* - the workman who manipulates the nozzle, and controls the consistency and final disposition of the material.

Contractor - the party to the contract who is constructing the structure (or undertaking the works).

Proprietor - the party to the contract for whom the structure is being constructed (or the works are being undertaken).

Superintendent - the person designated by the Proprietor to administer the contract on his behalf.

Approval or Approved - approval of or approved by the Superintendent.

A1.3 Applicable Publications

Standards Association of Australia

The following Standards, of the issues listed below but referred to hereafter by basic designation only, form part of this specification to the extent indicated by the references thereto:

AS 1012	Methods of Testing Concrete
AS 1129	Fly Ash for Use in Concrete
AS 1130	Code of Practice for Use of Fly Ash in Concrete
AS 1302	Steel Reinforcing Bars for Concrete
AS 1303	Hard-drawn Steel Reinforcing Wire for Concrete
AS 1304	Welded Wire Reinforcing Fabric for Concrete
AS 3972	Portland and Blended Cement
AS 1478	Chemical Admixtures for Use in Concrete
AS 1479	Code of Practice for the Use of Chemical Admixtures in Concrete
AS 3600	Concrete Structures Code
AS 1509	Formwork Code
AS 2350	Methods of Testing Portland and Blended Cements
AS 2758	Part 1 Concrete Aggregates

Concrete Institute of Australia

Z1 *Reference Specification for Concrete Work*

American Society for Testing and Materials

ASTM C 156 Test methods for water retention by concrete curing materials

A2 Materials

A2.1 General

The Contractor shall obtain approval for the use of all materials from the Superintendent before the work is started.

A2.2 Cement

Cement shall be Type GP (General Purpose Portland cement) complying with the requirements of AS 3972.

Other cements may be used only if approved, and if the resulting concrete has strength, durability and other characteristics not inferior to those required by this specification for portland-cement concrete.

A2.3 Aggregates

Aggregate shall comply with AS 2758.1 *Concrete Aggregates*. The maximum aggregate size shall not exceed 10mm unless approved by the Superintendent.

A2.4 Water

Water shall be free from matter that in kind and quantity is harmful to concrete or its reinforcement.

A2.5 Chemical Admixtures

An admixture, if approved for use, shall comply with AS 1478 *Chemical Admixtures for Use in Concrete* and be used in accordance with AS 1479 *Code of Practice for the Use of Chemical Admixtures in Concrete*. Any admixture used shall not adversely affect any reinforcement or its protective coating.

A2.6 Fly Ash and Microsilica

Fly ash, if approved for use, shall comply with AS 1129 *Fly Ash for Use in Concrete* and be used in accordance with AS 1130 *Code of Practice for Use of Fly Ash in Concrete*.

Microsilica (condensed silica fume) shall comply with the requirements of AS 3582.3. The carbon content of microsilica shall be less than 5% and the silica content shall be at least 85%.

A2.7 Reinforcement

Reinforcement shall comply with AS 1302 *Steel Reinforcing Bars for Concrete*, AS 1303 *Hard-drawn Steel Reinforcing Wire for Concrete* and AS 1304 *Welded Wire Reinforcing Fabric for Concrete*.

A2.8 Fibres

Steel or other fibres, if approved for use, shall be from a manufacturer approved by the Superintendent.

Polypropylene fibres shall be discrete fibrillated polypropylene fibres 19mm long.

Steel fibres shall 18 x 0.6 x 0.3 enlarged end fibres.

A2.9 Storage of Materials

A2.9.1 Cement and fly ash shall be stored in weather-tight buildings, bins or silos that provide protection from dampness and contamination. Bags shall be stacked so as to permit access for tallying, inspection and identification of each consignment. The stored materials shall be used in chronological order.

A2.9.2 Aggregate stockpiles shall be arranged and used in a manner that prevents segregation or any contamination with other-sized aggregate. Stockpiles shall be free-draining. Where colour uniformity of aggregates is important for concrete finishing, all the aggregates required for the project shall be stockpiled in a clean and protected location.

A2.9.3 Admixtures shall be stored in such a way as to ensure that there is no detrimental effect on their properties. The Contractor shall comply with any special requirements of the manufacturer of the product.

A3 Mix Design

A3.1 General

Mix proportions shall be determined by the Contractor and shall be to the approval of the Superintendent. Weight batching shall be employed unless volume batching is approved by the Superintendent. The weight of each material shall be within plus or minus 3% of that specified.

A3.2 Strength

The design of the mix shall be such that the strength as determined in accordance with Clause A12 shall be as stated in the contract.

A3.3 Materials

No material other than oven-dried or bagged pre-mix shall be used later than one hour after the addition of cement to the aggregate.

A3.4 Admixtures

Where accelerating admixtures are used (to the approval of the Superintendent), the following setting times and strengths shall apply unless otherwise stated in the contract:

Initial set of cement/admixture paste	3 min
Final set of cement/admixture paste	12 min
8-hour strength of concrete	4 MPa
24-hour strength of concrete	10 MPa

Setting times shall be tested in accordance with Clause 13.6 and strengths in accordance with Clause A12 except that the panels shall be cored at the appropriate times.

A3.5 Uniformity

All constituents shall be uniformly dispersed throughout the mix.

A4 Qualifications of Operators

A4.1 General

All operators shall be approved by the Superintendent.

A4.2 Certification

Before spraying is begun, the Contractor shall certify to the Superintendent that the foreman, nozzleman and delivery equipment operatives have completed satisfactory work in similar capacities elsewhere. Where required by the Superintendent, the operators shall spray pre-construction panels, which shall be approved by the Superintendent before the operators are employed on the works. Such panels may also be used by the Superintendent to assess the competence of operators or trainees for whom the above certification is not available.

A5 Plant

The Contractor shall state the numbers and type of plant he proposes to use for the construction of the works.

A6 Pre-construction Test Panels

A6.1 General

Pre-construction testing shall be carried out using plant identical to that proposed for the works and shall be undertaken in such time before the commencement of the works to allow completion of testing, and approval by the Superintendent.

A6.2 Trial Mixes

Trial mixes of each mix-design proposed shall be produced by the Contractor. For each mix design or for each type of plant, three test panels 500 x 500 x 150 mm thick shall be sprayed from each position that is to be used in the works, such as down-hand, vertical and overhead positions, with layer thickness appropriate to that position. Panel moulds shall be formed from plywood at least 20 mm thick, be adequately braced and be held rigidly in position.

A6.3 Test Panels

Where required by the contract or by the Superintendent, test panels of minimum size 600 x 600 x 150 mm thick shall be sprayed from each required position as above, with layer thickness appropriate to that position and with reinforcement as detailed by the Superintendent.

A6.4 Testing

Pre-construction test panels shall be tested in accordance with Clause A12.

A6.5 Alternatives

Where permitted by the Contract or by the Superintendent, the Contractor shall provide as an alternative to the requirements of Clauses A6.1, A6.2 and A6.3 evidence, satisfactory to the Superintendent, of properties of sprayed concrete obtained elsewhere using materials from the same source as those proposed for the contract and with the same mix proportions and employing similar plant.

A7 Substrate Preparation

A7.1 Natural Surfaces Other than Massive Rock

The surface shall be compact, trimmed and graded as required, and damp before the application of sprayed concrete. Natural surfaces must be sufficiently cohesive to prevent erosion when the sprayed concrete is applied, or, when required by the Superintendent, must be treated.

A7.2 Massive Rock

The rock surface shall be cleaned of loose material, mud and other foreign matter that might prevent bonding of the sprayed concrete onto the rock surface. After washing down, surfaces shall be damp but exhibiting no free water prior to the application of sprayed concrete.

A7.3 Wet Surfaces

Where flow of water could interfere with the application of sprayed concrete or cause leaching of cement, the water should be led by pipes or gutters to some point where it may be plugged off after the application of sprayed concrete. Stemming small flows by the use of special mixes of sprayed concrete containing abnormally high proportions of admixtures that will induce accelerated set will be permitted, but such sprayed concrete shall not be considered to form part of the structural thickness.

A7.4 Steelwork and Reinforcement

Loose rust, oil, scale, paint or any coating over the metal shall be removed prior to the application of sprayed concrete.

A7.5 Concrete, Brickwork or Masonry

Loose and unsound material shall be removed to the satisfaction of the Superintendent before applying sprayed concrete. The surface shall be damp before application of sprayed concrete. The surface shall be prepared so that no abrupt changes in thickness of the sprayed concrete occur.

A7.6 Freshly-sprayed Concrete Surfaces

Except for flash coats, no subsequent layer shall be applied until the penetration resistance of the preceding layer is twice that specified for the definition of initial set. Any laitance shall be removed.

A7.7 Temperature Limits

No concrete shall be sprayed onto surfaces outside the following limits without prior approval of the Superintendent,

	Minimum	Maximum
Surface Temperature, °C	10	30
Ambient Temperature, °C	5	37

A8 Formwork

A8.1 Formwork and Falsework Proposals

The Contractor shall submit his proposals for formwork and falsework to the Superintendent for approval.

A8.2 Hessian or Fine-aperture Fabric or Other Non-rigid Formwork

Non-rigid formwork shall be firmly fixed and held taut to minimise vibration or flapping so that sagging of the sprayed concrete will not occur.

A8.3 Timber or Steel Formwork

Formwork shall be coated with an approved release agent correctly applied to prevent

absorption of moisture and adhesion to the concrete. **A8.4 Stripping Times**

Stripping times for load-bearing forms shall be determined in a manner similar to that for poured concrete as given in Clause 3.10 of the CIA Recommended Practice *Reference Specification for Concrete Work*.

A9 Reinforcement

Reinforcement shall be firmly fixed to provide the cover, clearances and laps described in the contract or specified by the Superintendent. Unless otherwise specified, the minimum cover provided to reinforcement shall be 25 mm. Where stainless-steel tie wire is specified, other fixings or spacing devices shall be corrosion resistant.

A10 Spraying Procedures

A10.1 Adverse Conditions

A10.1.1 No concrete shall be sprayed in air temperatures less than 5°C.

A10.1.2 Freshly-sprayed concrete shall be protected from rain or water until the surface is of sufficient hardness to prevent damage.

A10.1.3 Spraying shall be discontinued if wind or air currents cause separation of the nozzle stream during placement.

A10.1.4 A minimum lighting intensity of 50 lux shall be maintained in the spraying area.

A10.2 Placing Techniques

A10.2.1 During starting or stopping of the spraying operation or whenever spraying is irregular, the nozzle shall be directed away from the works.

A10.2.2 All corners and any areas where rebound cannot escape or be blown free shall be filled prior to general spraying.

A10.2.3 Rebound shall not be worked into the construction or re-used in the works.

A10.2.4 Surfaces that are not to receive sprayed concrete shall be protected.

A10.3 Placing Around Reinforcement

A10.3.1 The nozzle shall be held at a distance and angle that will enable concrete to be sprayed behind reinforcement before any material is allowed to accumulate on its face.

A10.3.2 Concrete shall not be sprayed through more than one layer of reinforcing bars or mesh in one application unless pre-construction tests have shown that the steel will be properly encased.

A10.3.3 All reinforcement shall be completely surrounded by sprayed concrete,

A10.4 Line and Thickness Control

A10.4.1 Guides shall be set up to establish finished surfaces if required in the contract. These guides shall be approved by the Superintendent prior to spraying. When required, arrises shall be formed true to the details shown in the contract.

A10.4.2 Sprayed concrete shall be applied so that it neither sags nor slumps.

A10.4.3 The thickness of each layer of sprayed concrete shall not exceed the maximum stated in the contract.

A10.5 Tolerances

A10.5.1 Tolerances to which surfaces of sprayed concrete are finished shall be in accordance with Rule 4.4 of AS 1509 *Formwork Code* unless specified otherwise in the contract.

A10.5.2 in the case of tunnels, the finished surface shall not project beyond the clearance surface defined in the contract, Where sprayed concrete is to be placed to a specified shape it shall be within plus or minus 25 mm of that shape and contain no depression greater than 15 mm below a 2-m straightedge.

A10.5.3 For sprayed concrete on natural surfaces or surfaces with an undefined shape, the thickness shall be within -0/+15 mm of the nominal thickness unless specified otherwise in the contract.

A10.6 Repair of Surface Defects

Areas of the works that exhibit a lack of compaction or bonding, dry patches, voids, sand pockets or sagged or slumped material shall be removed and the areas re-sprayed immediately. Areas of re-spraying shall not be less than 300 x 300 mm and shall be to the approval of the Superintendent.

A10.7 Finishing

Unless otherwise stated in the contract, sprayed concrete shall be left as sprayed. All surface finishes shall be reasonably uniform in texture and free from blemishes.

Where a particular surface is required on layers less than 50 mm thick, the finish shall be formed in or on a subsequent layer.

A10.8 Curing and Protection

A10.8.1 Freshly-sprayed concrete shall be thoroughly protected from freezing or rapid

drying-out for a period of at least three days.

A10.8.2 Curing - the sprayed concrete shall be fully moist cured at 100% relative humidity for a curing period of 7 days, or an approved alternative.

Curing that satisfies this requirement may be undertaken by one of the following:

- (a) Applying a curing membrane with an efficiency in excess of 75% while the concrete surface remains moist and maintaining the membrane for a duration equal to twice the curing period.
- (b) Providing conditions to ensure the relative humidity will remain above 80% and wind speeds will remain below 12 knots (6m/s) for a duration equal to twice the curing period.
- (c) Other methods whereby it can be demonstrated that the curing conditions will remain between those indicated in item (b) and full moist curing at 100% relative humidity

The efficiency of a liquid membrane-forming compound or sheet material shall be determined from ASTM C 156.

A10.8.3 Liquid membrane-forming curing compounds shall not be used on any surfaces against which additional concrete is to be sprayed, or to which other cementitious finishing materials are to be bonded, unless positive measures, such as sandblasting, are taken to remove them completely before such additional materials are applied. On nozzle finishes the application rate shall be twice that recommended by the manufacturer. Liquid membrane-forming curing compounds shall be white pigmented or contain a fugitive dye to assist in achieving uniform coverage.

A10.8.4 Formed surfaces - If forms are removed during the curing period, one of the curing materials or methods detailed in Clause A10.8.2 shall be employed for the duration of the curing period.

A10.8.5 During the curing period, the sprayed concrete shall be maintained above 5°C and in a moist condition as specified in clauses A10.8.2. The sprayed concrete shall not be allowed to rapidly dry at the end of the curing period.

A10.9 Records

Full records of all materials delivered to the sprayed-concrete mixer shall be kept and made available to the Superintendent.

A11 Joints

A11.1 General

The positions and types of all construction joints shall be approved by the Superintendent.

A11.2 Construction Joints

Construction joints shall be formed by:

- (a) placing or trimming the sprayed concrete to an angle of approximately 30°;
- (b) forming an approximately square joint to part depth by placing the sprayed concrete against a former or making a cut to the depth of the reinforcement; or
- (c) forming a full-depth square joint placed against a former.

A11.3 Rebound Provisions

Arris formers and screeds shall have rebound exits.

A11.4 Control Joints

Control joints shall be installed as required in the contract documents. Reinforcement or other embedded-metal items bonded to the sprayed concrete shall not extend through the control joint.

A12 Test Panels

A12.1 General

Where required by the contract during the progress of the works, the Contractor shall provide moulds for unreinforced test panels, 500 x 500 x 150 mm thick, rigidly fixed alongside the works in positions and numbers as may be required by the Superintendent. The moulds shall be sprayed at such times and from such batches and by such personnel as the Superintendent may direct. The test panels shall be stored and cured alongside and under conditions similar to those for the sprayed concrete in the works.

A12.2 Core Samples

Where required by the contract, four 75-mm-diameter cores shall be cut from each test panel at right angles to the plane of the panel approximately 48 hours after the panel has been sprayed. One core shall be compression tested at 3 days, one core at 7 days and the remaining two cores at 28 days. The core capping and testing shall be carried out at the laboratory described in the Contract or at a laboratory approved by the Superintendent. The cores shall be secured, tested, stored and cured in accordance with AS 1012. All cores shall be suitably labelled to identify them with the panels from which they have been taken and the location in the works to which they relate.

A12.3 Acceptance

The appropriate compressive-strength requirement for each set of two 28-day cores shall be satisfied if:

- each core has an estimated compressive strength equal to or greater than that specified; or
- the average estimated compressive strength is equal to or greater than that specified and the difference between the strengths is less than 20% of the average.

A12.4 Rejection

Should any of the cores reveal defects such as a lack of compaction, dry patches, voids or sand pockets, the Superintendent may require further tests or cores to be taken from the remainder of the panel(s) or further panels made.

A13 Routine Quality-Control Tests

A13.1 Thickness

Where required in the contract, 25-mm-diameter cores shall be taken at specified centres in positions selected by the Superintendent to determine concrete thickness and quality of the sprayed concrete.

A13.2 Core Samples

Where required by the contract, sets of 75-mm-diameter cores shall be cut from the finished sprayed concrete at positions indicated by the Superintendent and tested as for cores taken from test panels.

A13.3 Filling of Core Holes

Core holes shall be filled by hand with well-rammed dry-packed concrete of mix similar to that used for sprayed concrete or with suitable resin mortar

A13.4 Compressive Strength

Where required in the contract, compressive strength of the sprayed concrete shall be assessed by the use of a Schmidt hammer, calibrated by reference readings taken on the sprayed concrete at locations where cores are to be taken. At least ten readings shall be taken for each strength assignment.

A13.5 Soundness

Soundness shall be tested by hand hammer, a 'hollow' response indicating a possible lack of bond or other defect.

A13.6 Setting Time

The setting times of the cement/admixture paste shall be determined by using the Vicat apparatus in accordance with AS 2350 *Methods of Testing Portland and Blended Cements*.

A13.7 Penetration Resistance

The measurement of in situ penetration resistance shall be carried out using a spring-loaded penetrometer or similar suitable equipment.

A13.8 Batch-plant Accuracy

The contractor shall supply for the duration of the works suitable means (to the satisfaction of the Superintendent) for demonstrating that the batching plant operates within the specified accuracy.