

Main Roads Technical Standard

MRTS70

Concrete

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Concrete

1 INTRODUCTION

This Technical Standard applies to the construction of road and bridge structures in concrete.

The aim of this Technical Standard is to achieve concrete of the required strength, durability and appearance. It describes the materials, supply, placing, compacting, finishing, curing and measurement of concrete, including mass concrete, reinforced concrete, prestressed concrete and no-fines concrete.

All concrete shall be manufactured and supplied in accordance with the requirements of AS 1379 and the additional requirements of this Standard.

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

A commentary does exist for this specification and provides further information.

This Technical Standard forms part of the Main Roads Specifications and Technical Standards Manual.

The requirements for the construction of road and bridge structures in concrete include the use of registered suppliers and products for the items listed in Table 1.

Table 1 – Items Requiring Use of Registered Suppliers and Products

Clauses	Category of Work
5.2 7.3 (b) 11.1	Fly ash
7.1	Cement Supply
7.4 (b)	Slag
9	Admixtures
7.6 (b)	Silica Fume
11.5	Precast manufacture
16.3.1	Evaporation retarding compounds
18.2	Bar Chairs

For information regarding registered suppliers and products for the above items refer to –

Queensland Department of Transport and Main Roads
 Concrete Technology
 GPO Box 1412
 Brisbane Qld 4001

2 DEFINITION OF TERMS

The terms used in this Standard shall be as defined in Clause 2 of MRTS01 *Introduction to Technical Standards* and in Table 2 below.

Table 2 – Definition of Terms

Term	Definition
approved	Approved by the Administrator.
batch	One load or charge of a mixing plant or transit mixer.
Characteristic Strength (f'_c)	The compressive strength of the concrete at age 28 days as specified in the Contract. The Characteristic Strength shall be exceeded by at least 95 per cent of the concrete as assessed by standard tests.

Term	Definition
lot	An identifiable quantity of concrete from which samples are taken, and about which decisions are made on the basis of tests carried out on specimen cylinders made from the samples. A lot shall consist of batches of concrete of the same Grade, produced and placed in an essentially uniform and continuous manner during a day's production.
mean strength	The arithmetic average of the compressive strengths achieved by two or more specimen cylinders all of the same age.
sample	A portion of fresh concrete drawn from a batch and from which specimen cylinders are made. All sampling shall be carried out in accordance with AS 1012.
specimen cylinder	A single concrete cylinder, 100 mm in diameter and 200 mm in length or 150 mm in diameter and 300 mm in length in accordance with AS 1012, Part 8, made from a sample for the purpose of testing.
standard deviation (s)	A statistical measure of the variation from the mean strength of the specimen cylinders.
Target Strength (f_t)	The compressive strength of the concrete at age 28 days selected for design of the mix as provided for in Clauses 11.2 and 11.3.

3 REFERENCED DOCUMENTS

Table 3 lists documents referenced in this Technical Standard

Table 3 – Referenced Documents

Reference	Title
AS 1012	Methods of testing concrete
AS 1379	Specification and supply of concrete
AS 1478	Chemical admixtures for concrete, mortar and grout
AS 1726	Geotechnical site investigations
AS 2758.1	Aggregates and rock for engineering purposes – Concrete aggregates
AS 3582.1	Supplementary cementitious materials for use with portland and blended cement – Fly ash
AS 3582.2	Supplementary cementitious materials for use with portland and blended cement – Slag – Ground granulated iron blast-furnace
AS 3610	Formwork for concrete
AS 3799	Liquid membrane-forming curing compounds for concrete
AS 3972	Portland and blended cements
AS/NZS ISO 9001	Quality management systems – Requirements
Policy EP108	Quarry Assessment and Certification

4 STANDARD TEST METHODS

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

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

Table 4 – Standard Test Methods

Property	Test No.	AS Test
Relative dry density	Q142A, Q141B, Q140A, Q141A	-
Flakiness index	Q201	-
Ten percent fines value	Q205A, Q205B	-
Wet/dry strength variation	Q205C	-
Particle density and water absorption	Q214A, Q214B	
Slump	Q451A	1012.3.1
Compressive strength	Q455A Q455B	1012.8.1 1012.9
Accelerated alkali-silica reaction	Q458	-
Texture depth of road surface	Q705	-

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 Standards*.

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

Table 5.1 – Hold Points, Witness Points and Milestones

Clause	Hold Point	Witness Point	Milestone
11.2			Submit proposed concrete mix (6 weeks)
11.5		Trial mixing.	
11.6 (referenced from 7.2, 7.8.1, 9, 11.4, 11.5, 13.3.4.1, 14.1, 14.2, 14.3, 15)	1. Mix and concrete plant approval prior to first concrete pour.		
13.4.3.2	2. Approval of test laboratory.		
16.1			Submit procedure for hot weather concreting (2 weeks).
17	3. Approval of falsework.		Provision of detailed falsework drawings and calculations. (4 weeks)
19.1 (Referenced from 13.2, 13.3.4.2, 13.3.4.3, 16.2, 18, 19.1, 19.4 and 20.2.1)	4. Approval to place concrete.	Placing of concrete.	
19.2 (referenced from 13.2)	5. Placing concrete underwater.		Submit procedure for underwater concreting (2 weeks)

Clause	Hold Point	Witness Point	Milestone
21.1	6. Unspecified construction joints.		
23	7. Removal of falsework, formwork and early loading		
24.1		Removal of formwork and Curing operations.	Submit procedure for curing (2 weeks)
24.4			Submit procedure for new steam curing process (2 weeks)
25.1	8. Approval of surface dressing standard.		

5.2 Construction Procedures

The Contractor shall prepare documented procedures for all construction processes in accordance with the quality system requirements of the Contract.

Construction procedures for those activities listed in Table 5.2 shall be submitted to the Administrator in accordance with the quality system requirements of the Contract.

Table 5.2 – Construction Procedures

Clause	Procedure
14	On-site batching and mixing of concrete
16.1	Hot weather concreting
19.2	Underwater concreting
24.1	Curing
24.4	Steam curing

5.3 Conformance Requirements

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

Table 5.3 – Conformance Requirement

Clause	Conformance Requirement
13.6	Acceptance or rejection of hardened concrete
16, 19, 20, 24 and 25	Verification of placing, including hot weather concreting and placing under water if appropriate, compaction, finishing, curing and surface dressing
20.2.1	Deck surface finish
22	Levels and dimensions

5.4 Testing Frequency

The minimum testing frequency for work covered by this Standard is specified in Clause 13.

6 CONCRETE CLASS

6.1 General

Concrete is designated as normal class or special class as described in Clauses 6.2 and 6.3.

6.2 Normal class concrete

Normal-class concrete shall only be specified as 20 or 25 MPa strength grades and shall be designated as Nx/y where x and y are defined in Clause 10. Concrete requiring higher strength grade shall be special class.

Production and delivery of normal-class concrete shall comply with the requirements of AS 1379 and it shall contain a minimum mass of registered fly ash (refer to Clause 1) of 20% (refer Clause 7.3(a) (by mass of cementitious material). For normal-class concrete, where more than 25 m³ of a grade of concrete is used, project assessment of strength grade shall be used in accordance with AS 1379. This requires at least one sample from each 50 m³ of concrete. Test methods shall conform to Table 4.

Ordering, forming, placing, compacting, finishing and curing normal class concrete shall comply with MRTS70 *Concrete*.

The following items may be normal-class –

- a) footings for noise barrier and sign posts, lighting and traffic poles;
- b) median slabs;
- c) roadworks furniture e.g. gullies and access chambers;
- d) slip formed median barriers (special mix but normal-class testing applies);
- e) blinding concrete and no fines concrete; and
- f) any item designated as normal class in the Contract.

6.3 Special Class Concrete

All concrete except that detailed in Clause 6.2 shall be special-class designated as Sx/y where x and y are defined in Clause 10 and shall comply with the requirements of this Standard.

Special class concrete shall comply with all of the requirements of MRTS70 *Concrete*.

7 MATERIALS

7.1 General

Unless otherwise stated, all concrete shall be composed of cementitious material, fine aggregate, coarse aggregate, additives if approved, and water, proportioned and mixed as detailed in this Standard. All such materials shall conform with the requirements of this Standard.

The mass of all materials shall be measured in a saturated surface dry condition (SSD) where applicable.

Cementitious materials shall be supplied only by a registered Cementitious Materials Supplier (refer to Clause 1).

To be eligible to be registered as a registered Cementitious Materials Supplier, a supplier shall operate a quality system certified to a minimum of AS/NZS ISO 9001 with an inspection and test plan acceptable to Transport and Main Roads which demonstrates the ability of the supplier to consistently supply cementitious materials that comply with this Standard. Each individual cementitious material must also be registered.

7.2 Cement

All cement used shall comply with AS 3972.

The type of cement used shall be Type GP or GB unless otherwise designated in the Contract or approved by the Administrator. If the Contractor wishes to use Type HE “highly early strength cement” in areas other than where its use is designated, it shall be used only with the written approval of the Administrator [**Refer to Hold Point 1**].

Documentary evidence of the quality of the cement shall be furnished by the Contractor if requested by the Administrator. Cement more than 3 months old shall be retested for conformance. **Nonconformance**

All mixes shall contain a minimum mass of Portland cement equal to 55% of the total mass of cementitious material. Type GP cement shall have a maximum total alkali content (measured as Na₂O equivalent) of 0.6%.

7.3 Fly Ash

Fly ash may be used in concrete subject to the following conditions –

- a) The Contractor shall nominate an intention to use fly ash (either separately or as blended cement) and state the proportions when submitting details of the mix design. To achieve the minimum 20% fly ash specified, a 25% blend is required except for precast batch plants at precast yards which can demonstrate statistically that a blend percentage lower than 25% will ensure the minimum 20% specified is always achieved.
- b) Fly ash shall conform to AS 3582.1 and shall be sourced from a registered supplier (refer to Clause 1). Only Fine Grade fly ash shall be used as defined in Table 1 of AS 3582.1;
- c) Fly ash shall be used in accordance with AS 3582.1;
- d) Where the Contractor wishes to use both fly ash and an air entraining agent in a mix, the Contractor shall submit with details of the mix design, proof (from tests on trial mixes or previous production) that the amount of air entrained can be controlled within specified limits and that the compressive strength is satisfactory; and
- e) Fly ash shall have a maximum total alkali content of 2% and a maximum available alkali content of 0.5% (Na₂O equivalent).

7.4 Slag – Ground Granulated Iron Blast-Furnace

Slag may be used in concrete subject to the following conditions –

- a) The Contractor shall nominate an intention to use slag (either separately or as blended cement) and state the proportions when submitting details of the mix design;
- b) Slag shall conform to AS 3582.2 and shall be sourced from a registered supplier (refer to Clause 1);
- c) Slag shall be used in accordance with AS 3582.2; and
- d) Slag shall have a maximum total alkali content of 1% and a maximum available alkali content of 0.5% (Na₂O equivalent).

7.5 Fly Ash and Slag in Combination

Fly ash and slag in combination may be used in concrete provided that the Contractor nominates an intention to use both fly ash and slag in combination with Portland cement and states the proportions when submitting details of the mix design.

7.6 Silica Fume

Silica fume may be used in concrete subject to the following conditions –

- a) The Contractor shall nominate an intention to use silica fume and state the proportions when submitting details of the mix design;
- b) Silica fume shall be obtained from a registered supplier; and
- c) Silica fume shall not be used in decks or slabs.

7.7 Water

Water shall be analysed to demonstrate that it meets the requirements of AS 1379.

7.8 Concrete Aggregate

7.8.1 General

No concrete shall be placed in the Works until the aggregate samples have been approved by the Administrator [**Refer to Hold Point 1**].

Aggregate shall conform to AS 2758.1 unless specified otherwise. Assessment for alkali-reactive materials shall conform to Clause 11.1.

7.8.2 Fine Aggregate

Fine aggregate shall consist of natural sand, or a combination of natural and manufactured sands containing not less than 40% natural sands. Particles shall be clean, hard and durable.

7.8.3 Coarse Aggregate

Coarse aggregate shall consist of clean, durable, natural gravel, crushed stone, or combinations thereof. The maximum size of coarse aggregate to be used in each Class of concrete is specified in the Drawings.

7.8.4 Quarry Assessment and Certification

Fine and coarse aggregate for a concrete mix shall be supplied from a quarry which holds certification (which shall be current at the date of supply) for the supply of such aggregate, as issued by Transport and Main Roads in accordance with Engineering Policy number EP108 "Quarry Assessment and Certification".

Where aggregate components are to be supplied from more than one source, a quarry assessment of each source shall be provided. Each source material shall be classified into one of the source material groups defined in Table 7.8.4.

A copy of the current Quarry Assessment Certificate shall be included with the proposed mix design information submitted to the Administrator as detailed in Clause 11.2.

Sedimentary and Duricrust source rocks shall not be used in concrete.

Table 7.8.4 – Materials Group

Term	Definition
Acid Igneous Rock	As defined in AS 1726. Including Rhyolite, Rhyodacite, Dacite, Tuffs (of same composition), Granite, Adamellite and Granodiorite.
Basic Igneous Rock	As defined in AS 1726. Including Basalt, Dolerite and Gabbro.
Intermediate Igneous Rock	As defined in AS 1726. Including Trachyte, Trachyandesite, Andesite, Tuffs (of same composition), Syenite and Diorite.
Material Group	A category selected on the basis of material classification, geological processes and material properties. Materials of one group may grade into another in the one quarry site.
Metamorphic Rock	As defined in AS 1726. Including Hornfels, Quartzite, Metagreywacke, Greenstone, Slate and Amphibolite.
Natural Gravel	Naturally occurring granular alluvial, colluvial or residual deposits.
Quarry	A site from which concrete aggregate is won by blasting, ripping or other excavation means for use after processing such as by crushing and/or screening. The term quarry also includes pits.
Sedimentary and Duricrust Rocks	As defined in AS 1726. Including Limestone, Dolomite, Mudstone, Arenite, Chert and Silcrete.

7.8.5 Aggregate Properties

7.8.5.1 General

The testing of individual samples shall be carried out in accordance with the test methods given in Table 4. The properties for concrete aggregate are as specified in Clauses 7.8.5.2 to 7.8.5.5 inclusive.

7.8.5.2 Flakiness Index

The aggregates shall exhibit a flakiness index not exceeding 30%.

7.8.5.3 Water Absorption

The maximum water absorption of the aggregates shall be 2.5%.

7.8.5.4 Ten Percent Fines Value (Wet) and Wet/Dry Strength Variation

The ten percent fines value (wet) and the wet/dry strength variation tests shall be carried out on the fraction from AS 13.2 mm to AS 9.5 mm. Any fraction which constitutes less than 10% of the sample shall not be tested.

The results shall conform to the limits given in Table 7.8.5.4.

For the Greenstone source material only (metamorphic group), if the Greenstone does not comply with the maximum wet/dry strength variation limits, it may be deemed to comply if its Ten Percent Fines Value (Wet) is 160 kN or greater.

Table 7.8.5.4 – Ten Percent Fines Value (Wet) and Wet/Dry Strength Variation

Material Group †	Minimum 10% Fines Value (Wet) (kN)	Maximum Wet/Dry Strength Variation (%)
Acid Igneous	110	40
Intermediate Igneous	120	35
Basic Igneous	130	30
Metamorphic	120	35

† Naturally occurring gravels are to be classified into a material group on the basis of the lithology of the major granular component.

7.8.5.5 Alkali-Reactive Materials

Requirements to minimise the degree of alkali-silica reaction in concrete are detailed in Clause 11.1.

8 STORAGE OF MATERIALS

8.1 Cement

Bulk cement shall only be stored in watertight silos.

Bagged cement shall be stored above ground level in dry, weatherproof sheds and be protected from dampness which may be acquired from contact with floors or walls. Bags shall be stacked so as to allow counting, inspection and identification of each consignment.

As far as practicable, cement shall be used in order of receipt. Cement which has been stored for more than three months shall not be used unless otherwise approved by the Administrator (refer also to Clause 7.2).

Nonconformance

Cement containing lumps may be rejected irrespective of age, at the Administrator's discretion.

8.2 Aggregates

Aggregates shall not be stored in direct contact with the ground. Aggregates shall be stored in such a manner that they will not segregate, become contaminated by foreign matter, or become intermixed. Stockpiles shall be arranged to prevent entry of adjacent surface or ground water and allow free drainage of rain water.

9 CHEMICAL ADMIXTURES

Admixtures shall conform with the requirements of AS 1478 and shall be used in accordance with AS 1379. Admixtures shall be a registered admixture (refer to Clause 1). Admixtures containing Calcium chloride shall not be used.

Chemical admixtures in concrete shall be used only with the written approval of the Administrator [**Refer to Hold Point 1**].

The total alkali contribution (measured as Na₂O equivalent) of all admixtures used in a mix shall not exceed 0.20 kg/m³.

Where air entrainment is specified, the air content of the concrete delivered on the Site shall have a maximum value of 6% unless otherwise specified. The Contractor shall provide an approved air content gauging device (which shall operate in accordance with the manufacturer's instructions) at the Site so that the air content of the freshly mixed concrete may be accurately determined.

Admixtures shall be accurately measured by means of a well maintained dispenser which operates correctly.

10 GRADE OF CONCRETE

Concrete in the works is specified as Grade “S or Nx/y” where –

- a) S is special class and N is normal class;
- b) “x” is the characteristic compressive strength (f'_c) of the concrete at 28 days, expressed in MPa; and
- c) “y” is the nominal maximum aggregate size in millimetres.

The Grade of concrete used in each section of the Works shall be as specified in the Drawings for that section.

Concrete of characteristic strength less than 25 MPa shall not be used for reinforced concrete.

11 CONCRETE MIX – DESIGN AND ACCEPTANCE

11.1 General

The Contractor shall be responsible for the design and production of all concrete used in the Works. The use of ready-mixed concrete shall in no way lessen or remove this responsibility.

In addition to the requirements of AS 2758.1, Clause 10 – Alkali-Reactive Materials, all proposed concrete mixes shall meet the requirements of the innocuous classification of Test Method Q458. Concrete mixes containing a minimum 20% fly ash by mass (Refer Clause 7.3(a)) of total cementitious material shall be deemed to comply with this additional requirement.

All concrete mixes proposed for precast and prestressed concrete elements shall contain a minimum 20% of fly ash by mass (Refer Clause 7.3(a)) of total cementitious material.

All fly ash used shall be a registered product (refer to Clause 1).

11.2 Proposed Mix Design

The Contractor shall submit details of the mix design for each specified Class of concrete to the Administrator for approval not less than 6 weeks prior to the commencement of concreting operations.

Milestone

The submission shall include the following information –

- a) Grade of concrete;
- b) the name of the Concrete Supplier and the proposed methods and degree of quality control;
- c) types and proportion by mass of various materials comprising the mix, including chemical admixtures and supplementary cementing materials;
- d) a copy of the Quarry Assessment Certificate for each material source;
- e) target strength; and
- f) target slump.

Where the supplier produces concrete on a regular basis, information is required regarding mean strength and standard deviation for recent output of each Class of concrete to be supplied.

The minimum cementitious content and maximum water/cementitious ratio shall be as shown in Table 11.2 for the Strength Grade shown in the Drawings.

Table 11.2 – Minimum Cementitious Contents

Exposure Classification	Minimum Cementitious Content (kg/m ³)	Maximum Water/Cementitious Ratio	Strength Grade (MPa)
B1	320	0.56	32
B2	390	0.46	40
C	450	0.4	50

11.3 Target Strength

The minimum target strength shall be calculated from the equation –

$$f_t = f_c + 1.65 s$$

where the terms of the equation are as defined in Table 2.

Where adequate plant records are available, the current standard deviation for the similar Class of concrete may be used but it shall not be less than 0.08 f_c .

Where adequate plant records are not available an estimated value of standard deviation shall be used which is not less than 0.12 f_c or greater than 0.20 f_c , depending on the degree of quality control nominated (refer to Clause 11.2).

The target strength may be reassessed based on the actual standard deviation of a minimum of 15 consecutive tests for the Strength Grade.

11.4 Target Slump

The target slump selected shall be consistent with the production of a workable mix for each section of the Works concerned.

The target slump nominated by the Contractor for each Class of concrete used in the Works shall be a value which falls within the range given in Table 11.4.

Super Workable Concrete (SWC) may be approved only by the Director Concrete Technology for Precast Concrete Elements subject to the precaster and concrete supplier meeting the conditions prescribed by the Director Concrete Technology and demonstrating that the concrete can be consistently produced.

Table 11.4 – Permissible Target Slump

Characteristic Strength (MPa) /Application	Target Slump Range (mm)
20 / Cast Insitu	70 – 120
25 / Cast Insitu	70 – 120
32 / Cast Insitu	70 – 150
40 / Cast Insitu	60 – 150
50 / Cast Insitu	50 – 150
32 – 50 / Pumped Concrete	100 – 150
32 – 50 / Sprayed Concrete	Slump to suit equipment
32 – 50 / Extruded Concrete	Slump to suit equipment
32 – 50 / Tremie Concrete (Clause 19.2):	
- Dry conditions	150 – 180
- Wet conditions	180 – 220
32 – 50 / Precast Concrete Elements	80 - 180

11.5 Trial Mix

Except as provided hereunder for the supply of ready-mixed concrete and for concrete used in certain precast units, the Contractor shall make trial mixes for all classes of concrete having a characteristic strength greater than 20 MPa.

Each mix shall use only such aggregates that have been shown by testing to meet the requirements of this Standard and have been approved for use by the Administrator [**Refer to Hold Point 1**].

The mixes shall be made using the plant and degree of quality control proposed for the Works. The minimum volume of the trial mix shall be 25% of the rated capacity of the mixer. Each trial mix shall be a witness point with a notice period of three days. **Witness Point**

Each trial mix shall be tested for slump, workability and strength. Where concrete is not batched and mixed on the Site, a time delay equal to an average delivery time on Site shall be applied between the mixing of the concrete and the sampling for slump and cylinder tests.

The slump measured shall be within the allowable range in Table 11.4 and shall become the approved slump if the mix is subsequently approved. At least nine cylinders shall be cast from each trial mix for compressive strength testing. Additional cylinders (a minimum of three per age) shall be required if strength gain is to be assessed for early stripping or loading.

If concrete is supplied by an approved ready-mixed manufacturer in accordance with AS 1379 or by a registered precast manufacturer (refer to Clause 1), or by an approved established precast manufacturer, the Contractor may submit the results of tests on specimen cylinders cast from identical mixes previously produced by the manufacturer, in lieu of trial mixes. The information relating to the mix design as detailed in Clause 11.2 shall be submitted with such test results.

11.6 Mix Design Certification

The trial mix, the plant and the degree of quality control for the Works shall be approved if the mean of the 28-day cylinder strengths equals or exceeds the target strength, the slump lies within the range given in Table 11.4 and the mix conforms with the requirements of Test Method Q458.

For concrete other than for precast concrete elements where the 28 day strength exceeds or is expected to exceed 1.4 times f'_c the contractor shall advise the administrator who will seek approval from the designer to use the mix.

No concrete shall be placed in the Works until approval of the trial mix has been obtained from the Administrator. **Hold Point 1** The Administrator may give provisional approval of a mix based on early testing, provided the mean compressive strengths of at least three trial cylinders tested at 7 days is not less than 0.8 of the specified characteristic strength for that Class of concrete. Notwithstanding any such provisional approval, all the concrete shall meet 28-day strength requirements.

Approved concrete mixes shall not be altered without the approval of the Administrator. The approved mix shall be used until approval is given for an altered mix.

If, during the course of the Works, the degree of quality control is not maintained (as evidenced by a decline in the strength of test cylinders taken on the Works and/or by a deterioration in the methods employed in batching and mixing), and / or the 28 day strength exceeds 1.4 times f'_c , without design approval the Administrator may withdraw approval of the mix pending establishment of improved quality control, or, if necessary, a redesign of the mix.

12 CONSISTENCY

The consistency and workability of concrete shall be such that it can be handled and transported without segregation and can be placed, worked and compacted into all corners, angles and narrow sections of forms, and around all reinforcement.

The consistency of each batch of concrete shall be checked by means of the slump test. Sampling and testing shall be carried out in accordance with AS 1012, Parts 1 and 3 respectively.

Where 10 batches of a concrete grade have been tested and are conforming, the Contractor may move to a reduced level of testing. The reduced level of testing shall consist of visually checking every batch and slump testing one third of batches.

The slump determined on the Site in accordance with AS 1012, Part 3 shall lie within the range established using the approved slump and the tolerances specified in Table 6 of AS 1379.

13 TESTING PROCEDURE

13.1 General

All concrete used in the Works shall be subject to sampling and testing in accordance with the provisions of AS 1012, except as detailed in this Standard.

13.2 Rejection of Wet Concrete

Before any concrete is placed in the Works it may be visually checked by the Administrator [**Refer to Hold Point 4 or 5**] and shall be liable to rejection if it is defective in any of the following ways –

- a) The slump is outside the range specified in Clause 12. If placement is delayed for a significant period, the slump shall be rechecked prior to placement; and
- b) The appearance, colour or cohesiveness of the batch is significantly different from other batches of the same mix.
- c) The concrete contains lumps of unmixed material.

13.3 Sampling

13.3.1 General

Samples shall be taken from separate batches of concrete selected at random during the placing operation. Two cylinders (minimum) shall be cast from each sample in purpose-made steel moulds conforming to AS 1012 and identified as a matched set. Each cylinder shall be identified with the relevant batch and/or lot and a written record made of the location of each batch within the structure. In addition, for precast concrete, the cylinders shall be so marked that they can be readily identified with their structural unit at all times.

All specimens shall be manufactured by a competent experienced person employed by the Contractor and they shall be delivered to the laboratory for testing (refer Clause 13.4.3.2 for testing laboratory requirements).

13.3.2 Concrete Other Than Precast Work

The normal rate of sampling per lot is defined in Table 13.3.2 (refer also to Clause 13.3.4). For the purposes of determining rate of sampling a lot shall not extend longer than 24 hours.

Table 13.3.2 – Sampling Frequencies per Lot for 28 Day Strength Tests

Number of Batches	Number of Samples
1 – 3	Every Batch
4 – 10	4
11 – 23	6
> 24	<u>Number of batches</u> 5

Where sampling, testing and assessment of concrete is carried out in accordance with AS 1379, and AS 1012 and 10 samples of a concrete grade have been tested and are conforming, the Contractor may –

- a) seek approval to move to a Reduced Level of Testing; and
- b) nominate the level of testing which shall not be less than half the Normal Level.

If requested by the Administrator, the Contractor shall supply copies of the concrete plant assessment reports.

13.3.3 Precast Concrete

For each element cast in one continuous operation the minimum rate of sampling shall be –

- a) 4 cylinders per 5 m³ or part thereof; and
- b) Additional cylinders as required if post-tensioning of the element is to be combined with pre-tensioning.

Where 10 samples of a concrete grade have been tested and are conforming, the Contractor may –

- a) seek approval to move to a Reduced Level of Testing; and
- b) nominate the level of testing which shall not be less than half the Normal Level.

13.3.4 Additional Sampling

13.3.4.1 Initial Testing

Where the information supplied in Clause 11.2 does not permit determination of standard deviation based on previous field testing for each Class of concrete, the frequency of initial sampling shall be increased above that shown in Table 13.3.2. The actual increase in initial sampling shall be at the Administrator's discretion (with Hold Point 1 approval).

13.3.4.2 Early Stripping and/or Loading

Any proposal by the Contractor for early removal of forms (refer to Clause 23) or for early application of significant loads to the structure (refer to Clause 17) shall be submitted in writing to the Designer prior to placing concrete [Refer to Hold Point 4]. The Designer shall then determine the number of additional cylinders required for early testing.

13.3.4.3 Further Construction prior to 28-Day Testing

If concrete is to be placed over or adjacent to and connected with a previous section prior to 28-day testing and acceptance, additional sampling and early age testing shall be undertaken. [Refer to Hold Point 4].

Any approval by the Administrator to proceed with construction shall not remove the Contractor's responsibility to satisfy acceptance criteria in Clause 13.6.

13.4 Curing of Specimen Cylinders

13.4.1 Concrete Other than Precast Work

The specimen cylinders shall be cured in accordance with AS 1012, Part 8. Where cylinders are temporarily stored at the Site of the Works they shall be stored in lime-saturated water at a temperature as close as practical to 27°C.

Cylinders shall not be moved for a period of 18 hours after casting. Specimens shall be handled with care, transported to the testing laboratory without bumping or vibrating, and placed in standard curing conditions within 36 hours, in accordance with AS 1012, Part 8.

13.4.2 Precast Concrete

Specimen cylinders shall be cured under conditions identical with those of the concrete they represent (refer also to Clause 24.4) for the initial curing period. After this initial curing the cylinders shall be stored and cured under standard conditions in accordance with AS 1012, Part 8.

13.5 Capping and Testing of Specimen Cylinders

Capping of concrete cylinders shall be in accordance with Clause 6 of AS 1012.9. However, use of the rubber capping system shall be allowed only when acceptable results are achieved. If the first cylinder of a matched pair is tested and the result is below f'_c then its partner shall be sulphur capped prior to testing.

Attention is drawn to –

- a) Clause 6.3.1 of AS 1012.9 and the notes in that clause; and
- b) Clause 13.5 of this Standard – when the average strength of three consecutive samples is less than $0.5 (f'_c + f'_t)$, sulphur capping shall be used until mean strengths achieve target strengths f'_t .

13.6 Testing of Specimen Cylinders

Acceptance Testing shall only be done at a NATA registered laboratory.

A minimum of two matched 28 days cylinders from each sample shall be tested at 28 days. For any early age testing (less than 28 days) a minimum of one cylinder per sample shall be tested. All early age cylinders tested must exceed the early age strength requirement.

The test strength of a sample at 28 days shall be the average of all the cylinder tests from that sample, except where abnormal test results are identified as set out below.

Where the range of test results exceeds the limits given in Table 13.4.6 the history of the cylinders shall be examined and their condition reported to the Contractor and the Administrator by the testing laboratory.

Nonconformance The cylinders shall be retained in the laboratory for at least 14 days to permit further examination.

Table 13.4.6 – Maximum Difference in Compressive Strengths for a Matched Set

Number of Matched Cylinders from a Sample	Difference in Strength Maximum – Minimum (MPa)
2	2
3	3

Test results of individual cylinders shall be excluded from the assessment of strength for the purposes of acceptance or rejection under the following conditions –

- a) where a low test strength can be attributed to an obvious defect in the cylinder or test procedure; or
- b) where test results from a matched set exceed the range set out in Table 13.4.6, the low test result shall be excluded even when no defect in the cylinder or procedure is obvious.

Where any test result is excluded by the above criteria, the Administrator and Contractor shall check that the manufacture, storage and testing of cylinders is being correctly carried out.

13.7 Monitoring of Target Strength

If the average strength of three consecutive samples is less than $0.5 (f'_c + f'_t)$, the Contractor shall submit to the Administrator as a matter of urgency proposals to upgrade the mix and/or procedures to achieve the approved target strength. **Nonconformance** Prior to its implementation, the Contractor's proposal shall be approved by the Administrator.

Where a significant amount of concrete is to be placed in a four-week period, monitoring shall include early age testing (typically 7 days) and a comparison of cylinder strengths with previously measured strength gain results.

13.8 Acceptance or Rejection of Hardened Concrete on the Basis of Strength

Subject to the concrete meeting all requirements set out in this Standard it shall be accepted or rejected on a statistical basis using the results of 28 day tests as set out below.

Concrete in a lot shall be deemed rejected if either of the following apply –

- a) any sample strength (average of two or more matched cylinders) is less than 0.9 times the specified characteristic strength, f'_c ; or
- b) the average strength of three consecutive samples from the lot is less than the specified characteristic strength or
- c) for concrete other than precast concrete, the average strength of three consecutive samples from the lot is greater than 1.4 times f'_c , without specific prior approval of the designer.

In addition, where 10 or more samples of a particular Class of concrete are tested in four consecutive weeks or less, all the concrete represented by these samples shall be rejected if the average strength of all the tests for that Class of concrete over that period is less than $0.5 (f'_c + f'_t)$.

The standard deviation shall be calculated from the tests from that period and compared with the value used to calculate the target strength. If the standard deviation from test results is significantly greater than that used in calculating the target strength, the Administrator may withdraw approval for the mix (refer to Clause 11.6).

Where hardened concrete has been rejected, the Contractor may offer either of the following alternatives **Nonconformance** –

- a) the rejected concrete, and any portion of the structure built on the rejected concrete, shall be removed and replaced with conforming concrete; or
- b) the rejected concrete may remain in place and additional works, approved by the Administrator, shall be undertaken to achieve adequate strength and/or durability.

14 ON-SITE BATCHING AND MIXING

14.1 General

If the Contractor proposes to mix concrete on the Site, the Contractor shall submit not less than six weeks prior to the commencement of concreting operations, a procedure for on-site mixing with the proposed mix design. **[Refer to Hold Point 1]**.

14.2 Batching

Aggregates for concrete with specified strength greater than 20 MPa shall be proportioned by mass. Volumetric batching may be employed for concrete with specified strength 20 MPa or lower.

Where batching by mass is employed, the method of delivery of the aggregate to the hopper shall be such that only a negligible amount of aggregate enters the hopper after closing off the supply.

Cementitious materials for concrete with a characteristic strength of less than 32 MPa shall preferably be batched by mass. However, where cementitious content is determined by bagged mass the use of fractions of a bag shall not be allowed.

Cementitious materials for concrete with characteristic strength of 32 MPa or greater shall be batched by mass.

Water and admixtures may be batched by mass or by volume. All mixers shall be equipped with adequate water storage tanks and an appropriate measuring device. Volumetric batching of water shall employ the use of a measuring device calibrated in 0.5 litre increments. Measuring devices for admixtures shall be calibrated with the increments not exceeding 1% of the total volume of the admixture to be measured **[Refer to Hold Point 1]**.

14.3 Mixing

Concrete shall be mixed in a batch mixer of an appropriate type having a capacity suitable for the type of work being undertaken. If cementitious material / cement is batched by bags, the capacity of the mixer shall be such that whole bags may be used in each charge of the mixer.

The mixer drum shall rotate at the speed recommended by the manufacturer but at a speed not less than 12 rpm. The volume of mixed concrete in the batch shall not exceed the rated capacity of the mixer. If concreting operations exceed 12 m³ per day, the Contractor shall maintain a standby mixer on the Site **[Refer to Hold Point 1]**.

The method of charging the materials into the mixer shall allow some water to enter in advance of the aggregates and ensure that at least two-thirds of the aggregates shall be in the drum prior to the entry of the cementitious material.

Mixing shall continue until the materials are thoroughly blended. The minimum mixing time after all materials have entered the mixer shall be in accordance with the manufacturer's instructions.

The first batch of materials charged into a clean mixer shall contain sufficient excess cement, water and sand to allow "coating" of the inside of the drum without diminishing the normal mortar content of the mix.

The entire batch of concrete shall be discharged from the mixer before any further charging of the mixer takes place.

If mixing operations cease for a period of time exceeding 45 minutes, the mixer shall be thoroughly cleaned out before subsequent batches are mixed.

Hand mixing of concrete is not permitted.

14.4 Placing Time

Concrete mixed on Site shall be placed and compacted within 45 minutes of charging the mixer for concrete temperatures up to 32°C and within 30 minutes of charging the mixer for concrete temperatures exceeding 32°C but less than 35°C.

15 READY-MIXED CONCRETE

If the Contractor intends to use ready-mixed concrete in the Works, the Contractor shall submit the name of the proposed supplier for the Administrator's approval **[Refer to Hold Point 1]**. Only manufacturers

approved by the Administrator shall be allowed to supply ready-mixed concrete. The Administrator may withdraw approval of any supplier at any time.

The production and delivery of ready-mixed concrete shall be in accordance with the requirements of AS 1379 except as otherwise specified.

The quantity of concrete delivered in any truck shall not exceed the rated capacity of its agitator drum. The timing of deliveries shall be such as to ensure an essentially continuous placing operation.

Ready-mixed concrete shall be placed and compacted within 1 hour of charging the mixer for concrete temperatures up to 32°C and within 45 minutes of charging the mixer for concrete temperatures exceeding 32°C but less than 35°C. These times may be varied at the Administrator's discretion where set-retarding admixtures are used in accordance with Clause 9 and a trial mix is conducted in accordance with clause 11.5.

In remote locations, where travel times exceed the above limits, the Administrator's approval is required for the process of combining the aggregates, cementitious materials and water [**Refer to Hold Point 1**].

A manufacturer's certificate in the form of a delivery docket in accordance with AS 1379 shall be supplied for each batch and shall be retained by the Contractor. Such certificates shall be available to the Administrator on request and shall show the total water in the mix as supplied.

16 TEMPERATURE AND EVAPORATION LIMITS FOR CONCRETING OPERATIONS

16.1 Procedure

The Contractor shall submit its procedure for hot weather concreting at least two weeks prior to the first concrete pour. **Milestone**

16.2 Temperature Limits

No concrete shall be placed in the Works if –

- a) the temperature of the concrete is less than 10°C or exceeds 35°C;
- b) based on temperature recording at the Site for 3 days prior to the proposed pour and the forecast by the Bureau of Meteorology, the ambient air temperature is likely to be greater than 45°C during placement or within 2 hours subsequent to placement [**Refer to Hold Point 4**]; or
- c) If the ambient air temperature measured at the point of placement is likely to exceed 35°C during placing and finishing operations, the Contractor shall take practical precautions, approved by the Administrator, [**Refer to Hold Point 4**] to ensure that the temperature of the concrete does not exceed the permitted maximum so that the concrete can be placed and finished without defects, otherwise it shall be rejected. Typical precautions include –
 - i) General
 - placing the concrete at a time of day when the ambient temperature is lower than the maximum,
 - ii) At the mixer
 - shading aggregate stockpiles;
 - painting water tanks white;
 - insulating or burying delivery lines;
 - adding crushed ice to replace mixing water (in part) or chilling the water; and
 - injection of liquid nitrogen into the mixer,
 - iii) At the Site
 - cooling the formwork by dampening with water sprays;
 - shading the work areas;
 - erecting wind breaks;
 - minimising the time for placing and finishing; and

Special attention shall be paid to providing early curing for hot weather concreting operations.

16.3 Evaporation Limits for Concreting Operations

16.3.1 General

When the predicted evaporation rate during the intended casting period exceeds $0.75 \text{ kg/m}^2/\text{hr}$, measures described in Clause 16.2 shall be taken to reduce the predicted evaporation to $0.75 \text{ kg/m}^2/\text{hr}$ or less.

The forecast evaporation rate shall be estimated by the specified method (refer to Clause 16.3.3) using the latest available meteorological forecast for the area from the Bureau of Meteorology. This information shall be obtained on the proposed day of construction before work commences.

The evaporation rate shall be monitored by the Contractor during concreting operations until such time as curing commences.

If the rate exceeds $0.75 \text{ kg/m}^2/\text{hr}$ and the contractor does not have measures in place as described in Clause 16.2, the contractor shall take immediate practical action to implement these measures.

The use of a registered evaporation retarding compounds shall be mandatory for all reinforced concrete, including but not limited to bridge decks, slabs, and precast concrete.

16.3.2 Application of Evaporation Retarding Compound

The evaporation retarding compound, shall be applied immediately after initial screeding and again after any finishing operations.

Application shall be made in accordance with the manufacturer's instructions. Details of the proposed compound including the application procedure shall be submitted to the Administrator as part of the procedures for hot weather concreting described in Clause 16.1

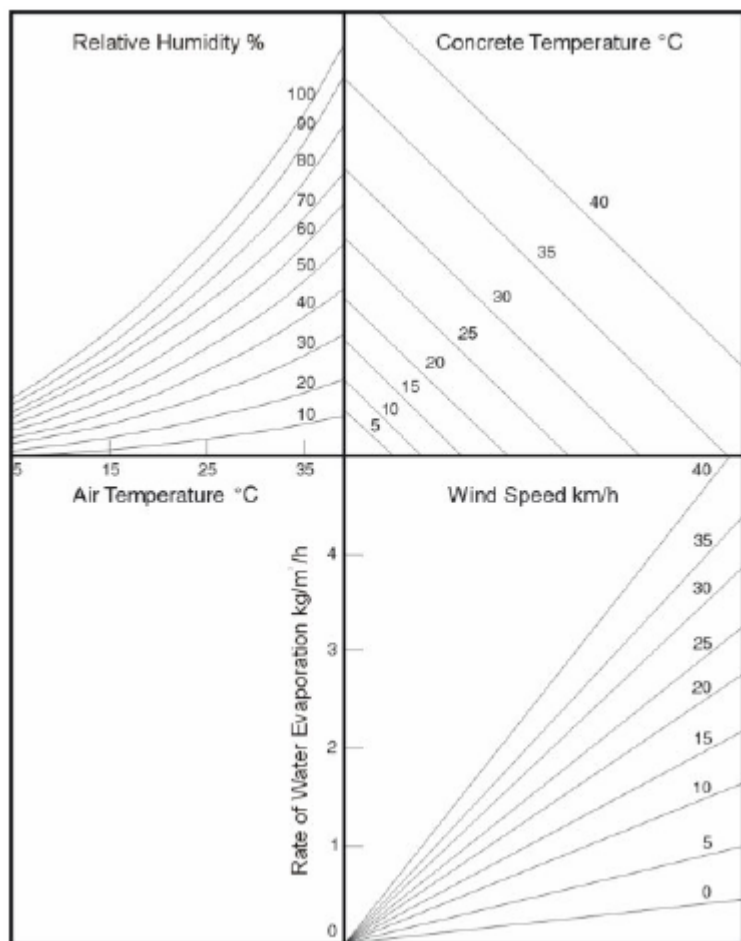
16.3.3 Method for Calculation of Evaporation Rates

To compute the evaporation rate of water from the exposed surface of the concrete the following information is required –

- a) air temperature;
- b) relative humidity;
- c) concrete temperature; and
- d) wind velocity.

Figure 16.3.3 is to be used for estimating the loss of surface moisture from the concrete for various weather conditions as represented by the above information. In the commentary to this specification an alternative formulae is quoted for the calculation of the evaporation rate.

Figure 16.3.3 – Chart for Estimation of Water Evaporation Rate



17 FALSEWORK

Falsework shall conform to AS 3610, except as otherwise required by this Standard.

The design and erection of falsework, the method of founding or supporting the falsework and the time, order and manner of its release shall all require approval of the Administrator. **Hold Point 3** The Contractor shall supply the Administrator with detailed drawings of such falsework at least 4 weeks prior to the commencement of erection. **Milestone** The provision of such drawings and release of the hold point by the Administrator shall in no way relieve the Contractor of any responsibility for the satisfactory performance of the falsework.

Subject to the Administrator's approval, falsework may be supported on completed sections of the Works provided that the construction loads imposed thereon do not result in over-stressing or instability and that due allowance is made for any deflection of the supporting sections.

The Contractor shall undertake structural strengthening or modification of such sections necessary for their use as support structures.

The Administrator's approval of the use of completed sections of the Works as support structures for falseworks shall in no way relieve the Contractor of any responsibility for the restoration or repair of any resulting damage caused by such use.

18 FORMWORK, BAR CHAIRS AND SPACERS

18.1 Formwork

All formwork shall be subject to inspection and approval by the Administrator [Refer to Hold Point 4].

Formwork shall conform to AS 3610 except as otherwise required by this Standard. Formwork shall conform to Class 2 AS 3610 surface finish, except as otherwise required in Clause 25.1. All forms shall be built surface smooth, mortar-tight and have sufficient rigidity to maintain the tolerances specified in Clause 22 when subjected to fresh concrete and other construction loads.

All forms shall be set and maintained to line and level such that the finished concrete shall conform within the specified dimensional tolerances (refer to Clause 22) to the proper dimensions and contours, as shown in the Drawings.

All forms shall be cleaned and coated with the lightest practical coating of release agent prior to erection. Reinforcing steel and construction joints shall not be contaminated with release agent.

Forms for plane exposed surfaces shall consist of plastic-coated plywood, waterproof plywood, timber lined with tempered hardboard or close-fitting unwarped metal forms. Unless otherwise specified, joints in the form sheeting for plane, exposed concrete surfaces shall be either vertical or horizontal and spaced with a regular pattern.

Forms for surfaces not exposed to general view may consist of modular timber or metal panels. Timber forms shall be constructed and maintained in such a manner as to prevent warping and opening of joints due to shrinkage of the timber. The timber shall be free of any defects which shall affect the structure.

Where rigid forms are specified on the drawings, only metal forms are accepted.

Only metal forms are accepted for precast concrete, forms for surfaces requiring special finishes are specified elsewhere in the Contract.

Unless otherwise shown in the Drawings, all corners shall be provided with 15 mm x 15 mm chamfers or fillets.

Where access is otherwise extremely difficult, openings shall be provided in the forms to facilitate cleaning operations and to allow proper inspection and ease of placement of concrete. Closure and sealing of these openings shall be effected in a manner which prevents mortar loss and results in minimal interference to the surface smoothness of the forms.

Cast in metal form ties shall be of a type which permits removal of the end fittings to a depth of at least 40 mm below the finished surface of the concrete. Ordinary wire ties shall not be used.

Form ties shall be located in a uniform symmetrical pattern relative to the finished surface. The cavities left when the end fittings of embedded ties are removed shall be as small as possible and shall be filled with cement mortar at the earliest possible time. The surface of such filled cavities shall be left smooth and uniform in colour.

When forms are re-used, their original shape, strength, rigidity, mortar tightness and surface smoothness shall be maintained. Forms which become unsatisfactory shall not be used.

In firm ground, buried concrete members shown with formed surfaces may be constructed without the use of back forms but, in this case, the specified cover shall be increased by not less than 25 mm.

18.2 Bar Chairs and Spacers

All bar chairs, spacers (including wheels) and supports, used in concrete to ensure the specified cover is maintained to reinforcement, or to support the reinforcement shall be an approved product, manufactured from extruded fibre concrete, or conventional concrete manufactured under factory controlled conditions. The minimum concrete strength shall be not less than 60MPa and the product shall have a minimum RCPT Test value of 1000 coulombs. Alternatively stainless steel nibs welded to the reinforcing may be used.

The fibres used in extruded fibre concrete bar chairs or spacers shall be non metallic, synthetic fibres. Asbestos or similar fibres based on naturally occurring silicate minerals shall not be used.

Bar chairs, spacers and supports manufactured from wood, metal, plastic, plastic coated metal or site cast concrete shall not be used.

Spacers shall be placed sufficiently close together to ensure that the specified cover is maintained before and during concrete placement and to prevent any potential crushing of the spacers or penetration into the formwork. Long continuous linear runs of spacers shall be avoided, where such a configuration may be considered each individual length of spacer shall be laterally offset from its adjacent spacer by at least 200 mm so as to avoid the potential for spacers to induce linear cracking in the concrete.

Where spacers are required to be attached to the reinforcement such attachment may be via steel wires or clips provided that no part of the wire or clip is located within three quarters of the required cover depth from the surface of the concrete. If stainless steel wire or clips are used they must be located at a depth of no less than half the specified cover from the concrete surface.

Welding of stainless steel nibs to reinforcing shall comply with the locational tack weld requirements of MRSTS71.

19 PLACING AND COMPACTING CONCRETE

19.1 Placing – General

No concrete shall be placed in the Works until the falsework, formwork, reinforcement and stressing materials have been inspected, all foreign material has been completely removed from the forms and the compaction equipment and placement procedures have been submitted and approved by the Administrator.

Hold Point 4

For cast-in-place piles, additional requirements are specified in MRTS63 *Cast-In-Place Piles*.

The placing operation shall be conducted in the presence of the Administrator **Witness Point** and the Contractor shall give at least 24 hours notice to the Administrator of the time that placing shall start.

Except as provided for in Clause 19.2, all concrete shall be placed under dry conditions, all pools of water shall be removed and no inflow of water shall be permitted.

Concreting operations shall be carried out in a continuous manner between the construction joints shown in the Drawings, or from end to end in the case of precast items. Fresh concrete shall not be placed against concrete which has taken its initial set. Initial set is defined for this purpose only as the concrete surface not being able to be easily penetrated with a 12mm bar. If an interruption greater than 45 minutes occurs, a construction joint approved by the Administrator shall be placed and, in addition, for precast work, the interruption may render the unit liable for rejection. **Nonconformance**

Chutes, if used, shall be arranged in a manner which avoids segregation of the concrete. Apart from an initial flushing immediately prior to commencement of concreting, the use of water in chutes to assist movement of concrete shall not be permitted.

Pneumatic placers and concrete pumps may be used only when a concrete mix designed for such placing is approved for use by the Administrator. The equipment shall be positioned such that freshly placed concrete is not damaged by vibration. The initial discharge containing the cement slurry used to coat the pipe line shall be discarded.

Buckets shall have the capability of a controlled rate of discharge. Concrete shall not be allowed to free fall from a height exceeding 2 m, nor shall it be placed in any other manner which results in segregation or loss of mortar or damage to formwork or reinforcement.

If placing operations necessitate a drop of more than 2 m, the concrete shall be placed using a flexible tube reaching to the base of the formwork or another method approved by the Administrator **[Refer to Hold Point 4]**.

Fresh concrete shall be deposited within the forms as near as possible to its final location. Excessive use of vibrators and tamping rods to move the concrete along the forms shall not be permitted.

Formwork shall not be disturbed or adjusted during the concreting operation, and shall remain undisturbed up to the minimum removal time specified in Clause 23. No strain shall be placed on any projecting reinforcing steel for a period of at least 12 hours following completion of concreting.

Where reinforced concrete is placed on earth, sand or rock foundations, the earth or sand shall be compacted to 95% Relative Dry Density as determined by Test Methods Q142A and Q141A or Q141B and the rock freed of loose material. Where shown in the Drawings the foundation shall be covered with a layer of blinding concrete.

Where concrete work is constructed on ground surfaces or on a foundation bedding, a polythene sheet separator of thickness not less than 100 µm shall be employed between the ground/bedding and the concrete. The separator shall extend not less than 300 mm beyond the concrete work. Care shall be taken to avoid puncturing or tearing the separator. Should puncturing or tearing occur, the damage shall be repaired prior to concreting. Joints in the separator shall be made by overlapping the sheets a minimum of 300 mm or by overlapping and taping.

19.2 Placing Under Water

The Contractor shall submit its procedure for underwater concreting at least 2 weeks prior to concreting.

Milestone

The placement of concrete underwater shall be carried out in the presence of the Administrator **Hold Point 5** and shall employ the following techniques –

- a) The slump of the concrete to be placed underwater shall be between 180 mm and 220 mm;
- b) Concrete shall not be placed under running water. The structure shall be sufficiently watertight to maintain effectively still-water conditions at the location required. All pumping of water shall cease and the water level shall stabilise before placement;
- c) The concrete shall be placed carefully in a compact mass in its final position by means of an approved tremie or other approved device;
- d) An approved tremie shall consist of a watertight tube fitted at the base of the tube with a valve or other approved device to ensure that the surrounding water is prevented from mixing with the concrete during the initial concrete charge. The base of the tube shall sit on the foundation while this initial charge is effected and the tube and hopper shall be completely filled with concrete before the base valve is opened for the first discharge of concrete.

The tremie shall be capable of controlled movement at the discharge end in both lateral and vertical directions and shall be capable of rapid lowering at any time to decrease the discharge rate of the concrete. The flow of concrete shall be regulated by adjusting the depth that the discharge end is submerged below the surface level of the concrete already placed.

A concrete pump may be used for underwater placing provided it has the same characteristics as a tremie, including the ability to separate the concrete from the surrounding water by a plate valve at the base or inflated ball or similar device approved by the Administrator. The discharge end of the pump line shall be capable of controlled vertical and horizontal movement.

The discharge end of the pump or tremie shall remain submerged in the concrete at all times and remain filled with concrete to a height which shall at least balance the external hydrostatic head. If, for any reason, the discharge end of the tremie is lifted clear of the surrounding concrete, thus breaking the seal and permitting entry of water, the placing operation shall be abandoned and all defective concrete subsequently removed **Nonconformance**;

- e) The concrete shall be placed in one continuous operation, the base of the tremie being moved laterally as necessary to maintain an approximately horizontal surface on the concrete;
- f) No tamping or vibrating of the concrete shall be allowed. The concrete shall not be subjected to any physical disturbance after deposition.

Adequate allowance shall be made when concreting to provide for the subsequent removal of the contaminated surface layer.

If the finished surface of the concrete rises above the water level, the contaminated concrete may be removed before hardening occurs. When dewatering is completed, structural concrete shall have all unsound or contaminated concrete areas removed, and the surface thoroughly scabbled and cleaned prior to subsequent placement of concrete; and

- g) Cofferdams or cylinders which have been sealed by underwater placement of concrete shall not be dewatered until at least 48 hours after completion of the concreting operation.

19.3 Use of Spalls

Spalls of solid rock (not exceeding 200 mm in size) may be used in “mass concrete”.

The spacing of the spalls shall be such that the clear distance between the spalls and their clearance from faces of forms shall not be less than 150 mm.

The spalls shall be surface wetted and bedded by hand, and the concrete shall be vibrated in place all around the spalls.

19.4 Compaction of Concrete

This clause specifies the compaction requirements for concrete other than that placed underwater (refer to Clause 19.2), for no-fines concrete (refer to Clause 26).

Unless otherwise approved by the Administrator [**Refer to Hold Point 4**], concrete shall be deposited in horizontal layers not more than 400 mm thick except in the manufacture of prestressed concrete elements. For prestressed elements the concrete shall be built up to the full depth of the section and the concrete face moved forward progressively. For prestressed elements over 600 mm deep this may occur in two or three passes.

Compaction of concrete shall commence immediately after deposition. Compaction shall be achieved by use of high frequency internal vibrators supplemented as required by external form vibrators. Where intense compaction is specified the use of external form vibrators is mandatory. The amount and type of vibration used shall be approved by the Administrator [**Refer to Hold Point 4**].

The following conditions shall apply when using internal vibrators –

- a) The vibrators shall be capable of transmitting vibrations at a frequency not less than 150 Hz with an intensity which shall visibly affect the concrete at a radius of 300 mm;
- b) The number of vibrators to be used by the Contractor shall be not less than one for each 4 m³ of concrete placed per hour, with a minimum of 2 vibrators to be provided at any time;
- c) Vibrators shall be inserted vertically at successive positions not more than 450 mm apart and in a manner which ensures compaction of the concrete around the reinforcing steel and any other embedded fixtures, and into all parts of the forms;
- d) Vibration shall continue at each position until air bubbles cease to emerge from the concrete. The vibrators shall then be withdrawn slowly so as to avoid leaving a “pocket”;
- e) Care shall be taken to ensure that newly deposited concrete is vibrated into any fresh concrete adjacent to it to provide a homogeneous concrete mass; and
- f) Vibration shall not be applied either directly or through the reinforcement to any concrete which has taken its initial set.

Where external form vibrators are used, the number, type, spacing and method of support of the vibrators shall be approved by the Administrator [**Refer to Hold Point 4**]. Internal vibration shall always be used in conjunction with external form vibration.

In prestressed concrete construction, special care shall be taken to ensure complete compaction in end blocks and around anchorages.

19.5 Concrete Temperature – Heat of Hydration

For concrete other than prestressed precast concrete elements. Where the cross section of a concrete member exceeds 1m thick by 1m thick in any direction or the total cementitious content of the mix exceeds 500 kg/m³, the contractor shall take precautions to ensure that the following requirements are met and shall monitor and record internal concrete temperatures from placement until a minimum of 120 hours after placement operations have been completed and the forms are stripped to ensure:

- a) The maximum internal concrete temperature does not exceed 75°C. **Nonconformance**
- b) The maximum temperature differential does not exceed 25°C including at the time of formwork stripping. **Nonconformance**

Precautions may include:

- a) Redesign of the concrete mix.
- b) Reducing the temperature of the concrete at the time of placement using techniques as per Clause 16.2(c).
- c) Insulating the formwork to reduce temperature differentials.
- d) Other measures as approved by the Administrator.

The contractor shall submit a procedure and plan for monitoring and procedures for ensuring compliance to the administrator for approval [**Refer Hold Point 4**] at least 4 weeks prior to the concrete pour.

A record of the monitoring results shall be submitted to the contract administrator within 48 hours of the completion of the monitoring.

20 FINISHING OPERATIONS

20.1 Introduction

20.1.1 General

All unformed surfaces shall be finished true to line and level within the tolerances specified in Clause 22.

All finishing operations shall be completed prior to the application of any curing. The finishing operations shall be such as to provide a dense surface free from visible surface cracking. The concrete surface shall be reworked as necessary to eliminate plastic cracking after the initial set has taken place and before the commencement of curing.

20.1.2 Prevention of Cracking

The Contractor shall plan and control the placing, compacting, curing and finishing operations to prevent cracking in the various concrete elements.

20.2 Cast-in-Place Surfaces

20.2.1 Top Surface of Decks and Relieving Slabs

Concrete placed in the deck slab shall be fully compacted before screeding, with particular care taken at each expansion joint. The concrete shall be brought to the levels and profiles shown in the Drawings by means of an approved screeding method. During screeding, a slight excess of concrete shall be maintained ahead of the screed. The number of passes of the screed shall be kept to a minimum. Where a vibrating screed is used, the number of passes shall not exceed one initial cutting pass plus two finishing passes.

After screeding, the surface of the wet concrete shall be checked with a 3 m long straight-edge. Any deviation from the straight-edge in excess of 4 mm shall be immediately made good.

All deck surfaces shall be finished as follows, unless otherwise approved by the Administrator [**Refer to Hold Point 4**].

The surface shall be brushed in a direction at right angles to the direction of traffic using a broom not less than 400 mm wide to achieve an average texture depth of 0.8 mm. The texture depth produced by brushing shall be measured by the method described in Test Method Q705. The average texture depth for each set of tests shall not be less than 0.8 mm and not more than one test in each set shall show a texture depth of less than 0.6 mm. Tests in a set shall be carried out at one metre intervals along a line one metre inside any lane edge. The number of tests in a set shall be ten. Testing shall be carried out as soon as practicable after curing of the concrete and before construction traffic is permitted to use the surface. Where compliance with the requirements of this section is not achieved, the Contractor shall make good the deficiencies in the texture depth by transverse mechanical grooving of the concrete surface by a means approved by the Administrator. **Nonconformance**

After texturing, the deck shall be cured as specified in Clause 24.

20.2.2 Other Cast-in-Place Surfaces

The tops of walls, kerbs, concrete barriers, headstocks and piers shall be steel trowel finished. Other surfaces may be wood float finished.

20.3 Precast Elements

20.3.1 Precast Kerb Units

Top and exposed side faces of precast kerb units shall have a steel form finish or be steel trowelled.

20.3.2 Precast Deck Units

The tops of precast deck units shall be coarse wood float finished.

20.3.3 Precast Beams

The top surface of precast beams shall be finished as for construction joints detailed in Clause 21.

20.3.4 Precast Piles

The top surfaces of precast piles shall be steel trowel finished.

20.4 Special Finishes

Special finishes shall be as detailed in the Drawings.

21 CONSTRUCTION JOINTS

21.1 Normal Joints

Construction joints shown in the Drawings are mandatory. The use of construction joints elsewhere in the concrete work shall require the prior approval of the Designer. **Hold Point 6**

Edges of all joints which are exposed to view shall be carefully finished true to line and level.

At horizontal construction joints along all exposed faces, dressed timber strips approximately 25 mm square shall be attached to the inner face of the form and the surface of the lower concrete lift shall be stopped slightly above the lower edge of the strips so as to provide a uniformly straight edge along the joint when the strips are removed prior to placing the next lift.

The surface of the joint shall be prepared by removing all laitance and sufficient surface mortar to expose the coarse aggregate, but leaving the coarse aggregate firmly embedded in the mortar matrix, without undercutting. This may be achieved by –

- a) use of sand-blasting techniques;
- b) use of wire brushes, hand tools and pneumatic tools;
- c) use of a “green cutting” technique whereby the surface laitance and mortar is removed from partially hardened concrete by means of a high pressure combined air/water jet directed through a single nozzle onto the concrete;
- d) use of surface retarding agents followed by any of the above; or
- e) construction joints shall be dampened prior to the placement of the adjoining concrete.

Membrane-curing agents shall not be applied to the surface of any construction joint.

The joint shall be cleaned of any foreign material and contaminants present prior to concreting the next lift and the fit of forms along the construction joint shall be checked to ensure a mortar-tight joint.

21.2 Construction Joints in Marine and Other Aggressive Environments

Where stated in the Drawings, construction joints in marine or other aggressive environments shall be prepared as follows –

- a) The surface of the joint shall be prepared as in Clause 21.1 immediately prior to casting concrete against the joint. The surface and any projecting steel shall then be washed with clean fresh water to remove any salt deposits or other contaminants, and either blown dry with oil-free air or allowed to dry while protected from further contamination; and
- b) The concrete surface shall be coated with a Transport and Main Roads’ approved wet-to-dry epoxy resin followed by placement of the fresh concrete before the epoxy on the interface has hardened.

22 DIMENSIONAL TOLERANCES

22.1 General

Where tolerances for individual components and associated dimensions are not specified in the Drawings, deviations from established lines, grades and dimensions in the completed work shall not exceed the values given in Clause 22.

Dimensions and levels shall be verified for all positions shown in the Drawings.

22.2 Dimensional Tolerances

The tolerances given in Table 22.2 are to ensure strength, durability and fit of prefabricated elements and cast-in-situ elements.

Table 22.2 – Dimensional Tolerances

Description	Tolerance (mm)
Cross sectional dimension of members and thickness of slabs	+ 10, - 3
Length of members, length and width of slabs – dimension up to 18 m dimension 18 m or over	± 6 1 in 3000
Clear cover to reinforcement	+ 10, - 5
Fitments for prefabricated elements, girder anchorages (including dimension between anchorages on adjacent piers), cored holes, handrail anchorages and other embedded items	1 in 1000 ± 5 max.

22.3 Positional Tolerances

Positional tolerances, listed in Table 22.3, refer to the departure of any point, plane or component of a structure from its correct position within the layout of the structure as shown in the Drawings.

Table 22.3 – Positional Tolerances

Description	Tolerance (mm)
Level of footings	± 20
Level other than footings	± 5
Horizontal location, where tolerance on fit is not applicable	± 25

22.4 Relative Position

Relative tolerances refer to departures from linearity or planarity in any part of the structure. Tolerances are measured as the departure of any point in a line or surface from the remainder of that line or surface.

Departure may be sudden (e.g. misfit at joint in formwork) or gradual (e.g. a wobble in the surface). Tolerance on gradual departure is the value calculated by multiplying the overall length of the line or surface under consideration by the factor given in Table 22.4.

Table 22.4 – Relative Tolerances

Description	Tolerance	
	Factor	Maximum (mm)
Exposed edge: Gradual departure	0.001	-
Exposed surface: Gradual departure Sudden departure	0.004 -	10 3

23 REMOVAL OF FORMWORK, FALSEWORK AND EARLY LOADING

Forms, falsework and centring shall remain in position until the times stated below have elapsed after completion of concreting **Hold Point 7** –

- a) for non-structural concrete, until such time as the concrete has reached 50% of the characteristic 28-day strength and a period of 72 hours, and
- b) for structural concrete –

- i) for soffits of slabs, headstock and diaphragms, until such time as the concrete has reached 70% of the characteristic 28-day strength and 7 days. In addition no loading shall be applied until these requirements are met.
- ii) for side forms on structural concrete, in accordance with Table 23.

Table 23 – Retention of Side Forms

Exposure Classification *	Minimum Form Retention (hours)
A	48
B1, B2	72
C	120

* Refer to Drawings.

Where the timing for the removal of forms is based on concrete strength or concrete strength forms part of the condition as specified in this clause, the strength shall be proven by testing (refer to Clause 13.3). In addition, the curing requirements of Clause 24 shall apply to the newly exposed surfaces.

Forms shall be removed with care, without hammering and wedging, and in a manner which shall not injure the concrete or disturb the remaining supports. Centres shall be lowered gradually and uniformly in such a manner as to avoid injurious stress in any part of the structure.

Loads which may cause damage to the work shall not be placed on or against any part of the structure. Loads placed on or against any concrete shall be subject to approval by the Administrator, and shall satisfy any requirement specified elsewhere in the Contract.

The Contractor shall repair any damage caused by such operations.

24 CURING

24.1 General

The Contractor shall submit its procedure for curing, including methods and materials, to the Administrator for approval at least 2 weeks prior to the first concrete pour. **Milestone** The curing of unformed surfaces of concrete shall commence as soon as finishing operations are complete.

If forms are removed in less than 7 days, curing of the formed surface shall commence within one hour of stripping, except as otherwise specified in Clause 25.1.

Curing shall continue for a period after placing the concrete of not less than –

- a) Top surface of slabs – 14 days; and
- b) Other surfaces – 7 days.

Curing shall be effected by one of the methods which follow.

Removal of formwork and application of curing shall be a witness point. **Witness Point**

24.2 Water Curing

Surfaces shall be kept moist for the period specified by continuous spraying, ponding, wet hessian or wet sand blankets. The water used shall conform to the requirements of Clause 7.7.

24.3 Membrane Curing

Membrane curing shall be effected by application of a sprayed curing compound or by covering with polythene sheet.

Curing compounds shall be approved by the Director Concrete Technology and comply with the requirements of AS 3799 for the classes and types specified in Table 24.3.

Table 24.3 – 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	1-D
Water borne compounds	Z	1-D

For each curing compound proposed for use the Contractor shall provide to the Administrator a certificate of compliance from the supplier, supported by test certificates from a laboratory with appropriate NATA registration, certifying that the curing compound complies with this Standard.

This certificate of compliance shall relate only to the formulation on which the tests were made and shall be valid for not more than three years from the date of issue.

The test certificates shall report the non-volatile content, the efficiency index and the density.

For each batch delivered, the Contractor shall provide to the Administrator a certificate of uniformity from the supplier, supported by uniformity testing of both non-volatile content and density in accordance with Clause 3.2 of AS 3799 and on viscosity in accordance with Clause 3.1.5 of AS 3799. The certificate of uniformity shall state that the same formulation has been used for the batch as is represented by the certificate of compliance.

Sampling and testing shall be carried out at a rate of not less than one test per 3000 litres, or part thereof, supplied.

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

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

Two coats shall be applied at the full rate.

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

The curing membrane shall be maintained intact after its initial application, for the period determined in accordance with Clause 24.1. Any damage to the curing membrane due to the Contractor's or other's activities shall be made good by respraying of the affected areas.

Where surface treatments other than bagging (refer to Clause 25.1) are to be applied, wax emulsion membranes shall not be used unless provision is made for subsequent removal of wax by sandblasting, prior to applying the coating or wearing surface.

Polythene sheeting shall be of sufficient strength to withstand wind and any imposed foot traffic and fully enclose the exposed surface. Torn or punctured sheeting shall not be used. Laps shall be 300 mm minimum and edges and laps shall be sealed by tape or held down by boards or reinforcing bars. Water shall be sprayed under the sheeting at edges and at laps on the day after placing concrete and at regular intervals to maintain moist conditions.

24.4 Steam Curing

Where a new steam curing process is being established, the Contractor shall submit the procedure for steam curing at least 2 weeks prior to commencing establishment of the plant. Low pressure steam curing of precast units shall be effected within an appropriate enclosure. The steaming shall continue until the required strength, as indicated by cylinder tests, is attained.

Curing is deemed to have commenced and continue once the temperature in the enclosure has exceeded 50°C. For all prestressed concrete members, curing shall continue from this point until the product of the time and enclosure temperature exceeds 420°C Hours.

The formwork, enclosure and steam lines shall be so arranged that the temperature distribution around the units being cured is uniform. The temperature variation between any two locations inside the enclosure shall

not exceed 5°C. Formwork and supports shall be designed to allow the steam to circulate freely around all sides of the units. The enclosure shall fully enclose the units including the top surface.

The atmosphere within the enclosure shall have 100% relative humidity to prevent loss of moisture and to provide excess moisture for proper hydration of the cement. The process shall not allow steam to be discharged directly onto the concrete or formwork.

The application of steam shall be such that the air temperature inside the enclosure is raised at a linear rate not exceeding 24°C per hour at any time until a minimum enclosure temperature of 50°C is attained. The maximum temperature in the enclosure shall not exceed 70°C. The corresponding maximum internal concrete temperature measured at the centre of the largest concrete cross section, of the concrete unit shall not exceed 75°C. **Nonconformance**

The application of steam to a freshly concreted unit shall be delayed for a period of time after completion of concreting to allow the concrete to gain sufficient tensile strength to resist the expansive forces. The actual delay period (T) shall be calculated as follows –

$$T = \frac{K}{t} \text{ hours}$$

where –

t = the numerical value of the concrete temperature in °C immediately after completion of concreting; and

K = a numerical factor having a value of 40 where the rate of temperature rise inside the enclosure is precisely controlled, and a value of 60 where precise control is not provided.

When super plasticisers or retarding admixtures are used, the delay period is to be determined from measurements of the initial setting time of the approved concrete mix.

Control is considered precise when the temperature inside the enclosure increases at a uniform rate and is within 5°C of the predicted temperature at any time.

If cracking occurs in units which have been steam cured and the Administrator attributes such cracking to an early application of steam, the delay time shall be extended for future units as approved by the Administrator. **Nonconformance**

Transfer of prestress may be performed when the concrete surface temperature of the units has cooled to 60°C. The enclosure shall not be removed until the surface temperature of the unit has cooled to within 40°C of the ambient air temperature. **Nonconformance**

Where a number of identical units are to be cured, uniform curing conditions shall be maintained for each of the units to minimise geometrical variations between units.

The manufacturer shall provide accurate instruments for recording and controlling the temperatures inside the enclosure and the maximum concrete temperature. These instruments shall record graphically the temperature inside the enclosure, and the maximum internal concrete temperature and concrete surface temperature during the whole of the steaming operation. Sufficient instruments shall be provided and so positioned to record variations in temperature between various points within the enclosure. Spacing of recording points in the enclosure shall not exceed 10 m. The instruments shall be secured against access by unauthorised persons.

Curing of associated concrete test specimen cylinders shall be achieved by placing the cylinders within the enclosure in a position adjacent to the lower face of the structural units which they represent. The cylinders shall be located midway between steam entry points and shall be distant at least half the width of the structural unit from these entry points. The cylinders shall not be positioned on top of the structural units, or on the steam lines and shall not be directly in line with any steam jet.

25 SURFACE DRESSING OF CONCRETE

25.1 Formed Surfaces Exposed to View

Prior to commencing concreting operations, the Contractor shall establish procedures for surface dressing of concrete. The standards established shall be subject to the approval of the Administrator. **Hold Point 8**

Following the removal of formwork the following operations shall be carried out to the standard approved by the Administrator –

- a) all fins and other unwanted projections shall be ground off to provide a smooth surface;
- b) any pockets or honeycombed areas shall be cleaned out to sound concrete;
- c) small voids shall be filled with a stiff mortar vibrated as necessary and having the same sand/cement ratio as the concrete concerned. The surface of the patches shall be finished flush with the adjacent formed surface. Large voids shall be formed and filled with vibrated concrete of the same mix design. An effective bonding agent in the mix and on the interface shall be used. The Administrator shall witness the operations required by this paragraph (c).

Where specified in the Drawings, surfaces shall achieve a Class 1 surface finish to AS 3610 (Figure B1) or be bagged as set out in (e) below within four hours of removal of formwork from each section of the concrete. Curing as specified in Clause 24 shall commence on completion of stripping or bagging as appropriate;

- d) where surface finish is not specified in the Drawings, a Class 2 surface finish to AS 3610 is required. Where surfaces of concrete do not achieve a Class 2 surface finish, the surface shall be bagged as set out below. Bagging to achieve this class of finish may be done immediately, prior to curing, or on completion of curing; and
- e) bagging shall be carried out by the following procedure –

Sand/cement grout consisting of equal parts of cement and fine sand passing a 0.60 mm sieve, mixed with a suitable bonding additive and water to produce a plastic mix, shall be applied uniformly to the surface in a suitable manner using a pad of hessian or similar material to fill all air holes and other minor surface blemishes. The surface shall be kept damp while this work is carried out. Surplus material shall be removed while the initial application is still plastic by rubbing with a dry mix of the same proportions and materials leaving residual material only in the depressions and not on the surface.

25.2 Formed Surfaces Hidden from View

Immediately following removal of forms any pockets or honeycombed areas accepted by the Administrator, subject to their undergoing satisfactory remedial work, shall be rectified as specified in Clause 25.1.

25.3 Contact Surfaces

Contact surfaces (ends of precast boxes, diaphragm junctions, etc) shall be prepared by the manufacturer in accordance with Clause 21.

26 NO-FINES CONCRETE

No-fines concrete shall consist of cement, water and coarse aggregate. The quantity of cement used shall be as specified in Table 26. The nominal size of the single-sized aggregate for no-fines concrete shall be as shown in the Drawings. Grading limits shall be as specified in Table 26.

Table 26 – Aggregate Grading for No Fines Concrete

AS Metric Sieve (mm)	Percentage Passing by Mass	
	Nom. Size 20 mm	Nom. Size 10 mm
26.5	100	-
19	85 – 100	-
13.2	-	100
9.5	0 – 20	85 – 100
4.75	0 – 5	0 – 20
2.34	-	0 – 5
0.075	0 – 2	0 – 2

AS Metric Sieve (mm)	Percentage Passing by Mass	
	Nom. Size 20 mm	Nom. Size 10 mm
Other: Minimum Cementitious Content (kg/m ³)	210	250

The water/cement ratio shall be approximately 0.5.

No-fines concrete shall be rodded sufficient only to ensure the form is completely filled. It shall be screeded to the required surface level without tamping or vibrating.

No-fines concrete shall be moist cured for at least 4 days by covering with wet hessian, polythene sheet or other similar material. The use of wet sand or any other material which can enter the voids shall not be permitted for curing purposes.