

Technical Specification

**Transport and Main Roads Specifications
MRTS70 Concrete**

July 2022

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1 Introduction

This Technical Specification applies to the construction of concrete road and bridge structures and may also be applied to other specified concrete elements.

For concrete pavements refer to MRTS39 *Lean Mix Concrete Sub-base for Pavements* and MRTS40 *Concrete Pavement Base* and for concrete for machine-manufactured concrete drainage pipes refer to MRTS25 *Manufacture of Precast Concrete Pipes* and MRTS26 *Manufacture of Fibre Reinforced Concrete Drainage Pipes*.

Shotcrete is covered by MRTS272 *Shotcrete for Aboveground Applications* and fibre-reinforced concrete by MRTS273 *Fibre-reinforced Concrete*. Both of these specifications refer back to this Technical Specification.

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

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

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

The use of commentary text, such as this, is covered by MRTS01 *Introduction to Technical Specifications* Clause 16.

For clarity, this Technical Specification is divided into sections which identify the requirements for the various concrete types and elements.

Table 1 – Clause applicability of MRTS70

| Clauses | Insitu Concrete | | Precast and Prestressed Concrete | |
|---------|-----------------|--------------|----------------------------------|--------------|
| | Special-Class | Normal-Class | Special-Class | Normal-Class |
| 1 – 6 | X | X | X | X |
| 7 – 14 | X | | X | |
| 15 | X | | | |
| 16 | | | X | |
| 17 | | X | | X |
| 18 | | X | | |

1.1 Registered products and suppliers

The requirements for the construction of concrete elements include the use of registered products and suppliers. For information regarding these products and suppliers refer to the Transport and Main

Roads website, <http://www.tmr.qld.gov.au>, or email Structures Construction Materials (TMRStructuralMaterials@tmr.qld.gov.au).

Note the differing submission requirements throughout this Technical Specification. Some approvals (e.g. procedures) are wholly dealt with by registration, some submissions (e.g. mix designs, Hold Points) are assessed by Structures Construction Materials but signed off by the Administrator after receipt of a certificate or similar, and others (e.g. niche project specific requirements) are assessed by the Administrator.

2 Definition of terms

The terms and symbols used in this Technical Specification shall be as defined in Clause 2 of MRTS01 *Introduction to Technical Specifications* and in Table 2(a) and Table 2(b) below.

Table 2(a) – Definition of terms

| Term | Definition |
|------------------------------------|--|
| Approved | Approved by the Administrator. |
| ASR | Alkali-Silica Reaction, a subset of Alkali-Aggregate Reaction (AAR). |
| ATIC | Australian Technical Infrastructure Committee. |
| Batch | One load or charge of a mixing plant or transit mixer. |
| Bed | A set of precast elements cast in a line and cured under a single enclosure. |
| Blended cement (GB) | As per AS 3972 <i>General purpose and blended cements</i> . |
| Blinding concrete | A layer of typically low strength concrete placed on ground to provide a hard surface for construction of concrete members. |
| Carbonate rock | A rock containing more than 50% by mass of carbonate material. |
| Cementitious Material | GP cement, GB cement, fly ash, ground granulated blast furnace slag and amorphous silica, in combination or alone. |
| Characteristic strength (f'_c) | That value of the concrete strength, as assessed by standard test, which is exceeded by 95% of the concrete. |
| Coarse aggregate | Aggregate having a nominal size equal to or larger than 5 mm. |
| Contractor | Unless noted otherwise, the entity responsible for producing the finished concrete element (insitu or precast). The use of this term does not diminish the responsibility of the Principal Contractor to ensure all Works are in accordance with the Contract, nor does it make any comment on the form of agreement between the various parties involved in the Contract. |
| Core temperature | Concrete temperature as measured at the centre of the largest cross-section. |
| Crushed fine aggregate | A purpose-made, fine crushed aggregate produced under controlled conditions from a suitable sound source rock designed for use in concrete (otherwise known as manufactured sand). General crusher fines (crusher dust) and sand resulting from lightly crushing (disaggregating) decomposed granite, similar igneous rock or weakly cemented sandstone rocks are not considered to be manufactured sand. The latter are classified as natural sands of residual origin. |

| Term | Definition |
|---------------------------------|--|
| Design characteristic strength | Value of the characteristic compressive strength nominated on the Drawings. |
| Designer | RPEQ engineer responsible for the design of the element. |
| Enclosure | A continuous covered space in which heat is contained for the purposes of heat accelerated curing. |
| Fine aggregate | Aggregate having a nominal size of less than 5 mm. |
| General Purpose (GP) cement | As per AS 3972 <i>General purpose and blended cements</i> . |
| Grading | Distribution of aggregate particle size. |
| High Workability Concrete (HWC) | Concrete with high workability where consistency is measured by spread. Only used for cast-in-place piles and specialised applications. Distinct from super-workable concrete in that it does not self-consolidate. |
| Lot | <p>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 strength grade, produced and placed in an essentially uniform and continuous manner during a day's production.</p> <p>A lot may be further defined by individual product Technical Specifications.</p> |
| Mass concrete | Unreinforced concrete placed generally in large volumes to the dimensions shown on the drawings. |
| Maximum nominal aggregate size | As per AS 2758.0 <i>Aggregates and rock for engineering purposes, Part 0: Glossary and general series information</i> . |
| Mean strength | The arithmetic average of the compressive strengths achieved by two or more specimen cylinders all of the same age. |
| No-fines concrete | Concrete, typically free draining, containing a minimum portion of aggregate below 4.75 mm (mix contains no fine aggregate source). |
| Pre-mixed concrete | Concrete delivered to site in an agitator truck having been batched off-site. |
| Product testing | Testing of a nominated product that is required by the respective technical specification, but where the testing is not detailed in Appendix A of QRS4: <i>Assigning Quarry-Specific Testing Frequencies for Source Rock Tests</i> . |
| RCPT | Rapid Chloride Penetration Test (ASTM C1202). |
| Registered | <p>Pre-qualified product or supplier in accordance with departmental registration schemes:</p> <ul style="list-style-type: none"> • <i>Registration Scheme: Suppliers and Products for Bridges and Other Structures</i> • <i>Product Index for Bridges and Other Structures</i> • <i>Construction Materials Testing (CMT) Supplier Registration Scheme</i> • <i>Quarry Registration System (QRS)</i> <p>Registration for certain products and suppliers is a pre-requisite for Administrator approval, not a substitute.</p> |
| Sample | A portion of fresh concrete drawn from a batch and from which specimen cylinders are made. |

| Term | Definition |
|-------------------------------------|---|
| Site | The location at which the concrete is placed. |
| Source rock | As per AS 2758.0 'the insitu rock mass located in a quarry, which is used ... in the production of crushed rock, aggregate or manufactured sand.' Source rock properties and testing frequencies are quarry-specific and detailed on the Quarry Registration Certificate issued as part of the QRS. The QRS provides testing of each of these properties, undertaken as part of the quarry's ongoing production. |
| Specimen cylinder | A single concrete cylinder, in accordance with AS 1012.8.1 <i>Methods of testing concrete, Method 8.1: Method for making and curing concrete - Compression and indirect tensile test specimens</i> , made from a sample for the purpose of testing. |
| Spread Measure of consistency | Also known as slump flow. |
| Standard deviation(s) | A statistical measure of the variation from the mean strengths of the specimen cylinders. |
| Strength grade | Specified value of the characteristic compressive strength at 28 days. |
| Super-Workable Concrete (SWC) | Concrete that is able to flow and consolidate under its own weight, completely filling the formwork even in the presence of dense reinforcement, whilst maintaining homogeneity. Minimal compaction may be required, particularly if there is a delay in placement between layers. |
| Target strength (f_t) | The compressive strength of the concrete at age 28 days selected for design of the mix as provided for in Clause 9. The mean strength required to ensure 95% of samples exceed the specified characteristic strength. |
| Water / Cementitious Material Ratio | Ratio of the total mass of the water and liquid admixture in the concrete mix, including any free moisture on the surface of the aggregates, to the total mass of the cementitious materials in the concrete mix. Free moisture on the surface of the aggregates is the total water in the aggregates less the water absorbed by the aggregate. |

Table 2(b) – Definitions of symbols

| Symbol | Definition |
|----------------|------------------------------------|
| f_c | Characteristic strength |
| f_t | Target strength |
| s | Standard deviation |
| σ | Test result (strength) |
| $\bar{\sigma}$ | Average of test results (strength) |

3 Referenced documents

Table 3 lists documents referenced in this Technical Specification. The latest revision of documents shall be used; dates are included when specific clauses have been referenced.

Table 3 – Referenced documents

| Reference | Title |
|------------------------|--|
| AS 1012 | <i>Methods of testing concrete</i> |
| AS 1141 | <i>Methods for sampling and testing aggregates</i> |
| AS 1289 | <i>Methods of testing soils for engineering purposes</i> |
| AS 1379 | <i>Specification and supply of concrete</i> |
| AS 1478 | <i>Chemical admixtures for concrete, mortar and grout</i> |
| AS 2350 | <i>Methods of testing portland, blended and masonry cements</i> |
| AS 2758 | <i>Aggregates and rock for engineering purposes</i> |
| AS 2876 | <i>Concrete kerbs and channels (gutters) – Manually or machine placed</i> |
| AS 3582.2 | <i>Supplementary cementitious materials. Part 2: Slag – Ground granulated blast-furnace</i> |
| AS 3600 | <i>Concrete structures</i> |
| AS 3610 | <i>Formwork for concrete</i> |
| AS 3799 | <i>Liquid membrane-forming curing compounds for concrete</i> |
| AS 3972 | <i>General purpose and blended cements</i> |
| AS 4198 | <i>Precast concrete access chambers for sewerage applications</i> |
| AS 5100.5 | <i>Bridge design, Part 5: Concrete</i> |
| AS/NZS 2425 | <i>Bar chairs in reinforced concrete – Product requirements and test methods</i> |
| AS/NZS 3582.1 | <i>Supplementary cementitious materials, Part 1: Fly ash</i> |
| AS/NZS 3582.3 | <i>Supplementary cementitious materials, Part 3: Amorphous silica</i> |
| AS/NZS 4680 | <i>Hot-dip galvanized (zinc) coatings on fabricated ferrous articles</i> |
| AS/NZS ISO 9001 | <i>Quality management systems – Requirements</i> |
| AS ISO/IEC 17025 | <i>General requirements for the competence of testing and calibration laboratories</i> |
| ASTM C39 | <i>Standard Test Method for Compressive Strength of Concrete Cylinders</i> |
| ASTM C157 | <i>Standard Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete</i> |
| ASTM C586 | <i>Standard Test Method for Potential Alkali Reactivity of Carbonate Rocks as Concrete Aggregates (Rock-Cylinder Method)</i> |
| ASTM C1105 | <i>Standard Test Method for Length Change of Concrete Due to Alkali-Carbonate Rock Reaction</i> |
| ASTM C1202 | <i>Standard Test Method for Electrical Indication of Concrete's Ability to resist Chloride Ion Penetration</i> |
| ATIC-SPEC Section SP43 | <i>Cementitious materials for concrete</i> |
| ATS 3050 | <i>Supply of Recycled Crushed Glass Sand</i> |
| CIA Z7/07 | <i>Recommended Practice: Performance Tests to Assess Concrete Durability</i> |
| CIA Z17 | <i>Recommended Practice, Tremie Concrete for Deep Foundations</i> |

| Reference | Title |
|------------------|--|
| CMT SRS | <i>Construction Materials Testing Supplier Registration System</i> |
| Design Criteria | <i>Design Criteria for Bridges and Other Structures</i> |
| Guideline QRS1 | <i>Quarry Registrations System Outline</i> |
| Guideline QRS2 | <i>Preparing a Quarry Assessment Report for a Hard Rock Quarry</i> |
| Guideline QRS3 | <i>Preparing a Quarry Assessment Report for a Natural Sand and/or Natural Gravel Quarry</i> |
| MRTS01 | <i>Introduction to Technical Specifications</i> |
| MRTS03 | <i>Drainage Structures, Retaining Structures and Embankment Slope Protections</i> |
| MRTS04 | <i>General Earthworks</i> |
| MRTS24 | <i>Manufacture of Precast Concrete Culverts</i> |
| MRTS25 | <i>Steel Reinforced Precast Concrete Pipes</i> |
| MRTS26 | <i>Manufacture of Fibre Reinforced Concrete Drainage Pipes</i> |
| MRTS36 | <i>Recycled Glass Aggregate</i> |
| MRTS39 | <i>Lean Mix Concrete Sub-base for Pavements</i> |
| MRTS40 | <i>Concrete Pavement Base</i> |
| MRTS50 | <i>Specific Quality System Requirements</i> |
| MRTS63 | <i>Cast-in-Place Piles</i> |
| MRTS63A | <i>Piles for Ancillary Structures</i> |
| MRTS71 | <i>Reinforcing Steel</i> |
| MRTS72 | <i>Manufacture of Precast Concrete Elements</i> |
| MRTS73 | <i>Manufacture of Prestressed Concrete Members and Stressing Units</i> |
| MRTS77 | <i>Bridge Deck</i> |
| MRTS84 | <i>Deck Wearing Surface</i> |
| MRTS270 | <i>Precast Geopolymer Concrete Elements</i> |
| MRTS272 | <i>Shotcrete for Aboveground Applications</i> |
| MRTS273 | <i>Fibre-reinforced Concrete</i> |
| Q208B | <i>Degradation factor of coarse aggregate</i> |
| Q229A | <i>Resistance to degradation by abrasion of fine aggregate</i> |
| Q478 | <i>Stability of super-workable concrete</i> |
| SA HB79 | <i>Alkali Aggregate Reaction – Guidelines on Minimising the Risk of Damage to Concrete Structures in Australia</i> |
| SCM-P-015 | <i>Supplier Registration Scheme: Bridges and Other Structures</i> |
| TN50 | <i>Treatment of Top Surface and 'Construction Joints' on Deck Units and Girders</i> |
| TN125 | <i>Long Distance Transport and Extended Placement Times for Concrete</i> |
| TN187 | <i>Controlled Low-Strength Material for Pipe Installation</i> |

4 Standard test methods

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

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

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

Table 4 – Standard test methods

| Property to be Tested | Method No. |
|---|--------------------------------|
| Air content | AS 1012.4.2 |
| Alkali-carbonate reactivity | ASTM C1105 |
| Chloride ion content (acid-soluble) | AS 1012.20.1 |
| Compressive strength (Concrete) | AS 1012.9 |
| Crushed particles | AS 1141.18 |
| Filtration loss Filter cake thickness | Q479 |
| Flakiness index | AS 1141.15 |
| Light particles | AS 1141.31 |
| Mass per unit volume (Concrete) | AS 1012.5 |
| Material finer than 2 µm | AS 1141.13 |
| Material finer than 75 µm | AS 1141.12 |
| Particle density and water absorption | AS 1141.5 AS 1141.6.1 |
| Particle size distribution | AS 1141.11.1 |
| Soil density (relative dry density, Hilf ratio) | AS 1289.5.4.1 AS 1289.5.7.1 |
| Resistance of Fine Aggregate to Degradation (by Abrasion in the Micro-Deval Apparatus) | ASTM 7428 or Q229A |
| Saturated resistivity (Rapid Chloride Penetration Test: RCPT) | ASTM C1202 |
| Slump | AS 1012.3.1 |
| Spread | AS 1012.3.5 |
| Sugar content | AS 1141.35 |
| Visual stability index | Q478 |
| Weak particles | AS 1141.32 |
| Wet Strength | AS 1141.22 |
| Wet / Dry Strength Variation | AS 1141.22 |

4.1 Test reports

Concrete strength reports shall include the information listed in AS 1012.1 Clause 9 and the mix (product) code.

All slump tests shall be reported, including out-of-tolerance tests. The concrete temperature at time of placement shall be included in the report.

For all early-age compressive strength tests (under 72 h), the curing conditions and the cylinder age (to the nearest hour) shall be reported.

Aggregate particle size distribution test reports shall include have the target grading envelope.

5 Quality system requirements

5.1 Hold Points, Witness Points and Milestones

General requirements for Hold Points, Witness Points and Milestones are specified in Clause 5.2 of MRTS01 *Introduction to Technical Specifications* and Clause 8.3 of MRTS50 *Specific Quality System Requirements*.

The Hold Points, Witness Points and Milestones applicable to this Technical Specification are summarised in Tables 5.1(a), 5.1(b), 5.1(c) and 5.1(d). Administrative points in Clause 15 (Insitu concrete), Clause 16 (Precast concrete) and Clause 17 (Normal-class concrete) apply to that clause only.

Table 5.1(a) – Hold Points, Witness Points and Milestones (special-class concrete)

| Clause | Hold Point | Witness Point | Milestone |
|--------|------------|---------------|---|
| 9.2 | | | Submit proposed concrete mix design (4 weeks) |
| 10.1 | | | Submission of on-site batching and mixing procedure (6 weeks) |
| 10.5.1 | | | Submission of long distance travel procedure (6 weeks) |
| 13.1 | | | Submission of hot weather procedure (2 weeks) |

Table 5.1(b) – Hold Points, Witness Points and Milestones (special-class insitu concrete)

| Clause | Hold Point | Witness Point | Milestone |
|--------|---------------------------|---------------|---|
| 15.1 | 1. Approval of mix design | | |
| 15.1.1 | | 1. Trial Mix | |
| 15.3 | 2. Approval of falsework | | Submission of falsework drawings (4 weeks) |
| 15.4.1 | 3. Approval of formwork | | |
| 15.5 | | | Submission of temperature control procedure (4 weeks) |

| Clause | Hold Point | Witness Point | Milestone |
|---------|--|------------------------|--|
| 15.6 | 4. Approval of concreting procedures | | |
| 15.6.1 | 5. Approval to place concrete | 2. Placing of concrete | |
| 15.6.3 | | 3. Placing of concrete | Submission of underwater placement procedure (2 weeks) |
| 15.8 | 6. Approval to remove formwork | 4. Removal of formwork | |
| 15.11.1 | | | Submission of curing procedure (2 weeks) |
| 15.12.2 | | 5. Repair of concrete | |
| 15.13 | 7. Approval of unspecified construction joints | | |

Table 5.1(c) – Hold Points, Witness Points and Milestones (special-class precast concrete)

| Clause | Hold Point | Witness Point | Milestone |
|--------|--|-----------------------|---|
| 16.1.1 | | 6. Trial mix | |
| 16.4.2 | | | Submission of temperature monitoring procedure (2 weeks) |
| 16.5.1 | 8. Approval to place concrete | | |
| 16.7.4 | | | Submission of heat accelerated curing procedure (2 weeks) |
| 16.8.2 | | 7. Repair of concrete | |
| 16.9 | 9. Approval of unspecified construction joints | | |

Table 5.1(d) – Hold Points, Witness Points and Milestones (normal-class concrete)

| Clause | Hold Point | Witness Point | Milestone |
|---------|--------------------------------|------------------------|--|
| 17.6.1 | | | Submission of long distance travel procedure (6 weeks) |
| 17.10 | 10. Approval of falsework | | |
| 17.11 | 11. Approval of formwork | | |
| 17.12.1 | 12. Approval to place concrete | 8. Placing of concrete | |
| 17.16 | 13. Removal of formwork | | |
| 17.18.1 | | 9. Repair of concrete | |

5.2 Construction procedures

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

All construction procedures for precast concrete (Clause 16) shall be submitted, reviewed and approved as part of supplier registration.

Table 5.2 – Construction procedures

| Clause | Procedure |
|----------------|---|
| 10 | On-site batching and mixing of concrete (including volumetric mixing) |
| 10.4.1, 17.5.1 | Long distance travel and extended placement times |
| 13.1 | Hot weather concreting |
| 15.5 | Temperature monitoring (large elements and/or high cementitious contents) |
| 15.6.3 | Placement under water |
| 15.11 | Curing |
| 15.12, 17.17 | Surface dressing of concrete |

5.3 Conformance requirements

The conformance requirements which apply to lots of work covered by this Technical Specification can be categorised as follows:

- a) Constituent and combined materials (Clauses 7-9, 11, 12)
- b) In-process monitoring (Clauses 10, 13, 16.7)
- c) Procedures and processes (Clauses 10, 15, 16), and
- d) Finished product (Clauses 15.7, 15.12, 16.8).

All normal-class concrete requirements can be found in Clause 17.

5.4 Testing frequency

The minimum testing frequency for work covered by this Technical Specification shall be as per:

- a) Clause 12 for special-class concrete, and
- b) AS 1379 for normal-class concrete.

6 Concrete class

6.1 Designation

All concrete supplied in accordance with this Technical Specification shall be designated as Nx/y (normal-class) or Sx/y (special-class) where x and y are defined as follows:

- a) 'x' is the strength grade and characteristic strength (f'_c) of the concrete at 28 days, expressed in megapascals.
- b) 'y' is the maximum nominal aggregate size in millimetres.

The strength grade of concrete and maximum nominal aggregate size used shall be as specified on the Drawings, unless otherwise approved by the Administrator. Substitution with a higher strength grade shall be limited to one step up from the Drawings (e.g. 32 to 40, 40 to 50, or 50 to 55) and will require Administrator approval.

For applications listed in Clause 18, where normal-class concrete is accepted by the design or project specifications, but the concrete is deemed special-class due to specified parameters being outside the range of AS 1379 Clause 1.5.3 (for example 'zero' slump concrete) then the requirements of MRTS70 Clauses 17 and 18 apply.

6.2 Normal-class concrete

Concrete designated in the Drawings as normal-class shall comply with the requirements of Clauses 17 and 18.

Where the Contractor supplies a concrete mix designated as special-class, instead of the specified normal-class, Clause 17 shall continue to apply and not Clauses 7 to 16. The substitution shall be at no cost to the Principal.

Normal-class elements (insitu or precast) will generally have a design life of less than 50 years, be situated in non-aggressive environments, or be used for temporary works.

6.3 Special-class concrete

Concrete designated in the Drawings as special-class shall comply with the requirements of Clauses 7 to 14 and either Clause 15 (for insitu applications) or Clause 16 (for precast applications).

All concrete in environments with an exposure classification of B2 or higher shall be special-class.

All concrete with a 100 year design life shall be special-class.

The need for designating concrete as special-class will be identified by the relevant design criteria. The requirements above are sourced from AS 3600 Clause 4.4 and AS 5100 Clause 4.4.

7 Materials

7.1 General

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

The mass of all aggregates shall be measured in a Saturated Surface Dry (SSD) condition where applicable.

7.2 Cementitious materials

Cementitious materials shall be a registered product, supplied by a registered supplier.

Use of cementitious material shall comply with the relevant Australian Standard.

Documentary evidence of the quality of the cementitious material shall be provided by the Contractor if requested by the Administrator.

Proprietary cementitious material systems, including any 'activators' shall be assessed for approval by the Director (Structures Construction Materials) on a case-by-case basis. Such activators need not necessarily comply with Clause 7.4.

Geopolymers are a special case of proprietary systems and are governed by MRTS270 *Precast Geopolymer Concrete Elements*.

All cementitious material delivery dockets and test certificates shall include the ATIC registration number for that material.

7.2.1 Cement

All cement used shall comply with ATIC-SPEC SP43 and AS 3972.

The type of cement used shall be Type GP or Type GB unless otherwise designated in the Contract or approved by the Administrator.

Cement more than three months old (from date of manufacture) shall be retested for conformance.

Nonconformance

Cement shall have a maximum total alkali content (measured as Na₂O equivalent) of 0.6%. Na₂O equivalent is calculated by:

$$[Na_2O]_{eq} = [Na_2O] + 0.658[K_2O]$$

The Contractor may use the following special purpose cements as defined by AS 3972:

- a) Type HE 'highly early strength'
- b) Type SL 'shrinkage limited'
- c) Type LH 'low heat'.

These cements may be used as a substitute for GP cement, subject to the approval of the Administrator. No additional payment shall be made where the Contractor elects to use special purpose cement where its use is not specified.

7.2.2 Fly ash

Fly ash used shall comply with ATIC-SPEC SP43 and AS/NZS 3582.1 and be Special Grade or Grade 1 as defined by the Australian Standard.

Fly ash shall have a maximum total alkali content of 3.0% (Na₂O equivalent).

7.2.3 Slag – ground granulated iron blast-furnace

Slag shall conform to ATIC-SPEC SP43 and AS 3582.2.

Slag shall have a maximum total alkali content of 1% and a maximum available alkali content of 0.5% (Na₂O equivalent).

Local availability of slag should be taken into consideration prior to specifying its use on a particular project.

7.2.4 Amorphous silica

Amorphous silica, including silica fume, shall comply with ATIC-SPEC SP43 and AS/NZS 3582.3.

Amorphous silica shall have a maximum total alkali content of 1% and a maximum available alkali content of 0.5% (Na₂O equivalent).

Amorphous silica shall not be used in bridge decks and flat slabs, in exposure classifications B2 and lower. In exposure classifications C1 and higher, amorphous silica shall only be used in bridge decks and flat slabs if suitable precautions are taken for placement and curing, with approval from the Administrator.

Note that mixes with amorphous silica tend to have less bleed and are therefore more susceptible to early age cracking.

7.2.5 Cementitious blends

Note that this clause relates to the registration of cementitious blends only and not to mix designs.

The following cementitious blends may be registered as a Type GB cement in accordance with this Technical Specification to meet durability and ASR-resistance requirements.

Table 7.2.5 – Cementitious blends (proportions)

| Blend | GP Cement | Fly Ash | Slag | Amorphous Silica |
|-----------|-----------|---------|-------|------------------|
| Binary 1 | ≥ 60% | ≥ 25% | | |
| Binary 2 | ≥ 30% | | ≥ 30% | |
| Ternary 1 | ≥ 40% | ≥ 25% | ≥ 20% | |
| Ternary 2 | ≥ 60% | ≥ 25% | | 4 – 8% |

7.3 Water

All water used in concrete production shall meet the requirements of AS 1379, being clean and free from amounts of suspended material, sugars, organic matter, alkali salts or other impurities which may adversely affect the properties of the concrete, or have harmful effects on the reinforcement, prestressing system or other fixtures embedded within the concrete.

Water sourced from other than a stable reticulated drinking water supply shall be tested in accordance with AS 1379. Frequency of testing shall be at least every three months. Such water shall only be used in concrete for exposure classifications B2 and below. If seasonal or process variations can be shown to be minimal over a 12 month period, testing may revert to six monthly with approval from the Administrator.

7.4 Chemical admixtures

Admixtures shall conform to the requirements of AS 1478 and shall be used in accordance with AS 1379. Admixtures shall be a registered product, supplied by a registered supplier.

Admixtures other than water reducing (WR, MWR, HWR), set retarding (Re), set accelerating (Ac), air-entraining (AEA), or a combination of the same (for example, WRRe) shall only be used for the following purposes or as approved by the Director (Structures Construction Materials):

- a) slump retention admixtures, for long distance / time concrete (see Clause 10.5.1), and
- b) rheology / viscosity modifying admixtures, for high workability and super-workable concrete, and for shotcrete.

Sugar, independent from an AS 1478.1 complying admixture, shall not be used as a set retarding agent.

Admixtures containing calcium chloride shall not be used.

The total alkali contribution (measured as Na₂O equivalent) of all admixtures used in a mix shall not exceed 0.2 kg/m³. Admixtures, at their maximum typical dosage (as noted on technical data sheets) shall not contain more than 50 g of sulphate ions (reported as SO₃) per kilogram of cementitious material nor more than 0.8 kg of chloride ions per cubic metre of concrete.

This chemistry is checked during registration, assuming a cementitious content of 450 kg/m³.

Admixtures in a single mix shall be sourced from the one supplier, unless approved on the basis of satisfactory mix trials and evidence of performance.

Where air entrainment is specified, or the Contractor wishes to use an air entraining agent, the air content of the concrete used shall have a maximum value of 6%, as measured by AS 1012.4.2, 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 place of discharge of the concrete from the concrete agitator or on site batch plant (precast applications) so that the air content of the freshly mixed concrete may be accurately determined. In addition, the Contractor shall submit proof that the air content can be sufficiently controlled, and that the compressive strength remains in compliance.

Admixtures added to concrete at the time of batching shall be accurately measured by means of a well maintained and calibrated dispenser, or in the case of powdered admixtures by full bags. Admixtures added at the time of delivery shall be accurately measured and the amount recorded.

7.5 Concrete aggregate

7.5.1 General

Aggregate shall conform to AS 2758.1 unless specified otherwise. Aggregates shall be supplied by a quarry registered and operated in accordance with the Transport and Main Roads Quarry Registration System (QRS). Aggregates sourced from the following shall not be used:

- a) sedimentary rocks (for example sandstone, siltstone, mudstone, arenite, limestone and chert)
- b) duricrust rocks (for example silcrete, ferricrete, and calcrete)

- c) carbonate rocks (for example limestone, dolostone, dolomite and their metamorphic equivalents)
- d) sulphide mineral-bearing rocks (for example pyrrhotite, pyrite, chalcopyrite)
- e) recycled concrete or industrial processes (e.g. synthetic and slag aggregates), and
- f) chemically precipitated materials and rocks (for example chert, agate).

Inclusions of up to 1% by mass of the above are permitted in the aggregate product.

The use of recycled concrete as aggregate is permitted under Clause 17 for normal-class concrete.

Each type and source of aggregate shall be tested separately.

All materials shall maintain conformity and have a homogeneous appearance for the duration of the work.

7.5.2 Fine aggregate

Fine aggregate shall consist of natural sand, or a combination of natural sand and crushed fine aggregate containing not less than 25% natural sand. Where satisfactory performance can be demonstrated in concrete mixes, for precast and precast prestressed concrete only, the percentage of natural sand may be wholly replaced with crushed fine aggregate.

Particles shall be clean, hard and durable and free from clay and other aggregations of fine material, soil, organic matter and other deleterious material.

The source rock for crushed fine aggregate shall comply with all the property requirements for hard rock coarse aggregates as per Table 7.5.4.

7.5.3 Coarse aggregate

Coarse aggregate shall be clean and durable, consisting of crushed natural gravel, crushed rock, or a combination thereof.

The maximum nominal aggregate size shall be specified in the Drawings but shall not be less than 10 mm. Approval shall be sought from the Designer prior to any reduction in aggregate size from that shown on the Drawings.

For prestressed precast concrete piles, deck units and girders the maximum nominal aggregate size shall be 20 mm with no reductions permitted.

Uncrushed natural gravels shall only be used where specified in concrete for architectural panels.

Drawings may be project-specific drawings or in-house proprietary precast designs.

A reduction in aggregate size may decrease the shear capacity of the concrete (refer to AS 5100.5 Clause 8.2.4.2) and increase creep and shrinkage.

7.5.4 Aggregate assessment – source rock

Source rock shall be tested in accordance with Table 7.5.4 and comply with the criteria listed in that table. Testing shall be conducted in accordance with MRTS50 *Specific Quality System Requirements*. Samples shall be taken from product stockpiles and tested without further processing (e.g. crushing in a laboratory to produce required size fractions for testing).

Submission of these test results is not required with mix designs.

Note that the monitoring of source rock properties is handled through the quarry registration process.

Note that it may be more economical to transport aggregates from a proven quarry source which does regular testing than to perform the suite of tests on a rarely used quarry source for small projects in remote areas.

Table 7.5.4 – Source rock testing applicability

| Source Rock Test Property | Test Method | Hard Rock Quarry | | Natural Deposit | | Acceptance Criteria |
|--|--------------------------|------------------|------|-----------------|------|-------------------------------|
| | | Coarse | Fine | Coarse | Fine | |
| Petrographic assessment ¹ | Q188 | X | X | X | X | Refer QRS |
| Wet Strength ² | AS 1141.22 | X | | X | | ≥ 150 kN |
| Wet / Dry Strength Variation ² | AS 1141.22 | X | | X | | ≤ 35% |
| Weak Particles | AS 1141.32 | X | | X | | ≤ 0.5% |
| Water absorption ³ | AS 1141.6.1 or AS 1141.5 | X | X | X | X | ≤ 2.5% |
| Degradation factor | Q208B | X | | X | | ≥ 50 |
| Particle density | AS 1141.6.1 AS 1141.5 | X | X | X | X | ≥ 2.1, < 3.2 t/m ³ |
| Chloride content | AS 1012.20.1 | X | X | X | X | Report (see Clause 9.8) |
| Sulphate content | AS 1012.20.1 | X | X | X | X | Report (see Clause 9.8) |
| Deleterious fines index | AS 1141.66 | | X | | | ≤ 150 |
| Percent abrasion (Micro-Deval) loss ⁴ | ASTM D7428 or Q229A | | X | | X | ≤ 15% |
| Soundness | AS 1141.24 | X | X | X | X | ≤ 6% |
| Organic impurities | AS 1141.34 | | | | X | Negative |
| Sugar content | AS 1141.35 | | | | X | Negative |
| Light Particles | AS 1141.31 | | | | X | ≤ 1% |

| Source Rock Test Property | Test Method | Hard Rock Quarry | | Natural Deposit | | Acceptance Criteria |
|---------------------------------------|-------------|------------------|------|-----------------|------|---------------------|
| | | Coarse | Fine | Coarse | Fine | |
| Material finer than 75 μm | AS 1141.12 | | | | X | $\leq 5\%$ |
| Material finer than 2 μm^5 | AS 1141.13 | X | | X | X | $\leq 1\%$ |

1. Where coarse and fine aggregate are produced from the same hard rock quarry source a petrographic report is required for each material.
2. The wet strength and the wet / dry strength variation tests shall be carried out on the fraction from AS 13.2 mm to AS 9.5 mm. Samples shall not be further crushed to generate this fraction. If the source rock does not comply with the maximum wet / dry strength variation limits, it may be deemed to comply if its wet strength is 160 kN or greater.
3. For aggregates with water absorption greater than the specified limit, project-specific approval may be granted by the Administrator provided that, in the opinion of the Administrator, the Contractor provides written documentation of a history of satisfactory performance of the aggregate in similar application.
4. When intended for use in concrete wearing surfaces directly trafficked by vehicles not including footpaths or cycleways.
5. Materials such as ultra-fine quartz are excluded from this requirement.

7.5.4.1 Alkali-reactivity (carbonates)

Where petrographic analysis, or testing to ASTM C586, identifies aggregates containing, or suspected of containing, reactive carbonate materials, these aggregates shall be tested for alkali-carbonate reactivity. If the aggregate exhibits expansion of greater than 0.015% over three months, the test shall be extended to six months. If at this time the total expansion is greater than 0.025% then the aggregate shall not be used.

AS 1012.13 is deemed to contain the same sample preparation and measuring regime as ASTM C157 (referenced in C1105). For the purposes of ASTM C1105, 'moist' is defined as $95 \pm 5\%$ relative humidity.

7.5.5 Aggregate assessment – products

Individual aggregate products shall be tested in accordance with Table 7.5.5 and comply with the criteria in that table. Test results, not more than three months old, shall be submitted with the mix design. Refer Clause 9.2.

Wet strength and wet / dry strength variation shall be tested on representative 20 mm products, without further crushing. That is:

- a) For a Sxx/20 mix, with all coarse aggregates from the same quarry, only the 20 mm stockpile needs to be sampled and tested.
- b) For a Sxx/10 mix, the 20 mm stockpile from the quarry supplying the 10 mm is sampled and tested.
- c) For a Sxx/20 mix, with coarse aggregate from multiple quarries, the 20 mm stockpile from each quarry is sampled and tested.

Table 7.5.5 – Product testing applicability

| Property | Test Method | Hard Rock Quarry | | Natural Deposit | | Acceptance Criteria |
|---|--------------|------------------|------|---------------------|------|--------------------------------------|
| | | Coarse | Fine | Coarse | Fine | |
| Flakiness index | AS 1141.15 | X | | X (Crushed only) | | ≤ 30% |
| Wet strength ² | AS 1141.22 | X | | X | | ≥ 150 kN |
| Wet/Dry strength variation ² | AS 1141.22 | X | | X | | ≤ 35% |
| Weak particles | AS 1141.32 | X | | X | | ≤ 0.5% |
| Degradation factor | Q208B | X | | X | | ≥ 50 |
| Particle size distribution (grading) | AS 1141.11.1 | X | X | X | X | As per supply agreement ¹ |
| Deleterious fines index | AS 1141.66 | | X | | | ≤ 150 |
| Material Finer than 75 µm | AS 1141.12 | X | | | | ≤ 2% |
| | | | X | | | ≤ 20% |
| | | | | | X | ≤ 5% |

1. Where no specific supply agreement is in place, Tables B1 and B2 of AS 2758.1 shall apply.
2. The wet strength and the wet / dry strength variation tests shall be carried out on the fraction from AS 13.2 mm to AS 9.5 mm. Samples shall not be further crushed to generate this fraction.

The testing of individual samples shall be carried out in accordance with the Quarry Registration System. The frequency of testing and reporting can be agreed between the quarry and the concrete supplier, but shall be not less frequent than every three months, during supply to Transport and Main Roads projects. These records are to be available for viewing during audits of the concrete batch plant.

Frequency of testing for source rock properties is in accordance with the QRS, or other clauses in this Technical Specification, not the requirements of this clause.

Note: Some tests are both source rock tests and product tests. All tests listed as product tests need to be submitted with mix designs.

7.5.6 Aggregate conformance

For all aggregates, the conformance with this Technical Specification shall be verified by sampling and testing in accordance with MRTS50 *Specific Quality System Requirements*.

Non-conforming aggregate shall not be used in concrete manufactured to this Technical Specification.

7.6 Curing compounds

Curing compounds shall be registered products and comply with the requirements of AS 3799. For registration, the supplier shall provide a certificate of compliance and NATA-endorsed test certificate showing compliance to the Australian Standard.

Type 3 (black) compounds as per AS 3799 are not to be used.

Class C (chlorinated rubber-based compounds) as per AS 3799 are not to be used.

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

8 Storage of materials

Materials shall be stored in such a way as to prevent damage, segregation, and degradation.

8.1 Cementitious materials

Bulk cementitious materials shall only be stored in watertight silos.

Bagged cementitious materials shall be stored above ground and 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.

Cementitious materials 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 bare earth. Aggregates shall be stored in such a manner to avoid segregation, becoming contaminated by foreign matter, or becoming intermixed. Stockpiles shall be arranged to prevent entry of adjacent surface or ground water and allow free drainage of rain water.

9 Concrete mix – design and acceptance

9.1 General

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

The Contractor shall ensure that the mix design is suitable for the particular application.

9.2 Proposed mix design

The Contractor shall nominate the special-class concrete mix to be used in the Works not less than four weeks prior to the commencement of concreting operations. **Milestone**

The four weeks lead time allows for the mix to be revised if required, and mix trials conducted, if required.

A full mix design submission shall be made to the department for assessment prior to, or concurrent with, nomination of the mix to be used in the Works. Where this submission is made to Structures Construction Materials for assessment (see Clauses 15.1 and 16.1) only the assessment certificate shall be submitted to the Administrator. Otherwise, all details shall be submitted to the Administrator.

The submission shall include the following information:

- a) Mix code and version.
- b) Intended application: insitu, precast, sprayed, extruded, piling (dry), or piling (wet).
- c) Strength grade of concrete.
- d) Target strength.
- e) Nominated slump or spread.
- f) Name of the concrete supplier.
- g) Location of batch plant.
- h) Types, proportion by mass, sources, and registration numbers (ATIC and QRS) of the various constituent materials:
 - i. if admixture dosages are nominated as a range, it shall not exceed the variance permitted in Clause 9.11
 - ii. aggregates to be listed as SSD masses.
- i) Target air-entrapment, if applicable.
- j) Test results as applicable:
 - i. air content, and corresponding AEA dose (when AEA in use) (refer Clause 7.4)
 - ii. aggregate product test properties (refer Clause 7.5.5)
 - iii. mean 28 day strength with standard deviation (refer Clause 9.3)
 - iv. water retention (cast-in-place pile mixes only) (refer Clause 9.6)
 - v. chloride content of hardened concrete (refer Clause 9.8), and
 - vi. RCPT Value (super-workable concrete only) (refer Clause 9.9).

Further information, for example material test certificates, may be required on a project basis.

Consideration should be given to the potential strength of the concrete mix if likely to exceed $1.4 \times f'_c$ (see Clause 12.5).

9.3 Target strength

The minimum target strength shall be calculated from the equation:

$$f'_t = f'_c + 1.65s$$

Where the terms of the equation are as defined in Table 2(b). The value of the standard deviation shall be calculated from the most recent 15 consecutive test results for that strength grade of concrete (not necessarily the nominated mix). If the calculated value of the standard deviation is:

- a) less than $0.08 f'_c$, then $s = 0.08 f'_c$
- b) greater than $0.20 f'_c$, then $s = 0.20 f'_c$
- c) between, or equal to, $0.08 f'_c$ and $0.20 f'_c$, then $s =$ calculated value

Where 15 test results are not available the standard deviation shall be taken as no less than $0.12 f_c$.

For example:

Let $f_c = 40$ MPa

Standard deviation (15 results) = 2.4 (= $0.06 f_c$)

Since $0.06 < 0.08$, $s = 0.08 f_c$

$f_t = f_c + 1.65 (0.08 f_c) = 45.3$ MPa

9.4 Nominated slump and spread

The nominated slump or spread selected shall be consistent with the production of a workable mix for each section of the Works concerned. The slump or spread nominated by the Contractor for each grade of concrete used in the Works shall be a discrete value which falls within those given in Tables 9.4(a) or 9.4(b) as appropriate.

Table 9.4(a) – Permissible nominated application and slump

| Application | Minimum Nominated Slump (mm) | Maximum Nominated Slump (mm) |
|---------------------------|-------------------------------|------------------------------|
| Insitu | 80 | 150 |
| Precast | 80 | 180 |
| Cast-in-place piles (Dry) | 180 | 180 |
| Cast-in-place piles (Wet) | 180 | 200 |
| Sprayed | As per equipment requirements | |
| Extruded | As per equipment requirements | |

Table 9.4(b) – Permissible nominated application and spread

| Mix Type | Minimum Nominated Spread (mm) | Maximum Nominated Spread (mm) |
|---|-------------------------------|-------------------------------|
| Highly workable concrete for cast-in-place piles ¹ | 500 | 600 |
| Super-workable concrete ² | 650 | 700 |

1. Refer Clause 9.10 for additional requirements for high workability concrete.

2. Refer Clause 9.9 for additional requirements for super-workable concrete.

Note that variations from the nominated value upon delivery are discussed in Clause 11.

High workability concrete is the preferred solution for wet cast-in-place piles.

9.5 Constituent materials

9.5.1 Cementitious content and maximum water-cement ratio

The minimum cementitious content and maximum water / cementitious ratio shall be as shown in Table 9.5.1(a) for the exposure classification shown on the Drawings.

Table 9.5.1(a) – Minimum cementitious content and maximum water cement ratio by exposure classification

| Exposure Classification | Minimum Cementitious Content (kg/m ³) | Maximum Water/Cementitious Ratio |
|-------------------------|---|----------------------------------|
| B1 | 330 | 0.50 |
| B2 | 400 | 0.45 |
| C1 | 450 | 0.40 |
| C2 | 470 | 0.36 |

The minimum cementitious content and maximum water/cementitious material ratio shall be as shown in Table 9.5.1(b) for the strength grade of the mix.

Table 9.5.1(b) – Minimum cementitious content and maximum water / cementitious material ratio by strength grade

| Strength Grade (MPa) | Minimum Cementitious Content (kg/m ³) | Maximum Water/Cementitious Ratio |
|----------------------|---|----------------------------------|
| 32 | 330 | 0.50 |
| 40 | 400 | 0.45 |
| 50 | 450 | 0.40 |
| > 50 | 470 | 0.36 |

Minimum cementitious contents and maximum w/c ratios for each strength grade are presented to validate underlying assumptions in the cover-to-reinforcement tables of AS 3600 and AS 5100.

Where the combined liquid admixture dosage is less than 2 L/m³, the contribution of the admixture to the total water content can be ignored for the purpose of calculating the w/c ratio.

9.5.2 Combined aggregate grading

The combined aggregate grading shall be such that the concrete mix has the required workability, resistance to segregation, and resistance to bleed.

With respect to bleed, some bleed is desirable to aid finishing in flat slabs. However in other applications particularly cast-in-place piles, bleed is detrimental. The CIA Publication 'Recommended Practice – Tremie Concrete for Deep Foundations' contains guidance on aggregate proportions and test methods to manage bleed in cast-in-place piles. See also Clause 9.6.

With reference to coarse aggregate products, a concrete mix shall only be designated as Sx/20 when the 20 mm aggregate product weighs more than the 10 mm aggregate product.

For example, an S50/20 mix will contain more '20 mm graded aggregate' than '10 mm graded aggregate'. This is to protect the Designer's assumptions particularly in relation to shear strength when specifying an aggregate size.

9.6 Water retention testing

Cast-in-place pile mixes shall be such that, when tested the filtration loss and filter cake thickness is in accordance with Table 9.6.

Test results submitted with mix design shall be less than 12 months old.

Table 9.6 – Filtration loss and filter cake thickness

| Property | All piles |
|---|-----------|
| Filtration loss (l/m ³) – maximum | 15 |
| Filter cake thickness (mm) – maximum | 100 |

This test can be performed once per year per mix design, it does not need to be repeated for every project. Changes to the mix which are outside the tolerances in Table 9.11 would require a retest.

9.7 Specific exposure classification requirements

9.7.1 Exposure classification B2 or less

Cementitious material is to be a blend compliant with any of the following options with the combined total adding to 100%. Blend tolerances to be as per AS 1379:

- a) 65 to 75% GP cement, 25 to 35% fly ash
- b) 40 to 55% GP cement, 20 to 35% ground granulated blast furnace slag, and 25 to 30% fly ash
- c) 65 to 71% GP cement, 4 to 8% amorphous silica, and 25 to 31% fly ash, or
- d) 30 to 40% GP cement, 60 to 70% ground granulated blast furnace slag.

Maximum chloride ion content of hardened concrete shall be 0.80 kg/m³ for reinforced concrete, 0.6 kg/m³ for prestressed concrete.

For batch plants in precast yards, where precise control can be demonstrated, the target proportion of fly ash may be decreased provided individual batches of concrete contain at least 20% fly ash by weight of cementitious material.

9.7.2 Exposure classification C mixes

Concrete for exposure classifications C, C1 and C2 shall meet the following requirements.

Cementitious material to be a blend compliant with any of the following options:

- a) 40 to 55% GP cement, 20 to 35% ground granulated blast furnace slag, and 25 to 30% fly ash
- b) 65 to 71% GP cement, 4 to 8% amorphous silica, and 25 to 31% fly ash, or

- c) 30 to 40% GP cement, 60 to 70% ground granulated blast furnace slag.

Maximum chloride content of concrete is to be 0.4 kg/m³.

There is a strong evidence to demonstrate that concrete mixes containing a ternary blend of cementitious materials and concrete mixes with high ground granulated blast furnace slag content provide significantly enhanced durability. This is particularly critical in aggressive environments. Use of supplementary cementitious materials such as fly ash and ground granulated blast furnace slag, also significantly decreases the environmental impacts associated with cement production and also controls Alkali-Silica Reaction (ASR).

The use of corrosion inhibitors and other alternatives to ternary blends may be considered through the department's innovation procedure. This procedure is initiated outside of existing contracts.

9.8 Chloride content testing

Chloride ion content of hardened concrete shall be determined by testing in accordance with AS 1012.20.1, on either hardened concrete or on individual components of the mix and summed by calculation in accordance with the following.

9.8.1 Testing of hardened concrete

Sampling to be in accordance with AS 1012.8.1 with a minimum sample size of 1.2 kg. Testing shall be in accordance with AS 1012.20.1 with the following conditions:

- a) 2 portions (subsamples) to be tested:
 - i. if either is non-conforming, a further three portions shall be tested.
- b) The test report shall include:
 - i. details as required by AS 1012.20.1
 - ii. individual chloride contents (by mass) from each sample
 - iii. average chloride content (by mass)
 - iv. standard deviation of chloride content (by mass), and
 - v. average chloride content (kg/m³).

The average mass of acid soluble chloride ion per unit volume of hardened concrete as placed must not exceed the values given in Clause 9.7.1 or 9.7.2 of this Technical Specification as appropriate.

Tests are to be undertaken by a NATA-accredited laboratory and results submitted with the mix design.

9.8.2 Individual components and calculation

Testing of individual components to be in accordance with AS 1012.20.1 for aggregates, and AS 2350.2 for cementitious materials.

Total chloride content of concrete to be calculated by summing the individual chloride contents of the mix components (cementitious material, aggregates, water and admixtures) as per the quantities in the mix design.

For fine aggregates sourced from salt-water environments, chloride content reports shall be included in the mix design submission and be less than three months old. Other individual reports of component chloride content shall be made available on request.

9.9 Super-workable concrete

Super-workable concrete may only be used for precast reinforced concrete, precast prestressed concrete, and special applications.

Super-workable concrete shall exhibit the following properties:

- a) Nominal spread of 650 – 700 mm (see Clause 9.4)
- b) Time to 500 mm spread (T_{500}) of ≤ 5 s
- c) Visual Stability Index of 0 or 1, and
- d) Rapid Chloride Penetration Test (ASTM C1202) value of less than 1000 Coulombs at 56 days.

Note: T_{500} is specified to whole seconds but measured to 0.1 s. Therefore a reading of 5.4 s is compliant.

Visual Stability Index is defined by Q478.

RCPT conducted at any time between 28 and 56 days will provide an upper limit for the value at 56 days. RCPT indicates whether SWC performance is equivalent to conventional slump concrete with rigid forms and intense vibration.

Super-workable concrete is a high risk product in that variations in the mix design normally considered as being insignificant may in a SWC result in the concrete not complying with the specification.

9.10 High workability concrete

High workability concrete shall only be used for cast-in-place pile concrete, and other specialised applications as approved by the Administrator, and shall meet the following requirements:

- a) Nominal spread of 500 – 600 mm (see Clause 9.4), and
- b) Visual Stability Index of 0 or 1.

9.11 Mix design acceptance

No concrete shall be placed in the Works until approval of the mix design has been obtained from the Administrator (**Refer to Hold Point 1 and Hold Point 8**).

Approved concrete mixes shall not be varied beyond the permitted limits in Table 9.11 without the approval of the Administrator. The approved mix shall be used until approval is given for a varied mix. Any change in material sources or types constitutes a variation.

Table 9.11 – Permissible variations in mix design proportions

| Component | Maximum Variation |
|--------------------|---------------------------|
| Total cementitious | 0, + 40 kg/m ³ |
| Each aggregate | ± 5% |

| Component | Maximum Variation |
|--|--|
| Water | ± 5% |
| Admixtures (excluding types Ac, AEA and Re) ¹ | ± 30% or ± 100 mL/100 kg of cementitious material (whichever is greater) |

Note 1. Permitted variation of admixture dose applies to a discrete target value, or the mean value of a range.

Notwithstanding variations, mixes must comply with stated requirements at all times, including w/c ratio.

Permitted admixture variances cannot be applied on top of a range. That is, if the approved dose is '400 – 600', no variance beyond that range is permitted without re-approval.

Note that these variations relate to the nominal design mix only. Batching tolerances are unrelated.

No variance limit applies to Ac, AEA or Re, but a range should be nominated.

10 Batching, mixing and transport

10.1 General

The requirements of this section apply whether the concrete is batched and mixed on site or delivered as pre-mixed concrete. The Contractor is responsible for ensuring that these requirements are met by any concrete supplier.

The production and delivery of concrete shall be in accordance with the requirements of AS 1379 except as otherwise specified by this Technical Specification.

The procedure for batching concrete on Site shall be submitted at least 6 weeks prior to the first concrete pour. **Milestone**

10.2 Batching

Aggregates and all cementitious material shall be batched by mass, unless batched and delivered in accordance with Clause 10.4. 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. If bagged cementitious material is used then fractions of bags are not to be used. The mass of individual aggregates shall be adjusted to account for free surface moisture. This moisture content of fine aggregates shall be determined daily.

Scales for weighing aggregates and all other materials shall be calibrated at least every six months. Calibration reports shall comply with AS ISO/IEC 17025 and include the working range of the scales / hopper (in addition to the capacity of the load cell). Calibration of scales shall extend to the full working range.

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 1.0 litre increments. Measuring devices for admixtures shall be calibrated with the increments not exceeding 5% of the total volume of the admixture to be measured or 20 mL whichever is the greatest.

Tolerances on specified batch components shall comply with the requirements of AS 1379 Table 4.1.

Where concrete mixes are nonconforming or there are concerns or issues with the concrete performance, batch records are to be made available for viewing at an audit. Batch records shall clearly and accurately show target and actual quantities, free water, and calculated w/c ratio.

Batch records should not make any assumptions about water additions at the slump stand. They are a factual record of what was batched.

The addition of dry components to an already mixed batch shall only be permitted under the following circumstances:

- a) concrete is a standard slump mix (that is not HWC nor SWC)
- b) concrete has not left the batch plant
- c) no concrete from the batch has been discharged
- d) materials are added at the same proportions as the mix designs, and
- e) accurate records are kept of all operations.

10.3 Mixing

Concrete shall be mixed in a mixer of an appropriate type having a capacity suitable for the type of work being undertaken. The mixer drum or mixing paddles shall rotate at the speed recommended by the manufacturer. The volume of mixed concrete in the batch shall not exceed the rated capacity of the mixer.

Sufficient documentation shall be made available on request to demonstrate compliance with AS 1379 uniformity requirements, including:

- a) Uniformity test (AS 1379 Appendix A) report on the prototype mixer design.
- b) Mixer Identification Plate which meets the requirements of AS 1379 Clauses 3.5.1(e) and 3.5.2.5.
- c) Traceability between mixer and prototype design.
- d) Inspection reports at no greater than six monthly intervals, showing no indications of defects, and complying with the requirements of AS 1379 Clause 3.5.1 (a) (iii) (A to D).
- e) Maintenance log with either:
 - i. no major repairs, or
 - ii. repairs and traceability to a subsequent uniformity test.

Mixers without sufficient documentation shall not be used until uniformity has been confirmed in accordance with AS 1379 Appendix A. Copies of the latest inspection report shall be kept with the mixer, include reference to the mixer serial number, and be available for sighting at the place of concrete delivery.

Mixing shall continue until the materials are thoroughly blended and there are no balls of mixed or unmixed material. The minimum mixing time after all materials have entered the mixer shall be in accordance with the manufacturer's instructions for the mixer.

The entire batch of concrete shall be discharged from the mixer before any further charging of the mixer takes place, unless continuous mixing in accordance with Clause 10.4 is used.

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.

This clause applies to whenever and wherever concrete is mixed.

10.4 Volumetric batching and mixing

The Contractor may elect to use mobile, continuous, volumetric mixers on site, subject to approval by the Administrator (**refer Hold Point 4**), in applications where small volumes of concrete are required, and conventional premix concrete is not available nor economic. The on-site batching procedure (see Clause 10) shall include details of the equipment proposed, the mix design, and transport and batching processes.

Volumetric mixer trucks shall:

- a) electronically record and store batch settings and material ratios
- b) have the ability to consistently mix concrete in a continuous flow, and
- c) be calibrated every three months.

The requirements of Clauses 10.2 and 10.3 are also applicable.

Testing, acceptance and rejection of concrete shall be in accordance with this specification with a maximum nominal 'batch' size of 5 m³.

Mobile volumetric mixes are often used in conjunction with fast setting concrete. These concretes are considered proprietary cementitious material systems, see Clause 7.2, and require approval from the Director (Structures Construction Materials).

10.5 Transport and delivery

The timing of deliveries shall be such as to ensure an essentially continuous placing operation. If concreting operations, for a single element, exceed 12 m³ per day, the Contractor shall maintain the availability of a standby agitator truck or supply.

For example, an additional truck over and above that required for completion of the works is required to be held in reserve.

Concrete shall be placed and compacted within the times in Table 10.4 from the charging of the mixer.

Table 10.5 – Placement and transport time limits

| Temperature of Concrete | Time Limit |
|-------------------------|-------------|
| ≤ 32°C | 75 minutes |
| 32 – 35°C | 60 minutes |
| > 35°C | Reject load |

These times may be extended at the Administrator's discretion where set-retarding admixtures are used and a trial mix has been conducted (refer to Clause 10.4.1).

Water shall not be added to offset long travel or wait times under any circumstances, other than in accordance with Clause 11.2.

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, and how much water is available for addition on site noting the restrictions in Clause 11.2. Total water includes free water in the aggregates, mix water, slump stand water and any ice added.

The amount of water available for addition on site is the free water listed on the mix design minus the actual water included.

10.5.1 Long distance travel and extended placement times

Where travel or placement times are, by necessity, longer than those listed in Table 10.5 a procedure for long-distance travel or extended placement times shall be submitted to the Administrator for approval six weeks before concreting begins. **Milestone**

Where approval for extended working times has been granted, the temperature of the concrete at the time of placement shall not exceed 35°C.

Note that construction procedures for insitu concrete are assessed as part of Hold Point 4. Technical Note 125 provides further guidance on procedures for long distance travel and extended placement times.

This procedure shall include one or more of the following options:

- a) for up to 90 minutes, the use of a set retarding admixture, added at the batch plant
- b) for up to 120 minutes, the use of a set retarding admixture at batch plant and high range water reducing admixture at site, and
- c) for over 90 minutes, the use of a high range water reducing admixture and hydration stabiliser at batch plant and an activating admixture at site.

The conformance of a trial mix for extended placement times shall be in accordance with Clause 15.1.2 or 16.1.2 as appropriate.

Note that additional safety considerations are applicable when adding admixtures to agitators on site.

Transporting dry cementitious material and aggregates together to site and then adding water is not permitted. As per Clause 11.2, water may not be added to increase workability if 45 minutes has elapsed from time of charging the mixer.

Note that for cast-in-place piling mixes there may be a requirement to extend the placement or working time of the concrete for an extended time that includes the time to place the concrete in the pile (dry piles), or until the completed pile is poured (wet piles).

In these cases, care must be taken to ensure that the target working times are not overly conservative, and in some cases the working time of the concrete supplied may need to reduce as the pile is poured. Overly conservative working times may lead to the concrete sitting in the pile in the plastic state for an extended time which increases the risk of bleed of the concrete in the pile and increases the risk of defects in the pile concrete which may lead to rejection of the pile.

11 Acceptance and rejection of plastic concrete

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.

11.1 Rejection of plastic concrete

Before any concrete is placed in the Works it shall be visually checked and shall be rejected if it is defective in any of the following ways: **Nonconformance**

- a) the slump is outside the limits specified in Table 11.3(a), noting Clauses 11.3.1 and 11.3.2, or
- b) the spread, VSI, or T_{500} is outside the limits specified in Table 11.3(b), noting Clause 11.3.1 and 11.3.2, or
- c) the air content differs from the specified or target value by more than 1.5%, or
- d) the appearance, colour or cohesiveness of the batch is significantly different from other batches of the same mix, or
- e) the concrete contains significant lumps of unmixed material that are unresponsive to further mixing.

If a load is to be rejected due to differences between batches, a visual record should be kept. A significant difference will be one that is immediately obvious to all present on site at the time of delivery.

Super-workable concrete shall be observed during testing to ensure concrete likely to segregate is not incorporated into the precast element.

Super-workable concrete with a spread approaching 750 mm may pass the spread test but still segregate. If coarse aggregate does not float at or near the surface of the tested or finished concrete, regardless of the spread test result, then the concrete may not be suitable and should not be used.

11.2 Air-entrainment

Where air-entrainment has been specified or the Contractor has elected to include an air-entraining admixture in the concrete mix, the air content shall be measured prior to the first pour, whenever the admixture dosage is adjusted by more than 10% or 100 mL/m³ and whenever concerns are raised about the concrete performance.

'First pour' is the first pour of that mix on that project.

11.3 Consistency

The consistency of concrete of each batch shall be checked by means of the slump or spread test. Sampling shall be carried out in accordance with AS 1012.1 and testing by AS 1012.3.1 or AS 1012.3.5. Sampling and testing shall be conducted by a NATA-accredited laboratory and reported as a NATA-endorsed test report. The base plate used during testing shall be of sufficient width to allow the concrete to slump and flow unhindered.

The plastic material properties shall lie within the range established using the approved nominated value and the tolerances specified in Table 11.3(a) and Table 11.3(b).

Where the first test falls outside tolerance, an immediate single repeat test for slump or spread, as per AS 1379 shall be permitted with the results of both tests recorded and reported.

Table 11.3(a) – Tolerances for consistency test (slump)

| Nominated Slump (mm) | Tolerance (mm) |
|----------------------|----------------|
| < 60 | ± 10 |
| ≥ 60, ≤ 80 | ± 15 |
| > 80, ≤ 110 | ± 20 |
| > 110, ≤ 150 | ± 30 |
| > 150, ≤ 200 | ± 40 |

Table 11.3(b) – Tolerances for consistency test (spread)

| Nominated Spread (mm) | Tolerance (mm) | Visual Stability Index | T ₅₀₀ (s) | T _{final} (s) |
|-----------------------|----------------|------------------------|----------------------|------------------------|
| 500 – 600 (HWC) | ± 80 | 0 or 1 | – | Report only |
| 650 – 700 (SWC) | ± 50 | 0 or 1 | ≤ 5 | – |

Note: T_{final} is the time from raising the cone to when the concrete stops flowing. The mechanics of timing are as per the T₅₀₀ measurement of AS 1012.3.5.

Note that tolerances do not guarantee similar performance, and changes to procedures may be required to cater for reduced workability. For example, concrete slumping at lower values may require additional compaction compared to slump at the specified target value. In some applications tighter tolerances may be required than those specified above.

11.3.1 Slump or spread below tolerance

If the slump or spread is below the tolerance range, or workability needs to be increased within the tolerance range, it is permitted to add water or admixture to the mix to bring the slump or spread within specification, provided:

- a) the maximum water available to be added has been listed on the concrete delivery docket or batch record
- b) the amount of water added does not exceed 10 litres per m³
- c) the added water is recorded on the delivery docket
- d) the design water / cementitious ratio is not exceeded
- e) any admixture is within the range of the approved mix design
- f) the load is remixed in accordance with AS 1379
- g) only a single sample has been taken previously, and
- h) for water addition, the elapsed time from the time of charging the mixer has not exceeded 45 minutes.

All slump and spread test results shall be reported.

Calculation of water / cement ratio of remaining concrete is impossible without an accurate measurement of amount of discharged concrete. For this reason only a single addition of water and a second slump sample is allowed.

If the addition of 10 L/m³ of water on site is not effective then this would indicate that batching control should be checked or the mix redesigned.

11.3.2 Slump, or spread, above tolerance

If the slump or spread initially tests above the tolerance range, the concrete may be accepted provided:

- a) a retest falls within the tolerated range
- b) the placement time limits are not exceeded (refer to Clause 10.4)
- c) a new sample is taken prior to each test
- d) the concrete is remixed between samples in accordance with AS 1379, and
- e) the results of all tests are reported.

The addition of more dry concrete mix components to decrease slump or spread is not permitted after any concrete has been discharged (see Clause 10.2).

Note that there is no limit on the number of retests allowed for over slumping concrete, but time limits may come into play (see Clause 10.4).

11.3.3 Reduced rates of testing

Where approval for reduced rates of testing for compressive strength has been granted (see Clauses 15.2 and 16.2), the rate of testing for slump may be reduced to the same frequency, with approval of the Administrator. For super-workable or high workability mixes, spread testing shall be undertaken on each load or batch.

For super-workable concrete, batched at precast yards only, where appropriate batching control is used and approval for reduced levels of testing have been granted, testing frequencies may be reduced to one test per 5 m³ plus each of the first three batches of the day of that mix.

If any slump or spread test falls outside tolerance, then each subsequent batch shall be tested. Reduced rates of testing shall be restored once three consecutive batches have been tested and are conforming.

12 Acceptance and rejection of hardened concrete

General requirements for testing and acceptance of concrete are listed in the following clauses. More specific requirements are listed in Clauses 15 and 16.

Testing of slip formed median barrier shall be in accordance with AS 1379 Project Assessment.

12.1 General

All concrete used in the Works shall be subject to sampling and testing in accordance with the provisions of AS 1012, along with the additional requirements detailed in this Technical Specification.

12.2 Sampling

A sample for compression testing shall be cast as cylinders in purpose-made moulds according to AS 1012.8, and identified as a set. This set is to be linked to the batch and location it represents.

All specimens shall be manufactured and tested by a NATA-accredited laboratory.

12.3 Acceptance testing of specimen cylinders

Acceptance of hardened concrete is to be based on the results of compression testing, performed in accordance with AS 1012.9. This testing, including early strength testing, shall only be performed at a NATA-accredited laboratory and departmental registered supplier, and shall be reported to the Administrator as a NATA-endorsed report. Test reports shall be traceable to concrete delivery dockets and the construction lot. All equipment used in testing shall be calibrated as per NATA requirements.

The corresponding sample strengths, when two or more cylinders are crushed at the same age, shall also be submitted to the Administrator.

Therefore, the Administrator shall receive:

- a) individual cylinder (specimen) results on a NATA-endorsed test report, and
- b) calculated strength (sample) results.

Note that the reporting of strength (sample) results is beyond the scope of AS 1012.9 and therefore is the Contractor's responsibility.

A minimum of two cylinders from each sample shall be tested at 28 days. For any early age testing (less than 28 days), including transfer strength testing for prestressed precast concrete, a minimum of one cylinder per sample shall be tested and all sample results shall exceed the early age strength requirements. For early age strength testing (less than 60 hours) the time of the test shall be reported, as well as the age of the test sample.

In addition to the recording requirements of AS 1012.9, it is strongly recommended that the mass and density of cylinders be recorded for investigative purposes should cylinders not produce expected results.

The testing of cylinder pairs (or sets) should not be interrupted due to a lower-than-expected result on the first cylinder, unless there is a clear testing / equipment error. Postponing the testing of remaining cylinders is a breach of the above clause. It is good practice to retain the crushed cylinders for further examination in these cases.

The test strength of a sample (of more than one cylinder) at a certain age shall be calculated as follows:

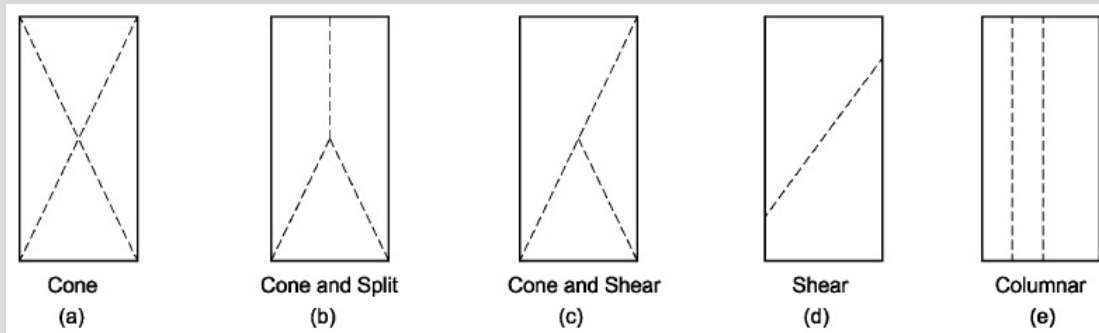
- a) list the results of all cylinders in the sample tested at that age in descending order
- b) exclude any result that can be attributed to an obvious defect in the cylinder or testing activity
- c) exclude the lowest result if it differs by more than 2 MPa (for two cylinders) or 3 MPa (for three or more cylinders) from the highest result, and
- d) average the results of the remaining cylinders.

In the case when the cylinder results differ by more than 10% of the highest value, this shall be reported to the Administrator along with the cylinder history and condition, including the fracture pattern.

For comparison this is a modified version of the process in AS 1379 Clause 6.2.5.2.

Note that no extra cylinders are required to replace the excluded values, but all cylinder results need to be reported.

As an example, ASTM C39 categorises fracture patterns according to the following illustration.



Source: ASTM C39

Cylinder history and condition would include a timeline of handling and curing, along with any notes about capping, defects and how the cylinder cracked. This information is not for the purposes of accepting the result (the higher of the results stand), but for investigating why there was a difference in the pair and how that can be prevented.

With Designer and Administrator approval, testing at ages greater than 28 days may be used for acceptance testing. Approval must be sought prior to concrete being placed.

This would usually only be suitable for mixes with high ash or slag content when either:

- further construction or loading is not required until later-age testing is completed, or
- concrete grade is selected for durability and not strength.

12.4 Monitoring of concrete strength

The compressive strength of the concrete (insitu and precast) shall be monitored, and trends observed. Where a significant amount (more than 700 m³) of concrete is to be placed in a four week period, monitoring shall include seven day testing and a comparison of cylinder strengths with previously measured strength gain results.

For each insitu concrete mix, where 10 or more samples have been taken across the project, the Contractor shall provide a monthly report covering the concrete supplied in that month confirming the concrete lies within the limits of Table 12.4.

Table 12.4 – Long-term monitoring of concrete (insitu only)

| Measure | Limit |
|-------------------------|--|
| Standard deviation | ≤ 1.29 x nominated standard deviation |
| Average 28 day strength | ≥ 0.5 (f _c + f _t) |

Where the concrete performance lies outside these limits, the Contractor shall provide the raw data and a trend graph showing seven day (if available) and 28 day strengths. If the Administrator determines that control of concrete performance is not being maintained, approval of the mix design shall be withdrawn.

Note that an increase in the standard deviation by a factor of 1.29 reduces the confidence of exceeding the characteristic strength from 95 to 90%.

The nominated standard deviation is that used to calculate the target strength in Clause 9.3.

12.5 Acceptance or rejection of hardened concrete on the basis of strength

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

An example format for tracking these statistics is provided as Appendix A.

Concrete in a lot shall be deemed rejected if any of the following apply:

- a) Any sample strength is less than 0.9 times the specified characteristic strength, f_c .
- b) The average strength of three consecutive samples of the mix (regardless of lot) is less than the specified characteristic strength.
- c) The average 28 day strength of three consecutive samples from the lot is greater than 1.4 times f_c , without prior Administrator and Designer approval. The following applications are exempt from this requirement:
 - i. precast concrete
 - ii. extruded concrete
 - iii. cast-in-place piling
 - iv. shotcrete.

The aim of criterion (c) is to ensure that if higher strengths than expected are being achieved or are likely, the Designer has confirmed that there are no adverse effects from the use of a higher strength concrete than that assumed in the design. This should be confirmed before concrete is placed.

It would be unusual for this criterion to be used to reject concrete, as Designer approval is generally given.

13 Environmental limits for concreting operations

13.1 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, or
- b) based on temperature recording at the Site for three 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 two hours subsequent to placement, or
- c) the temperature of the formwork or reinforcement exceeds 55°C.

If the ambient air temperature measured at the point of placement is likely to exceed 35°C, noting an absolute maximum of 45°C, during placing and finishing operations, the Contractor shall take practical precautions, approved by the Administrator, to ensure that the temperature of the concrete does not exceed the permitted maximum. These precautions shall be submitted as a procedure for hot weather concreting at least two weeks prior to the first concrete pour. **Milestone**

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

Additional temperature control of the concrete, prior to placement, to achieve the limits specified in Clauses 15.5, 16.4, and 16.7.4 may be required.

13.2 Evaporation limits

13.2.1 General

When the predicted evaporation rate during the intended period of placement and finishing exceeds 0.75 kg/m²/h, measures shall be taken to reduce the predicted evaporation to below this value.

The forecast evaporation rate shall be estimated by the specified method (refer to Clause 13.2.3) using the latest available data 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 control measures are not successful or are impractical, no concrete shall be poured.

For example, control measures include addition of chilled water or ice to the concrete, barriers against wind and sun, and pouring in cooler parts of the day.

13.2.2 Application of evaporation retarding compound

The use of a registered evaporation retarding compound on the top surface of the concrete is mandatory for all concrete works. It shall be applied within 10 minutes of placement and initial screeding, and any subsequent screeding or finishing.

Application shall be made in accordance with the manufacturer's instructions and be by a fine continuous spray. Compounds shall consist primarily of aliphatic alcohol suitable for use on concrete.

Evaporative retarders do not replace curing compounds.

Care shall be taken to ensure that delamination of the surface layer does not occur due to overuse of evaporation retarding compounds, particularly if being used as a finishing aid. Pouring or applying evaporation retarding compounds from a bottle is generally not appropriate or acceptable.

13.2.3 Method for calculation of evaporation rates

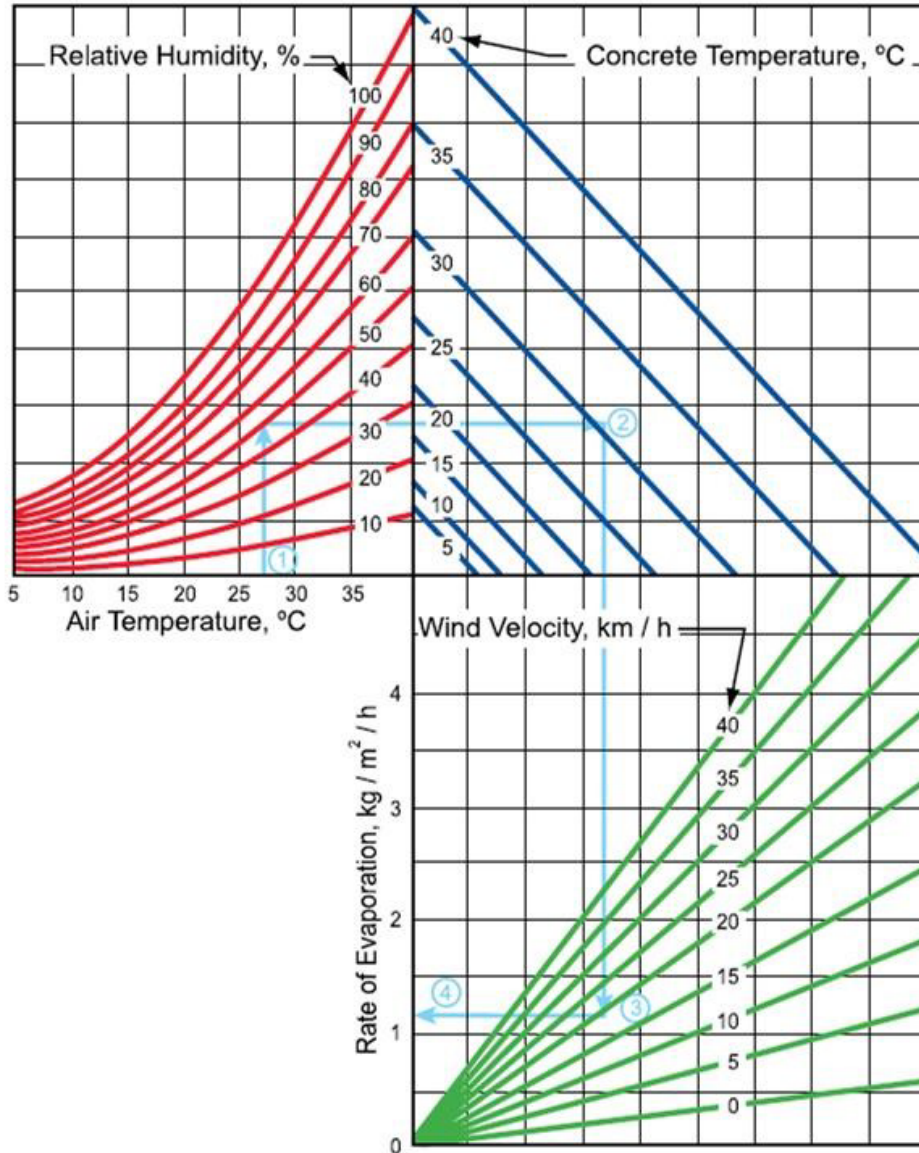
The evaporation rate shall be calculated using the following parameters:

- a) air temperature
- b) relative humidity

- c) concrete temperature, and
- d) wind velocity.

Figure 13.2.3 is to be used for estimating the evaporation of surface moisture from the concrete for various weather conditions as represented by the above information.

Figure 13.2.3 – Chart for estimation of water evaporation rate



Source: 'Q&A' Concrete International, March 2007 (ACI)

13.3 Protection from rain

Concrete shall not be poured in the rain or if rain is imminent unless adequate measures are taken to protect the plastic concrete from the falling rain. Protection is defined as a waterproof covering which protects all exposed surfaces of the concrete.

For example, suitable protection includes tarpaulins or roofing.

All water shall be removed from the form before concrete is poured.

Concrete which is exposed to significant rain from the time of commencement of placement to the commencement of curing shall be rejected. **Nonconformance**

For example, the effects of significant rainfall may include:

- increased workability
- ponding of water, and/or
- disturbance (cratering) of concrete surface.

14 Defects and rectification

Where concrete does not comply with the requirements listed in this Technical Specification, the following options are permitted, at the discretion of the Administrator:

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

This work shall be at the Contractor's expense.

The method of rectification shall be approved by the Administrator.

Any damage, including deterioration and disfigurement (for example rust staining), shall be made good prior to Practical Completion.

For example, cracks in concrete are undesirable, and indicative of Nonconformance to this Technical Specification (see Clauses 15.10.2 and 16.6.2). The acceptability of cracks with, or without, rectification will be dependent on crack size, type and extent, and the concrete structure and environment. Structural cracks should be referred to the Designer. Other relevant Specifications may have defined acceptance criteria.

15 Requirements for insitu concrete

This clause applies to mass and reinforced concrete poured insitu including cast-in-place piles.

15.1 Mix designs

Mix designs for insitu concrete shall be as per Clause 9, with additional requirements for mix acceptance as follows.

No concrete shall be placed in the Works until approval of the mix design has been obtained from the Administrator. **Hold Point 1**

For established pre-mix batch plants, with a proven track record and supplying concrete to multiple Transport and Main Roads projects, an application for mix designs assessment may be made direct to

Structures Construction Materials (See Clause 1.1). Evidence of this assessment shall then be submitted to the Administrator in lieu of full mix design details.

15.1.1 Trial mixes

When requested by the Administrator, and where extensive performance data is not available, mix design acceptance shall be on the basis of trial mixes. Concrete intended for long distance or extended placement time use (see Clause 10.4.1) shall be trialled.

'Extensive performance data' refers to test results for the proposed or similar mixes over a recent timeframe of at least one month. Individual test reports are not required.

Trial 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 1**

Note that higher volumes of trial mix may be required depending on the range of testing to be conducted.

Trial mixes shall be batched using the nominated (design) value for the water / cementitious material ratio.

Each trial mix shall be tested for slump or spread, and strength, and other tests as required (for example water retention).

The trial mix shall be batched and delivered in a manner as per the anticipated final procedures used, including any admixtures added on site. 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 or spread and cylinder tests.

The slump or spread measured shall be within tolerance (see Tables 11(a) and 11(b)) of the nominated slump or spread. At least four cylinders shall be cast from each trial mix for compressive strength testing at 28 days. Additional cylinders (a minimum of three per age) shall be required if strength gain is to be assessed for early stripping or loading.

The Administrator may give provisional approval of a mix based on early testing, provided the mean compressive strength of at least three trial cylinders tested at seven days is not less than 0.8 of the specified characteristic strength. Notwithstanding any such provisional approval, all the concrete shall meet 28 day strength requirements.

15.1.1.1 Trials for extended placement times

Trial mixes for long distance travel and extended placement times shall emulate the estimated travel time. In addition to the requirements of Clause 15.1.1, the trial mix shall be tested, at intervals nominated by the Administrator, for:

- a) Workability retention (slump, or spread, as measured by AS 1012.3)
- b) Extent of hydration (concrete temperature).

Cylinders for strength testing shall be cast from the final sample drawn from the batch.

For example, samples for workability retention could be taken at 0, 30, 60, 90 and 120 minutes from time of batching, or at expected arrival time of truck to site, and then every subsequent 15 minutes.

15.1.2 Trial mix – conformance

The trial mix, the plant and the degree of quality control for the Works shall be approved if the:

- a) 28 day sample strength equals or exceeds $0.5 (f_c + f_t)$.
- b) Slump or spread falls within the tolerances in Tables 11.3(a) or Table 11.3(b).
- c) Materials within the mix meet the requirements of this Technical Specification.
- d) Batch records indicate conformance with AS 1379 (batching tolerances).
- e) Mix design submission meets the requirements of Clause 9.2, and
- f) For trials of extended placement times:
 - i. the slump, or spread, is maintained within the acceptable tolerance limits for the entire nominated time frame, and
 - ii. no increase in temperature other than expected due to ambient conditions is noted and the concrete temperature at the time of placement does not exceed 35°C.

Approval of the trial mix does not relieve the concrete supplier of the responsibility to maintain the performance of the concrete mix.

15.2 Testing procedures (compressive strength)

Sampling of concrete for insitu work shall be undertaken in accordance with this clause. Testing and acceptance of concrete shall be in accordance with Clause 12.

15.2.1 General

Samples for compression strength testing, shall be taken from separate batches of concrete during the placing operation. Two cylinders (minimum) shall be cast from each sample. Samples shall be taken in accordance with AS 1012.1 with records kept as per that Standard.

15.2.2 Standard testing

The normal rate of sampling per lot is defined in Table 15.2.2. For the purposes of determining rate of sampling, a lot shall not extend longer than 24 hours. Sampled batches shall be evenly distributed through the lot. For continuous mixing (see Clause 10.4), every 5 m³ produced shall constitute one 'batch'.

Table 15.2.2 – Sampling frequencies per lot for 28 day strength tests

| Total Number of Batches in Lot (n) | Number of Samples |
|------------------------------------|-------------------|
| 1 – 3 | Every Batch |
| 4 – 10 | 4 |
| 11 – 23 | 5 |
| > 23 | n/4 |

Where sampling, testing and assessment of concrete is carried out in accordance with AS 1379, and AS 1012, and 10 samples of a concrete mix 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.

Samples shall be taken based on estimated number of batches in the lot.

For example, in a lot of 15 batches the following batches would be sampled:

- a) 1, 4, 8, 12 and 15 (normal)
- b) 1, 8, 15 (reduced).

Clause 11.5 requires spread testing of each batch of HWC regardless of reduced testing for strength.

15.2.3 Initial testing

Where the information supplied as part of the mix design does not permit determination of standard deviation, based on previous field testing for each grade of concrete, the frequency of initial sampling shall be increased above that shown in Table 15.2.2. The actual increase in initial sampling shall be at the Administrator's discretion (**with Hold Point 1 approval**).

Note that this requirement relates to concrete pours with more than four batches of concrete.

15.2.4 Curing of specimen cylinders

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 1012.8.1.

The specimen cylinders shall be cured in accordance with AS 1012.8.1. 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.

15.2.5 Early age testing

Where additional testing is specified, or required before 28 days, one cylinder from each sampled batch shall be tested. All specimens from the lot or sub-lot shall exceed the specified strength before the relevant construction activity is progressed or Hold Point released. If the specimen from one or more batches fails, further testing at a later time may be conducted; only those batches that failed need be re-tested.

Examples of early age testing include further construction prior to 28 days (Clause 15.6.5).

15.3 Falsework

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

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 2** The Contractor shall supply the Administrator with detailed drawings of such falsework at least four 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 falsework shall in no way relieve the Contractor of any responsibility for the restoration or repair of any resulting damage caused by such use.

15.4 Formwork, bar chairs and spacers

15.4.1 Formwork

All formwork shall be subject to inspection and approval by the Administrator. **Hold Point 3**

Any proposal to use completed sections of the Works to fix formwork in place shall be submitted as part of this hold point. Any repairs or restorations required by this activity shall be the responsibility of the Contractor and shall be of a standard equivalent to the existing works.

Formwork shall conform to AS 3610 except as otherwise required by this Technical Specification. Formwork shall provide a Class 2 AS 3610 surface finish, except as otherwise specified. All forms shall be surface smooth, mortar tight and have sufficient rigidity to maintain the tolerances specified 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, and 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 pour. Reinforcing steel and construction joints shall not be contaminated with release agent.

Forms for unpatterned 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 exposed concrete surfaces shall be either vertical or horizontal and spaced with a regular pattern. Spirally-wound tubes of any material shall not be used for round sections (e.g. columns).

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 acceptable.

In firm ground, buried reinforced 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 no less than 25 mm, and no more than 50 mm. The increase in cover and member dimensions shall be nominated with tolerances applying to the nominated values. The increase in volume of concrete shall be at no cost to the Principal.

Where a hole or void in the concrete is shown on the Drawing the formwork or void former shall be removed after casting. Permanent hole formers are not accepted unless shown on the Drawing.

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

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. Wire ties, not cast into the concrete, 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, of strength equivalent to the concrete element, 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.

15.4.2 Supports (bar chairs and spacers)

All bar chairs and spacers shall comply with AS/NZS 2425 and be a registered product. Minimum strength grades to AS/NZS 2425 are 300 kg for concrete supports and 200 kg for steel supports. Strength grades shall be chosen to be appropriate to the mass of reinforcement supported, any other loads and the spacing of supports.

Bar chair materials to be as per the following sub-clauses dependant on location. Plastic bar chairs or spacers shall not be used, except in the case of piles (see Clause 15.4.2).

Supports 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 supports shall be avoided; each individual length of support shall be laterally offset from its adjacent support by at least 200 mm so as to avoid the potential to induce linear cracking in the concrete. The maximum length of any one support shall be 330 mm.

Concrete supports shall be extruded fibre concrete or conventional concrete manufactured under factory controlled conditions. The minimum concrete strength shall be 60 MPa and the product shall have a maximum RCPT value of 1000 coulombs at 56 days.

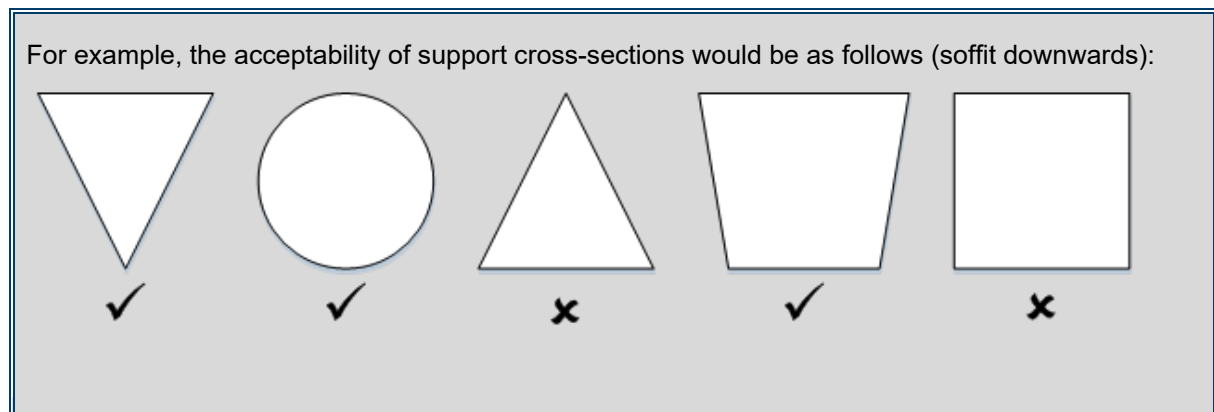
The fibres used in extruded fibre concrete bar chairs shall be non-metallic, synthetic fibres. Asbestos or similar fibres based on naturally occurring silicate minerals shall not be used.

15.4.2.1 Cover to formwork or ground

Where supports are used to distance reinforcement from formwork or the ground, the support shall be manufactured from concrete or stainless steel.

Where supports are required to be attached to the reinforcement, such attachment may be via clips or steel wires 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 or galvanised wire or clips are used they must be located at a depth of no less than half the specified cover from the concrete surface.

Supports used to provide cover to the soffit formwork shall either be attached to the reinforcement or shaped to positively interlock into the concrete.



Stainless steel nibs are to be manufactured from a material compliant with MRTS71 *Reinforcing Steel* and welded to the reinforcing complying with the locational tack weld requirements of MRTS71.

15.4.2.2 Cover to concrete

Where supports are used to distance reinforcement from existing concrete such as a construction joint, or cast insitu decks on top of deck units or girders, but excluding blinding concrete, the following support types may be used:

- a) concrete spacers
- b) stainless steel nibs, or
- c) plastic-tipped wire chairs.

15.4.2.3 Spacing of reinforcement

Where supports are used to distance reinforcement from reinforcement (that is, between two layers of mesh), steel frames may be used. These frames shall be placed so as not to be directly above other spacers.

15.4.2.4 Spacers for piles

For piles to MRTS63 *Cast-In-Place Piles*, MRTS63A *Piles for Ancillary Structures* and MRTS64 *Driven Tubular Steel Piles (with reinforced concrete pile shaft)* the following spacer types are permitted:

- a) For cover to shaft or liner / tube of pile:
 - i. concrete spacers
 - ii. stainless steel nibs (arches), and

- iii. carbon-fibre reinforced polymer wheels (≥ 200 g strength grade).
- b) For cover to base of pile:
 - i. concrete blocks
 - ii. stainless steel nibs
 - iii. carbon-fibre reinforced polymer feet (≥ 300 kg strength grade), and
 - iv. polyolefin feet (≥ 300 kg strength grade).

15.4.3 Joint formers

Where permitted by the Administrator, cast-in joint formers for expansion, isolation and contraction joints in slab-on-ground construction shall either be stainless steel, galvanised to AS/NZS 4680 or manufactured from durable polymers. Cast-in crack inducers are not permitted.

Cast-in joint formers for construction joints are not permitted.

15.5 Concrete temperatures

Concrete shall be managed to ensure that at no stage does the concrete temperature during hydration exceed 80°C or the difference in temperature between the geometric centre of the cross section and any adjacent edge location exceed 25°C (see Clause 15.5.3 for location details). If these limits are exceeded, appropriate rectification or rejection of the element shall occur, and additional precautions enacted. **Nonconformance**

Internal temperatures above 80°C can cause delayed ettringite formation in blended cement concretes reducing the durability of the concrete. Excessive differentials can cause thermal cracking. Note that GP cement only concretes are not permitted for special-class concrete, thus the 80°C limit is appropriate.

Monitoring shall be in accordance with Clauses 15.5.2 and 15.5.3, as required, with temperatures recorded from placement for 120 h (five days) or until the core temperature has decreased to 50°C . Elements not meeting the criteria of either clause do not need to be monitored.

The Contractor shall submit a procedure and plan for monitoring and procedures for ensuring compliance to this clause to the Administrator for approval at least four weeks prior to the concrete pour. **Milestone** The maximum interval between readings shall be 15 minutes. This plan shall be approved by the Administrator before concrete is placed (**refer to Hold Point 5**)

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

Precautions to reduce concrete temperatures may include:

- redesign of the concrete mix
- reducing the concrete temperature at the time of placement
- insulating the formwork to reduce temperature differentials
- other measures as approved by the Administrator.

15.5.1 Mix trials

Where specified by the Designer (e.g. MRTS62.1 or Supplementary Specification) or initiated by the Contractor, a hot box trial shall be conducted in accordance with CIA Z7/07. The data from the trial can be used to establish or refine the adiabatic temperature profile and hence a prediction of the peak temperature and differential. The construction procedure shall be amended with updated placement temperatures and/or formwork retention periods as required.

The 80°C / 25°C limits do NOT apply to the hot box trial. It is a data gathering exercise to refine the construction procedure, not a compliance test.

15.5.2 High cementitious contents

For elements manufactured with a concrete mix containing 520 kg/m³ of cementitious material or more, the following location shall be monitored for temperature:

- a) one at the geometric centre.

For elements with concave sections, the geometric centre shall be determined as the point furthest from the formwork.

15.5.3 Large elements

For elements with a cross sectional area exceeding 1 m x 1 m square, or 1 m diameter, the following locations, at a minimum, shall be monitored for temperature:

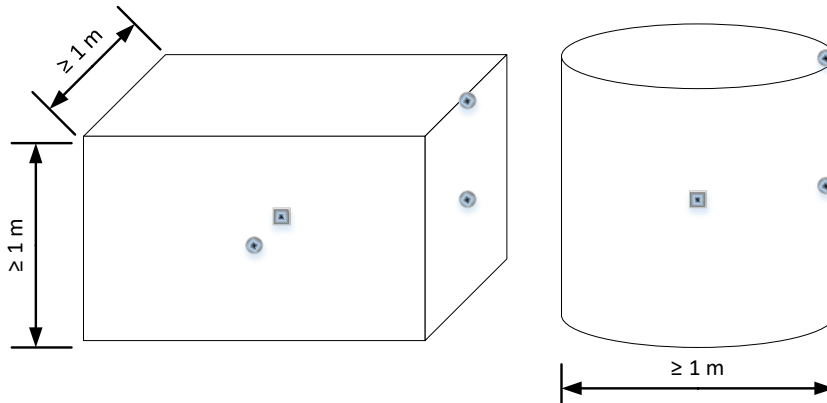
- a) one at the geometric centre (core)
- b) one at an upper edge, and
- c) two at centres of adjacent side faces (long and short side for rectangular elements, one only for circular columns).

Surface temperatures (b and c above) shall be measured at the cover depth of reinforcement.

For cast-in-place piles, (a) and (c) above shall be measured at a depth of two pile diameters from the top concrete surface of the pile as poured (including an overpour). In the case of piles, the temperature sensor at the geometric centre can be installed after the completion of the pile pour.

For the purposes of this clause the cross section is defined as the plane perpendicular to the longitudinal direction (longest dimension).

Figure 15.5.3 – Indicative thermocouple placement (square = core location)



15.6 Placing and compacting concrete

Concrete operations shall not commence until all relevant procedures, listed in Table 5.2 have been approved by the Administrator. **Hold Point 4**

15.6.1 General

No concrete shall be placed in the Works until: **Hold Point 5**

- the formwork and reinforcement have been inspected
- all foreign material has been completely removed from the forms
- the mixing, batching, and compaction equipment have been approved by the Administrator.

The Administrator shall be granted sufficient time for this inspection, and shall not be responsible for any delay to commencement of the concrete pour.

The risk of agitator trucks sitting on site, while inspections and any remedial work are performed, rests solely with the Contractor.

After 10 lots have been poured, the Administrator may exclude (a) and (b) above from the Hold Point, reverting it to a Witness Point.

The placing operation shall be conducted in the presence of the Administrator **Witness Point 2** 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 15.6.3, 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. 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 12 mm bar.

If an interruption to pouring greater than 45 minutes occurs, the surface shall be tested for initial set and if initial set has occurred, a construction joint approved by the Administrator shall be placed, or the laid concrete shall be rejected. **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. Internal poker vibrators shall not be used to move concrete on chutes.

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.

Cast-in-place piles (see MRTS63, MRTS63A and MRTS64) shall be placed by means of tremie. Direct placement by means of pump is not permitted.

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 15.8. 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 or Hilt density ratio as determined by Test Methods AS 1289.5.4.1 or AS 1289.5.7.1 and the rock freed of loose material. Where shown in the Drawings the foundation shall be covered with a layer of blinding concrete. The maximum thickness of unreinforced blinding concrete, where the applied foundation load is being transferred through the blinding concrete, shall be 100 mm unless otherwise approved.

Where concrete work is constructed on ground surfaces or on a foundation bedding, a polythene sheet separator of thickness not less than 100 μ m 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. If puncturing or tearing occurs, 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.

15.6.2 Compaction of concrete (excluding cast-in-place piles)

Unless otherwise approved by the Administrator, concrete shall be deposited in horizontal layers not more than 400 mm thick.

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.

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 10 m³ of concrete placed per hour, with a minimum of two 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 five to fifteen seconds have elapsed. 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, to ensure that all sections of the formwork are being vibrated. External vibration shall always be accompanied by internal vibration.

15.6.2.1 Compaction of concrete (cast-in-place piles)

Compaction of concrete in cast-in-place piles shall be as per MRTS63 *Cast-In-Place Piles*, MRTS63A *Piles for Ancillary Structures* or MRTS64 *Driven Tubular Steel Piles (with reinforced concrete pile shaft)*, as appropriate.

15.6.3 Placement under water

The Contractor shall submit a procedure for underwater concreting which includes placement of concrete in wet cast-in-place piles at least two weeks prior to concreting. Placement of concrete underwater in a pilecap is not permitted, and the pilecap formwork must be dewatered before the reinforcement and concrete is placed. **Milestone**

The placement of concrete underwater shall be carried out in the presence of the Administrator **Witness Point 3** and shall comply with the following:

- a) The nominated slump of the concrete to be placed underwater shall be between 180 mm and 200 mm (inclusive) or be high workability concrete.
- 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) Any salt water shall be pumped out and replaced with fresh water as much as possible, to the satisfaction of the Administrator. The resulting water in the pile or formwork before concrete placement shall have a chloride ion content of no more than 2000 ppm and be sufficiently clear to allow any underwater inspection by camera if required.

- d) The concrete shall be placed carefully in a compact mass in its final position by means of an approved tremie such that:
 - i. The tremie shall consist of a watertight tube fitted with a valve at the base of the tube or other approved device (or method) 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.
 - ii. 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.
 - iii. An air gap is maintained between the tremie and hopper to permit air bubbles to escape.
- e) A concrete pump may be used to load the tremie or hopper, but not act as a substitute for the tremie.
- f) The discharge end of the tremie shall remain submerged to a depth of 2 m 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

- g) 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.
- h) No tamping or vibrating of the concrete shall be allowed unless permitted or mandated in accordance with the other relevant specifications. The concrete shall not be subjected to any physical disturbance after deposition.

Note: For example, MRTS63 requires vibration of the top 3 m of the pile once water and impaired concrete has been let to flow to waste.

- i) Adequate allowance shall be made when concreting to provide for the subsequent removal or overflow of the contaminated surface layer.
- j) 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.
- k) 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.

15.6.4 Use of spalls

Spalls of solid rock (not exceeding 200 mm in size) compliant to the requirements of Clause 7.5.4 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.

15.6.5 Further construction prior to 28 day testing

Concrete shall not be placed over or adjacent to and connected with a previous section prior to 28 day testing and acceptance, without Administrator approval, and subject to early age test results indicating 28 day characteristic strength will be obtained.

Potential 28 day strength can be indicated by comparison to previous trends of strength gain over time.

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

15.7 Dimensional tolerances

15.7.1 General

Where tolerances for individual components and associated dimensions are not specified in the Drawings or other Technical Specification, deviations from established lines, grades and dimensions in the completed work shall not exceed the values given in this section.

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

Note that additional tolerances for individual products may be listed in the relevant Technical Specification and they take precedence.

15.7.2 Dimensional tolerances

The tolerances given in Table 15.7.2 are to ensure strength, durability and fit of cast-in-situ elements.

Table 15.7.2 – Dimensional tolerances

| Description | Tolerance (mm) |
|--|----------------------|
| Cross sectional dimension of members and thickness of slabs | + 10, - 3 |
| Length of members, length and width of slabs: <ul style="list-style-type: none"> • 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 |

15.7.3 Positional tolerances

Positional tolerances, listed in Table 15.7.3, 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 15.7.3 – Positional tolerances

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

15.7.4 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 15.7.4.

Table 15.7.4 – Relative tolerances

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

15.8 Removal of formwork

Forms, falsework and centring shall remain in position until the times stated below have elapsed after completion of concreting. **Hold Point 6**

- for soffits, until seven days
- for side forms, in accordance with Table 15.8.

Table 15.8 – Retention of side forms

| Exposure Classification | Minimum Form Retention (hours) |
|-------------------------|--------------------------------|
| A | 48 |
| B1, B2 | 72 |
| C1, C2 | 120 |

Longer formwork retention times may be required in some cases to comply with differential temperature compliance requirements (refer Clause 15.5).

In addition, the curing requirements of Clause 15.11 shall apply to the newly exposed surfaces within one hour of stripping the forms.

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. **Witness Point 4**

The Contractor shall repair any damage caused by such operations.

15.8.1 Early stripping

The Contractor may submit a proposal for early stripping of side forms for approval by the Administrator under the following conditions:

- a) minimum 48 h for exposure classifications A, B1 and B2
- b) minimum 72 h for exposure classifications C1 and C2
- c) achievement of 70% of the specified characteristic strength, and
- d) compliance with Clause 15.5 regarding concrete temperatures.

'Specified characteristic strength' is that listed on the drawings. Therefore the Contractor may use a higher strength mix for earlier stripping.

15.9 Early loading

Concrete shall not be loaded until seven days has elapsed from placement of all elements within the load path, including foundations and base slabs, and 70% of the specified characteristic strength has been obtained.

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.

Loads include, but are not limited to, supported formwork / falsework, construction traffic and material storage

15.9.1 Early loading of culvert base slabs

For culvert base slabs only, the Contractor may submit a proposal for early loading for approval by the Administrator under the following conditions:

- a) minimum three days elapsed since concrete placement
- b) 70% of design characteristic strength achieved prior to landing crown units
- c) 100% of design characteristic strength achieved prior to backfilling or opening to traffic
- d) no trafficking of slab permitted by vehicles
- e) curing for seven days is maintained
- f) use of higher-grade concrete mix, with no reduction in cover-to-reinforcement, and
- g) benefit for early opening of traffic lanes accepted by Administrator.

The design of base slabs typically require 40 MPa concrete with 60 mm cover. This clause allows (for example) the use of a 50 MPa concrete and land units once three days and 28 MPa ($0.7 * 40$) has been achieved. Cover-to-reinforcement remains at 60 mm.

15.10 Finishing operations

15.10.1 General

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

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.

The addition of water to aid finishing is prohibited.

15.10.2 Prevention of cracking

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

15.10.3 Top surface of decks and relieving slabs

Decks and relieving slabs shall be finished and tested in accordance with MRTS77 *Bridge Deck*.

15.10.4 Other cast-in-place surfaces

The tops of walls, kerbs, concrete barriers, headstocks and piers shall be steel trowel finished.

Culvert aprons and pathways including shared pathways and shared pathway bridge decks, shall be broom-finished. Additional requirements or testing for footpaths and shared pathways may be required for slip or skid resistance for pedestrians and cyclists.

Where specified on the drawings, a wood float shall be used.

A wood float or broom finish produces a rougher surface compared with a steel float that may be required for slip resistance.

15.10.5 Special finishes

Special finishes shall be as detailed in the Drawings.

15.11 Curing

15.11.1 General

The Contractor shall submit a procedure for curing, including methods and materials, to the Administrator for approval at least two weeks prior to the first concrete pour. **Milestone** The curing of unformed surfaces of concrete shall commence as soon as the concrete surface has hardened.

Curing shall continue for a minimum period of seven days, fourteen days for bridge decks and slabs. If forms are removed in less than seven days, curing of the formed surface shall commence within one hour of stripping, unless otherwise specified in Clause 15.12.

Note that curing for longer periods, up to 28 days, will generally result in a superior product.

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

15.11.2 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 7.3.

15.11.3 Membrane curing (curing compounds)

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 L/m² per coat, whichever is the greater. The application rate shall be checked by measuring the volume of compound applied to a given area.

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. 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 are to be applied, wax emulsion membranes shall not be used unless provision is made for subsequent removal of wax, prior to applying the coating or wearing surface.

Note that on bridge decks any curing compound residue (regardless of type) may need to be removed before application of bridge deck wearing surface or water proofing membrane to ensure satisfactory adhesion (Refer MRTS84 *Deck Wearing Surface*).

15.11.4 Membrane curing (sheeting)

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.

15.12 Surface dressing of concrete

Prior to commencing concreting operations, the Contractor shall establish procedures and standards for surface dressing and repair of concrete. The standards and procedures established shall be subject to the approval of the Administrator (**refer to Hold Point 4**).

Concrete surfaces shall be free of honeycombing or pockets, and free of voids larger than 20 mm in lateral dimensions or 3 mm deep. Any unrepaired cracking, unless specified otherwise, shall not exceed:

- a) 0.3 mm in width (B2 exposure classification and below)
- b) 0.15 mm in width (C1 exposure classification and above)
- c) 300 mm in any one continuous length, or
- d) 300 mm in combined total length per square metre of surface.

Staining due to rust, oil, and dirt, as well as visible pouring layers are unacceptable.

Tarps, or similar, should be placed beneath any materials stored on new construction that are likely to leave marks (e.g. reinforcing steel).

Stains due to vegetation and wildlife are acceptable unless specified otherwise.

15.12.1 Formed surfaces

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) Where specified in the Drawings, surfaces shall achieve a Class 1 surface finish to AS 3610 (Figure B1) or be bagged as set out below within four hours of removal of formwork from each section of the concrete. Curing as specified in Clause 15.11 shall commence on completion of stripping or bagging as appropriate.
- c) 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.

15.12.1.1 Bagging to achieve required finish

Bagging shall be carried out by the following procedure:

- a) Produce a plastic grout mix consisting of equal parts of cement and fine sand passing a 0.600 mm test sieve, mixed with a suitable bonding additive and water.
- b) An equivalent proprietary product (for example a fairing coat mortar) is a suitable alternative.
- c) Apply 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.
- d) Keep surface damp while this work is carried out.
- e) Remove surplus material while the initial application is still plastic.

15.12.2 Rectification of non-compliant surfaces

Where surfaces fail to meet the requirements of Clause 15.12, the following actions shall be undertaken: **Nonconformance**

- a) All pockets or honeycombed areas shall be cleaned out to sound concrete.
- b) Small voids or bug holes, not more than 150 mm in lateral dimensions or 20 mm deep, shall be filled with a registered repair mortar with a 28 day strength not less than the concrete being repaired, vibrated as necessary. The surface of the patches shall be finished flush with the adjacent formed surface.
- c) 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.
- d) Cracks shall be sealed with a registered crack injection epoxy or sealant, and
- e) The repaired area shall be cured in accordance with Clause 15.11.

Repairs shall be a **Witness Point 5**

15.13 Construction 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 7**

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 the use of:

- a) sand-blasting techniques
- b) wire brushes, hand tools and pneumatic tools
- c) 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, or
- d) proprietary surface retarding agents followed by any of the above (sugar solutions are not to be used).

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.

Construction joints are not to be facilitated with permanent metal formwork, mesh or similar products.

TN50 *Treatment of Top Surface and 'Construction Joints' on Deck Units and Girders* provides examples of acceptable construction joints.

15.13.1 Construction joints in marine and other aggressive environments

Construction joints in exposure classification C1 or C2, environments shall be prepared as follows:

- a) The surface of the joint shall be prepared as in Clause 15.13 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.
- b) If practical, the concrete surface shall be coated with a wet-to-dry epoxy resin, as approved by the Administrator, followed by placement of the fresh concrete before the epoxy on the interface has hardened. Alternatively the construction joint shall be dampened with water prior to placement of concrete for a period of four hours before concrete placement.

16 Requirements for precast and precast prestressed concrete

This clause applies to concrete produced for manufacture of precast and precast prestressed concrete items as defined by MRTS24 *Manufacture of Precast Concrete Culverts*, MRTS72 *Manufacture of Precast Concrete Elements* and MRTS73 *Manufacture of Prestressed Concrete Members and Stressing Units*. Notwithstanding alterations listed below, Clauses 1 to 14 of this Technical Specification continue to apply.

16.1 Mix designs

Mix designs shall be assessed on a yearly basis as part of the registration of precast concrete suppliers.

Trial mixes shall be conducted in the following cases:

- a) establishment of new batch plant at casting yard
- b) formulation of new mix type
- c) super-workable concrete, and
- d) requests for extension of placement time (to be conducted in accordance with Clause 15.1.1.1).

Mix design approval certificates shall be submitted to the Administrator for approval to use the mix in the Works (**see Hold Point 8**).

For example, new mix types would include triple-blend concrete

16.1.1 Trial mixes

Trial 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 6**

Each trial mix shall be tested for slump or spread, 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 or spread and cylinder tests.

The slump or spread measured shall be within tolerance (see Table 11(a) or Table 11(b)) of the nominated slump or spread. At least four cylinders shall be cast from each trial mix for compressive strength testing at 28 days. Additional cylinders (a minimum of three per age) shall be required if strength gain is to be assessed for early stripping or loading.

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 seven days is not less than 0.8 of the specified characteristic strength for that grade of concrete. Notwithstanding any such provisional approval, all the concrete shall meet 28 day strength requirements.

Trial mix programmes for super-workable concrete shall include a minimum of three batches to determine that the mix can be reliably produced.

16.1.2 Trial mix – conformance

The trial mix, the plant and the degree of quality control for the Works shall be approved if the:

- a) Mean 28 day cylinder strengths equals or exceeds $0.5 (f_c + f_t)$.
- b) Slump or spread falls within the tolerances in Table 11(a) or Table 11(b).
- c) Materials within the mix meet the requirements of this Technical Specification.
- d) Mix design submission meets the requirements of Clause 9.2.
- e) For trials of extended placement times:
 - i. the slump, or spread, is maintained within the acceptable tolerance limits for the entire nominated time frame, and
 - ii. no increase in temperature other than expected due to ambient conditions is noted and the concrete temperature at the time of placement does not exceed 35°C.

Note that approval of the trial mix does not relieve the concrete supplier of the responsibility to maintain the performance of the concrete mix as per Clause 9.

16.2 Testing procedures (compressive strength)

Sampling for compressive strength testing of concrete for precast work shall be undertaken in accordance with this clause.

16.2.1 Normal rate of testing

Samples shall be taken from each pre-mixed truckload or from each 5 m³ of concrete continuously batched on site at the precast yard. Four cylinders (minimum) shall be cast from each sample. Each sample shall be identified with the relevant batch and the precast elements cast from the batch sampled.

Note that additional cylinders may be required to satisfy all early strength testing requirements and ensure a matched pair is available for 28 day testing.

16.2.2 Reduced rate of testing

Where sampling, testing and assessment of concrete is carried out in accordance with this specification, and 10 samples of a concrete mix 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.

Half the normal level is defined as one sample from every second truck for premixed concrete delivered in trucks, or one sample every 10 m³ for concrete wet batched in the precast yard.

This approval will be managed through the supplier registration scheme, and relevant mix design approval certificates. The schedule of sampling for release strength testing shall include a sample taken from the final batch or truck.

For example, testing would be from truck 2 of 2, 1 and 3 of 3, 1 and 4 of 4, and 1, 3 and 5 of 5.

16.3 Formwork, bar chairs and spacers

16.3.1 Formwork

Formwork shall be constructed from metal; timber forms are not acceptable, except as noted below. Forms for surfaces requiring special finishes are specified elsewhere in the Contract.

In the case of flat panel work only, the following exceptions to metal formwork apply:

- a) use of timber edge forms for custom panels
- b) use of proprietary form liners or other suitable material as a form liner for patterned panels, and
- c) polystyrene to form custom blockouts.

Formwork shall conform to AS 3610 except as otherwise required by this specification. Formwork shall provide a Class 2 AS 3610 surface finish, except as otherwise specified. All forms shall be surface smooth, mortar-tight and have sufficient rigidity to maintain the tolerances specified when subjected to fresh concrete and intense vibration.

All forms shall be set and maintained to line and level such that the finished concrete shall conform within the specified dimensional tolerances, and 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 pour. Reinforcing steel, prestressing strand and construction joints shall not be contaminated with release agent.

Where a hole or void in the concrete is shown on the Drawing the formwork or void former shall be removed after casting. Permanent hole formers are not accepted unless shown on the Drawing.

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

The form's original shape, strength, rigidity, mortar tightness and surface smoothness shall be maintained. Forms which become unsatisfactory shall not be used.

16.3.2 Supports (bar chairs and spacers)

All bar chairs and spacers shall comply with AS/NZS 2425 and be a registered product. Minimum strength grades to AS/NZS 2425 are 300 kg for concrete supports and 200 kg for steel supports. Strength grades shall be chosen to be appropriate to the mass of reinforcement supported, any other loads and the spacing of supports.

Bar chair materials to be as per Clauses 16.3.2.1 and 16.3.2.2 dependant on location. Plastic bar chairs or spacers shall not be used.

Supports 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 supports shall be avoided; each individual length of support shall be laterally offset from its adjacent support by at least 200 mm so as to avoid the potential to induce linear cracking in the concrete. The maximum length of any one support shall be 330 mm.

16.3.2.1 Cover to formwork

Where supports are used to distance reinforcement from formworks, the supports shall be manufactured from concrete or stainless steel.

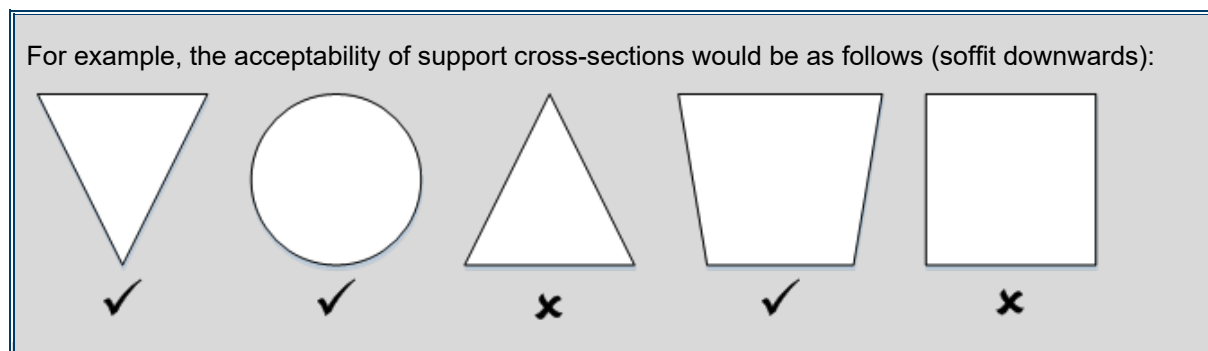
Concrete supports shall be extruded fibre concrete or conventional concrete manufactured under factory controlled conditions and be a registered product.

The minimum concrete strength shall be 60 MPa and the product shall have a maximum RCPT value of 1000 coulombs at 56 days.

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.

Where supports are required to be attached to the reinforcement, such attachment may be via clips or steel wires 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 or galvanised wire or clips are used they must be located at a depth of no less than half the specified cover from the concrete surface.

Supports used to provide cover to the soffit formwork shall either be attached to the reinforcement or shaped to positively interlock into the concrete.



Stainless steel nibs are to be manufactured from a material compliant with MRTS71 *Reinforcing Steel* and welded to the reinforcing complying with the locational tack weld requirements of MRTS71.

16.3.2.2 Spacing of reinforcement

Where supports are used to distance reinforcing from reinforcing (that is, between two layers of mesh), steel frames may be used. These frames shall be placed so as not to be directly above other spacers.

16.4 Concrete temperatures

Concrete shall be managed to ensure that at no stage does the concrete temperature exceed 80°C or the difference in temperature between the geometric centre of the element and an adjacent edge exceed 25°C. If these limits are exceeded, appropriate rectification or rejection of the element shall occur, and additional precautions enacted. **Nonconformance**

Internal temperatures above 80°C can cause delayed ettringite formation in blended cement concretes reducing the durability of the concrete. Excessive differentials can cause thermal cracking. Note that GP cement only concretes are not permitted for special-class concrete, thus the 80°C limit is appropriate.

Monitoring shall be in accordance with Clauses 16.4.1 and 16.4.2, as required, with temperatures recorded from placement for 120 h (five days) or until the core temperature has decreased to 50°C. Elements that do not meet either criteria do not need to be monitored. Elements being cured using high temperatures shall instead be monitored in accordance with Clause 16.7.4.

A record of the monitoring results shall be submitted to the Administrator prior to delivery.

Precautions to reduce concrete temperatures may include:

- redesign of the concrete mix
- reducing the concrete temperature at the time of placement
- insulating the formwork to reduce temperature differentials, and/or
- other measures as approved by the Administrator.

16.4.1 High cementitious contents

For elements manufactured with a concrete mix containing 520 kg/m³ of cementitious material or more, the following location shall be monitored for temperature:

- a) one at the geometric centre.

Where a batch of identical elements are manufactured together from the same mix, one unit only shall be monitored.

For elements with concave sections, the geometric centre shall be determined as the point furthest from the formwork.

For example, culverts would be monitored in the centre of the haunch.

A reduced rate of monitoring may be sought, following a period of satisfactory results. This rate shall not be less than one element per week.

16.4.2 Large elements

For elements with a cross sectional area exceeding 1 m x 1 m square, or 1 m diameter, the following locations, at a minimum, shall be monitored for temperature:

- a) one at the geometric centre
- b) one at an upper edge, and
- c) two at centres of side faces (for rectangular elements one on long and one on short side).

Surface temperatures (b and c above) shall be measured at the depth of reinforcement.

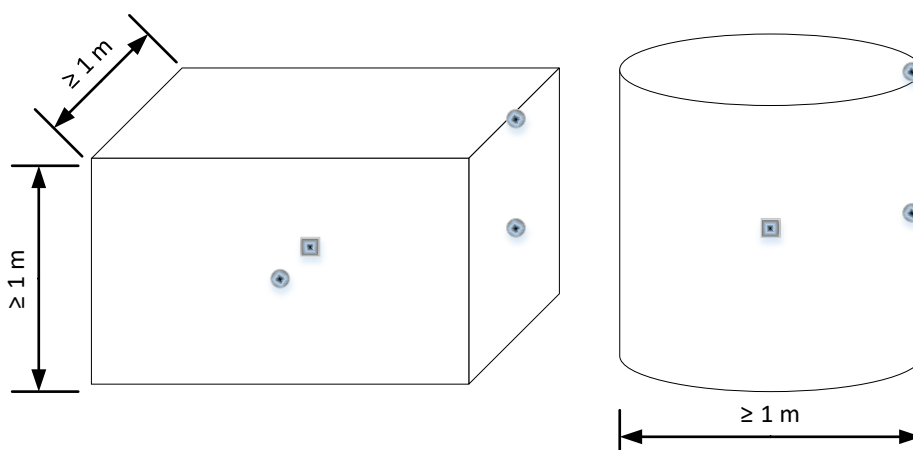
For the purposes of this clause the cross section is defined as the plane perpendicular to the longitudinal direction (longest dimension).

The Contractor shall submit a procedure and plan for monitoring and procedures for ensuring compliance to this clause to the Administrator for approval at least four weeks prior to the concrete pour. **Milestone** The maximum interval between readings shall be 15 minutes. This plan shall be approved by the Administrator before concrete is placed.

A record of the monitoring results shall be submitted to the Administrator prior to delivery.

Elements requiring monitoring due to their size are more likely to be one-off and/or project-specific therefore approval is not managed through the Registration Scheme.

Figure 16.4.2 – Indicative thermocouple placement (square = core location)



16.5 Placing and compacting concrete

16.5.1 General

No concrete shall be placed in the Works until: **Hold Point 8**

- a) the mix design has been approved by the Administrator

- b) the registration status of the precaster has been confirmed, and
- c) any project-specific requirements have been addressed regarding placement and curing.

Note additional Hold Points in product Technical Specifications (MRTS24, MRTS72, MRTS73).

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 for each precast item or between the construction joints shown in the Drawings. 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 12 mm bar.

If an interruption greater than 45 minutes occurs, without prior approval from the Administrator, or a cold joint occurs, the precast member shall be rejected. **Nonconformance**

Note that particular care is required with SWC to avoid cold joints. Concrete which has been placed can develop a skin very quickly which leads to a cold joint. This risk may be able to be managed by vibration of layers of SWC together to avoid a cold joint.

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 0.5 m above the formwork, 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 0.5 m, the concrete shall be placed using a flexible tube reaching to the top of the formwork or another method approved by the Administrator.

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

Note that deposition near final location is particularly important for super-workable concrete.

16.5.2 Compaction of concrete

Compaction of concrete shall commence immediately after deposition. Compaction shall be achieved by use of high frequency vibrators. Where intense compaction is specified the use of external form vibrators is mandatory, with the exception of prestressed concrete piles.

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 10 m³ of concrete placed per hour.
- 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 for between 5 and 15 seconds. 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.
- f) Vibration shall not be applied either directly or through the reinforcement to any concrete which has taken its initial set.

External vibration shall be supplemented with internal vibration as necessary. Where rigid forms and intense vibration is specified, and SWC is not being used, external vibration is mandatory. Sufficient external vibrators shall be attached to all external form surfaces to ensure that all formwork surfaces are being vibrated.

For SWC only, vibration is not mandatory but may be required either internal and/or external particularly to ensure that joints do not occur between layers. When used, it shall comply with the above, excluding subclause (d).

Care should be taken to ensure that any layering of SWC is mitigated by the use of vibration to mix the layers together.

16.6 Finishing operations

16.6.1 General

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

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.

The addition of water to aid finishing is prohibited.

Staining due to rust, oil, and dirt, as well as visible pouring layers are unacceptable.

Stains due to vegetation and wildlife are acceptable unless specified otherwise.

16.6.2 Prevention of cracking

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

16.6.3 Degrees of finish

Top surfaces of precast or prestressed piles and surfaces of precast elements visible after installation are to be finished with steel trowels.

Surfaces with starter bars, and those marked in the Drawings as construction joints, are to be treated as construction joints.

Other surfaces are to be broom or trowel finished as indicated on the Drawings.

Special and other finishes shall be as detailed in the Drawings or Specifications.

Note that MRTS73 *Manufacture of Prestressed Concrete Members and Stressing Units* includes more detailed requirements for precast prestressed elements.

16.7 Curing

16.7.1 General

The curing of unformed surfaces of concrete shall commence as soon as the concrete surface has reached initial set.

Curing shall continue for a minimum period of seven days. If forms are removed in less than seven days, curing of the formed surface shall commence within one hour of stripping, except as otherwise specified in Clause 16.8.

In the case where heat accelerated curing is achieved for 420°C·h, curing is deemed complete. If heat accelerated curing is applied but 420°C·h is not achieved, curing shall continue for seven days by either water or membrane curing.

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

Precast prestressed concrete constructed in accordance with MRTS73 *Manufacture of Prestressed Concrete Members and Stressing Units* shall be heat accelerated cured for a minimum of 420°C·h.

16.7.2 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 7.3.

16.7.3 Membrane curing (compounds)

The curing compound shall be applied by a pressurised sprayer to give a uniform cover. The sprayer shall ensure adequate mixing of the compound to eliminate separation of product.

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 L/m² per coat, whichever is the greater. The application rate shall be checked by measuring the volume of compound applied to a given area.

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. 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 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.

16.7.3.1 Membrane curing (sheeting)

Where used as an alternative to curing compounds, 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.

16.7.4 Heat accelerated curing

Heat accelerated curing shall be effected using either steam or hot water curing methods.

Where a new heat accelerated curing process is being established, the Contractor shall submit the procedure and Drawings detailing the proposed system, to Structures Construction Materials, at least two weeks prior to commencing establishment of the plant. **Milestone**

Note that this procedure will be assessed as part of the supplier registration scheme.

16.7.4.1 Steaming curing arrangement

Steam curing of precast and precast prestressed concrete units shall be effected within an appropriate enclosure.

The formwork, enclosure and steam lines shall be arranged so that the temperature distribution around the units being cured is uniform. The temperature variation between any two enclosure locations, in a single bed / enclosure, shall not exceed 10°C for a cumulative period for 30 minutes throughout the curing cycle. Formwork and supports shall be designed to allow the heat to circulate freely around all sides of the units. The enclosure shall fully enclose the units including the top surface and be maintained in good condition.

The atmosphere within each enclosure shall have a minimum average relative humidity of 90% over the heating and curing cycle. This shall be confirmed by spot checks.

It is recommended that spot checks on temperature or humidity be conducted by the Administrator when concerns are raised regarding the steam curing system or the condition of the enclosure.

16.7.4.2 Hot water arrangement

Curing of precast and precast prestressed concrete units shall be effected within a steel mould fitted with hot water piping that transfers the heat from the hot water uniformly to the steel mould and the concrete.

At all times the difference between the inlet temperature and the outlet temperature of the hot water curing system shall not exceed 10°C for a cumulative period for 30 minutes throughout the curing cycle. An enclosure shall fully enclose the free concrete surface of the units being cured and a system used to ensure that the minimum average relative humidity in the enclosure shall be maintained at 90%.

For example, a typical system to ensure that the relative humidity in the enclosure remains at 90% would be wet hessian and a soaker hose running along the top of the units.

16.7.4.3 Process Control

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

The maximum temperature within the enclosure (steam curing), or the maximum water temperature (hot water curing) shall not exceed 70°C.

The maximum temperature at any point within the concrete shall not exceed 80°C at any point during or after the heating or curing process. The internal concrete temperatures shall be measured at the largest cross section for a period of 48 hours after concrete placement or until temperatures have dropped to 5°C below the peak temperature whichever occurs first.

The maximum internal temperature of the concrete is limited to avoid damage due to delayed ettringite formation.

The supplier shall provide accurate and sufficient instruments for controlling and digitally recording the relevant temperatures detailed in the following sections throughout the entire heat accelerated curing operation. Accurate control is considered to be the ability to maintain an enclosure (or hot water) temperature at $\pm 5^\circ\text{C}$ of the target temperature at a given point in time.

16.7.4.4 Temperature monitoring locations (steam curing)

All relevant temperatures, as described below, are to be recorded, at no more than 10 minute intervals, for each bed and submitted to the Administrator.

Temperatures shall be monitored at concrete core and enclosure locations at a rate as described in Table 16.7.4.4.

Core temperatures shall be recorded at the geometric centre of the element's largest concrete cross-section or centre of mass of the largest concrete volume.

For elements with continuous cross sections along the length (for example, prestressed piles, and panels) temperatures shall be recorded evenly along the length.

For elements with a concave cross-section (e.g. box culverts) consider only the centre of mass of largest portion of concrete volume (for example, in culverts this is the centroid of the haunch).

The aim is to find the point in the concrete the furthest away from the surface / formwork as this will typically be the location with the highest temperature.

Where curing is carried out in accordance with this clause, and consistent and even temperatures can be demonstrated, the Contractor may seek approval, as part of the Registration Scheme, to move to a reduced level of monitoring. The reduced rate of monitoring shall be not be less than that listed in Table 16.7.4.4. Approval for reduced monitoring shall be granted on a bed-by-bed basis. For the purposes of this clause, the definition of a bed includes a batch of elements (for example, culverts) run off a single heat controller / manifold.

Note that approval for a reduced level of monitoring will be managed through the supplier registration scheme.

Demonstration of consistent and even temperatures can be evidenced by data from four curing cycles over a 14 day period.

Table 16.7.4.4 – Number of temperature monitoring points

| Element | Location | Standard Rate | Reduced Rate |
|---|-----------|---------------------------|---------------------------|
| Prestressed piles | Core | 1/element | 1/bed |
| | Enclosure | ≤ 10 m apart ¹ | 1/pile |
| Prestressed decks and girders | Core | 1/element ² | 1/bed |
| | Enclosure | ≤ 10 m apart ¹ | ≤ 20 m apart |
| Precast Elements (continuous enclosure) ³ | Core | ≤ 10 m apart | 1/bed |
| | Enclosure | ≤ 10 m apart | ≤ 20 m apart |
| Precast Elements (individual enclosures) ⁴ | Core | 1/element | 1/batch (largest element) |
| | Enclosure | 1/element | 1/element |

1. Minimum of 2.
2. For end-to-end units, these shall be non-adjacent ends (that is, monitor the same end of each unit).
3. Typically panels.
4. Typically culverts.

16.7.4.5 Temperature monitoring locations (hot water curing)

For hot water curing processes temperature monitoring shall be conducted in accordance with Table 16.7.4.4 except that the enclosure temperature requirements shall be satisfied by measuring the inlet and outlet water temperatures.

16.7.4.6 Curing process

The curing process for both steam and hot water curing systems shall proceed as follows:

Delay period

The application of heat to a freshly concreted unit shall be delayed for a period of time after completion of concreting.

The delay period (t) in hours shall be calculated as follows:

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

T = concrete temperature (°C) after finishing,

K = 40 (precisely controlled system) or 60 (otherwise).

Control is considered precise when it can be demonstrated that the enclosure or hot water temperature 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 cured using accelerated curing and the Administrator attributes such cracking to an early application of heat, the delay time shall be extended for future units as approved by the Administrator. **Nonconformance**

Heating period

The application of heat shall be such that the enclosure temperature or hot water temperature is raised at a linear rate not exceeding 24°C/h, with no more than an 8°C rise in any 15 minute interval. Any further temperature rise within the curing period shall be at the same rate.

Curing period

For precast prestressed concrete components manufactured to MRTS73 *Manufacture of Prestressed Concrete Members and Stressing Units*, the curing period shall commence once the temperature of the enclosure or the outlet hot water temperature exceeds 45°C. The curing period shall continue, while the enclosure or outlet hot water temperature exceeds 45°C, until the product of time and enclosure temperature exceeds 420°C h. This product shall be calculated using either the enclosure temperatures for steam curing, or the outlet hot water temperatures for hot water systems.

For precast concrete products manufactured to MRTS24 *Manufacture of Precast Concrete Culverts* and MRTS72 *Manufacture of Precast Concrete Elements* the curing period shall be as per the previous paragraph or until the required strength is achieved noting the requirements of Clause 16.7.1 if 420°C h is not achieved.

Clause 16.7.1 describes the requirements should 420°C·h not be reached for precast concrete products. This may be either due to system failure or when heat is used only for the purpose of gaining early release strengths.

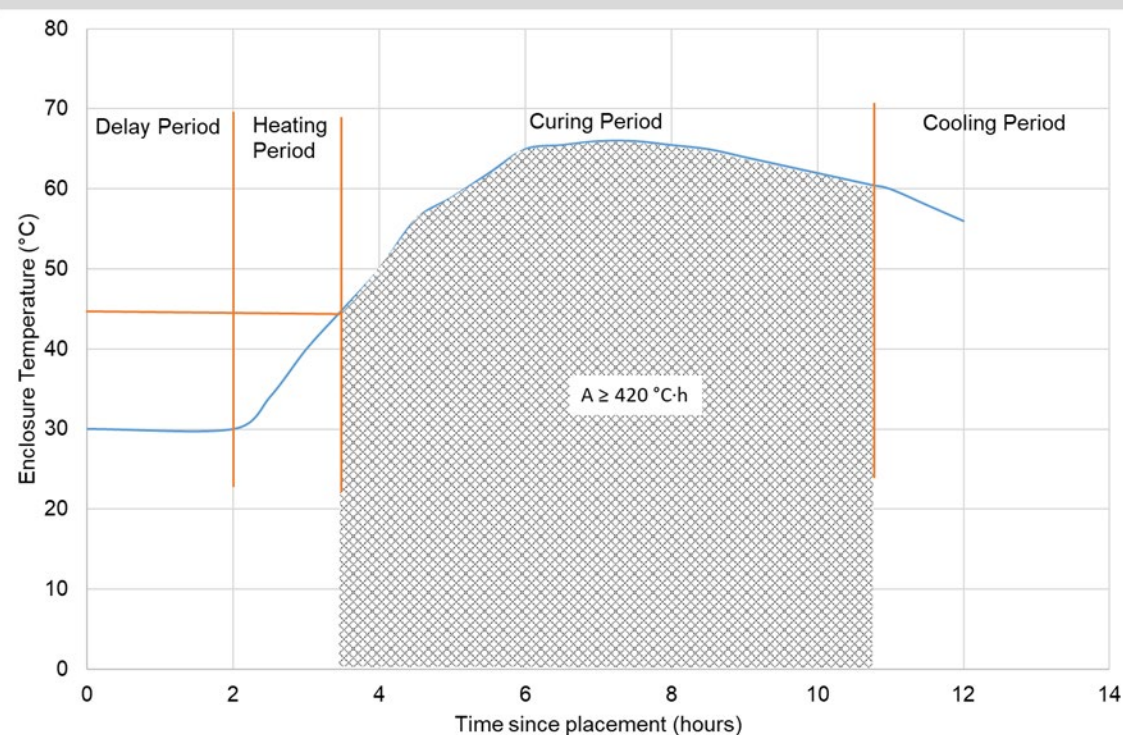
Cooling period

For products manufactured to MRTS73 *Manufacture of Prestressed Concrete Members and Stressing Units* transfer of prestress may be performed when the concrete external surface temperature of the units has cooled to 60°C and the design concrete transfer strength has been achieved.

For all products the enclosure shall not be removed until the surface temperature of the unit has cooled to within 40°C of the ambient air temperature. If a curing compound is to be applied (for example because 420°C h has not been achieved) the enclosure shall not be removed until the concrete surface cools to 40°C.

This chart exemplifies a compliant steam curing regime. Note that actual steam records require more data series (see Clause 16.7.4.9).

Curing compounds will be adversely affected by application to hot concrete surfaces.



The enclosure could be removed in this instance at 10.5 hours if the ambient temperature exceeded 20°C

16.7.4.7 Test cylinders (steam curing)

Curing of associated concrete test specimen cylinders shall be achieved by either:

- a) Placing all 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 heat input points and shall be distant at least half the width of the structural unit from these input 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, or

- b) Submerging all cylinders in a temperature matched curing (TMC) tank which is controlled by a thermocouple placed 100 mm below the surface at the largest cross-section of the member being cured. Where multiple units are being curing the TMC thermocouple shall be inserted into the youngest (last poured) element. The TMC shall be controlled within -10°C and $+2^{\circ}\text{C}$ of the thermocouple 100 mm below the surface. When the cylinders are placed into the TMC, the TMC tank temperature shall be equal to the concrete temperature. The TMC tank temperature shall be monitored using a thermocouple to ensure it matches the temperature 100 mm below the surface.

16.7.4.8 Test cylinders (hot water curing)

Curing of associated concrete test specimen cylinders shall be achieved by either:

- a) using a TMC tank as per Clause 16.7.4.7(b), or
- b) using a TMC tank as per Clause 16.7.4.7(b) but with the tank controlled by the outlet hot water temperature.

16.7.4.9 Submission of data

The following temperature records shall be submitted on one graph to the Administrator:

- a) Core and enclosure temperatures as per Table 16.7.4.4.
- b) Temperature 100 mm below the surface and TMC tank temperature if TMC is used.

16.8 Surface dressing of concrete

Prior to commencing concreting operations, the Contractor shall establish procedures and standards for surface dressing and repair of concrete.

Unless specified otherwise, concrete surfaces shall be free of honeycombing and pockets, and free of voids larger than 20 mm in lateral dimensions or 3 mm deep. Unrepaired cracking shall not exceed:

- a) 0.3 mm in width (B2 exposure classification and below)
- b) 0.15 mm in width (C1 exposure classification and above)
- c) 300 mm in any continuous length, or
- d) 300 mm cumulative length /m² in over a surface.

Where individual product specifications have different defect limits or crack limitations, those limits shall take precedence.

16.8.1 Formed surfaces

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) Where specified in the Drawings, surfaces shall achieve a Class 1 surface finish to AS 3610 (Figure B1) or be bagged as set out below within four hours of removal of formwork from each section of the concrete. Curing as specified in Clause 16.7 shall commence on completion of stripping or bagging as appropriate.

- c) 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.

16.8.1.1 Bagging to achieve required finish

Bagging shall be carried out by the following procedure:

- a) Produce a plastic grout mix consisting of equal parts of cement and fine sand passing a 0.600 mm test sieve, mixed with a suitable bonding additive and water.
An equivalent proprietary product (for example a fairing coat mortar) is a suitable alternative.
- b) Apply 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.
- c) Keep surface damp while this work is carried out.
- d) Remove surplus material while the initial application is still plastic.

16.8.2 Rectification of non-compliant surfaces

Where surfaces fail to meet the requirements of Clause 16.8, the following actions shall be undertaken: **Nonconformance**

- a) All pockets or honeycombed areas shall be cleaned out to sound concrete.
- b) Small voids, not more than 150 mm in lateral dimensions or 20 mm deep, shall be filled with a registered repair mortar with the same 28 day characteristic strength as the parent concrete, vibrated as necessary. The surface of the patches shall be finished flush with the adjacent formed surface.
- c) Large voids shall be formed and filled with vibrated concrete of the same mix design. An effective bonding agent on the interface shall be used.
- d) The repaired area shall be cured in accordance with Clause 16.7.

Repairs shall be a **Witness Point 7**

16.9 Construction 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 9**

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 the use of:

- a) sand-blasting techniques
- b) wire brushes, hand tools and pneumatic tools

- c) 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, or
- d) proprietary surface retarding agents followed by any of the above (sugar solutions are not to be used).

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.

Construction joints are not to be facilitated with permanent metal formwork, mesh or similar products.

16.9.1 Construction joints in marine and other aggressive environments

Construction joints in exposure classification C1 or C2, environments shall be prepared as follows:

- a) The surface of the joint shall be prepared as in Clause 16.9 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.
- b) Where practical the concrete surface shall be coated with a wet-to-dry epoxy resin, as approved by the Administrator, followed by placement of the fresh concrete before the epoxy on the interface has hardened. Alternatively the joint can be kept damp for a period of four hours before concrete placement against the joint.

17 Normal-class concrete

This clause applies to insitu and precast concrete elements, where the Drawings specify normal-class concrete.

17.1 Concrete class

The strength grade of concrete and maximum nominal aggregate size used shall be as specified on the Drawings.

17.2 Materials

17.2.1 Cementitious materials

All cement (except GL cement) shall comply with ATIC-SPEC SP43 and AS 3972. GL cement to AS 3972 is permitted.

Fly ash shall comply with ATIC-SPEC SP43 and AS/NZS 3582.1.

Slag shall conform to ATIC-SPEC SP43 and AS 3582.2.

Amorphous silica, including silica fume, shall comply with ATIC-SPEC SP43 and AS/NZS 3582.3.

17.2.2 Chemical admixtures

Admixtures shall conform to the requirements of AS 1478 and shall be used in accordance with AS 1379.

17.2.3 Concrete aggregate

Aggregate shall conform to AS 2758.1 and must satisfy the requirements for exposure classification as specified for the concrete application.

Where calcareous aggregate (both coarse and fine) is specified for concrete access and maintenance chambers for sewerage, or similar, applications the calcareous aggregate shall comply with the aggregate requirements in AS 4198.

Recycled crushed concrete and reclaimed aggregate may be used as a partial replacement of coarse aggregate up to 20% of the coarse aggregate component. The recycled crushed concrete shall comply with AS 2758.1 but with a water absorption less than 6% and shall contain less than 1% by mass of contaminants such as bricks, metals, plastics, and other demolition wastes.

Recycled crushed glass may be used as a partial replacement of fine aggregate up to 20% of the fine aggregate component. The recycled crushed glass shall comply with ATS 3050. The requirement to provide test certificates (**Hold Point 2 of ATS 3050**) is waived, however they shall be made available on request of the Administrator.

Note: ATS 3050 includes a Hold Point for submission of a Quality Plan. This plan may be a generic document produced by the crushed glass supplier.

17.2.4 Alkali reactive materials

Control of alkali aggregate reaction (including recycled aggregates) shall be either by using a blended cement in accordance with Clause 9.7.1 of this Technical Specification, or by testing of aggregates to AS 1141.60.1 with a result of non-reactive.

17.3 Curing compounds

Curing compounds shall comply with the requirements of AS 3799 and be registered products.

17.4 Storage of materials

Materials shall be stored in such a way as to prevent damage and degradation.

17.5 Concrete mix

The Contractor shall design and produce all normal-class concrete used in the Works. The use of pre-mixed concrete shall in no way lessen or remove this responsibility.

The Contractor shall ensure that the mix design is suitable for the particular application.

Concrete slump shall be nominated as appropriate for the intended application.

17.6 Batching, mixing and transport

Batching, supply and delivery of concrete shall comply with AS 1379.

17.6.1 Long distance travel and extended placement times

Where travel times are, by necessity, longer than 90 min as listed in AS 1379, a procedure for long-distance travel or extended placement times shall be submitted to the Administrator for approval six weeks before concreting begins. **Milestone**

Note that TN125 *Long distance transport and extended placement times for concrete* provides guidance on procedures for long distance travel.

Transporting dry cementitious material and aggregates together to site and then adding water is not permitted.

A trial mix shall be undertaken emulating the estimated travel time. The trial mix shall be tested, at intervals nominated by the Administrator, for:

- a) strength development (as measured by AS 1012.9)
- b) workability retention (slump, or spread, as measured by AS 1012.3), and
- c) extent of reaction (concrete temperature).

The concrete performance shall be assessed as satisfactory where:

- a) the strength complies with the specified performance requirements
- b) the workability (slump or spread) is maintained within the acceptable tolerance limits as per AS 1379 for the nominated time frame, and
- c) no increase in temperature other than expected due to ambient conditions is noted.

17.7 Acceptance and rejection of plastic concrete

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.

Consistency testing shall be undertaken in accordance with AS 1379.

Acceptance and rejection of plastic concrete shall be on a batch basis and in accordance with AS 1379.

Note that AS 1379 requires a consistence test every time a sample is taken for strength testing.

17.8 Acceptance and rejection of hardened concrete

Acceptance and rejection of hardened concrete shall be on a production assessment basis in accordance with AS 1379 except as noted below. Concrete for the following applications shall be tested on a project assessment basis, where more than 25 m³ of concrete is used:

- a) signpost footings and plinths with dimension greater than 150 mm
- b) spill through or rock grouting, and
- c) manually placed kerb and channel on or alongside concrete base.

Production assessment reports in accordance with AS 1379 shall be submitted to the Administrator.

Note that production assessment reports are statistical summaries of concrete strength results over a nominated production interval.

Project assessment (Clause 6.5 of AS 1379) requires sampling on the project site and testing 1 sample per 50 m³ of concrete.

17.9 Defects and rectification

Where normal-class concrete does not comply with the requirements of this specification, the unit or lot may, at the discretion of the Administrator, be rejected and replaced or undergo rectification.

This work shall be at the Contractor's expense.

The method of rectification shall be approved by the Administrator.

17.10 Falsework

Falsework shall conform to AS 3610.

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 10**

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

17.11 Formwork

All formwork shall be subject to inspection and approval by the Administrator. **Hold Point 11**

Formwork shall conform to AS 3610 and provide a Class 2 AS 3610 surface finish, except as otherwise specified.

17.11.1 Supports (bar chairs and spacers)

All bar chairs and spacers shall comply with AS/NZS 2425.

17.11.2 Joint formers

Where permitted by the Administrator, cast-in joint formers for expansion, isolation and contraction joints in slab-on-ground construction shall either be stainless steel, galvanised to AS/NZS 4680 or manufactured from durable polymers. Cast-in crack inducers are not permitted.

Cast-in joint formers for construction joints are not permitted.

17.12 Placing and compacting concrete

17.12.1 General

No concrete shall be placed in the Works until: **Hold Point 12**

- a) the formwork and reinforcement have been inspected, and
- b) all foreign material has been completely removed from the forms.

The Administrator may revert this Hold Point to a Witness Point.

The placing operation shall be conducted in the presence of the Administrator **Witness Point 8** and the Contractor shall give at least 24 hours notice to the Administrator of the time that placing shall start.

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.

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. If puncturing or tearing occurs, 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.

17.12.2 Compaction of concrete

Concrete shall be compacted to achieve dense and durable concrete, to the levels and tolerances specified.

17.13 Tolerances

17.13.1 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 this section.

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

Note that additional tolerances for individual products may be listed in the relevant Technical Specification.

17.13.2 Dimensional tolerances

The tolerances given in Table 17.12.2 are to ensure strength, durability and fit of cast-insitu elements.

Table 17.12.2 – 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 |

17.13.3 Positional tolerances

Positional tolerances, listed in Table 17.12.3, 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 17.12.3 – Positional tolerances

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

17.13.4 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 17.12.4.

Table 17.12.4 – Relative tolerances

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

17.14 Finishing operations

17.14.1 General

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

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.

17.14.2 Prevention of cracking

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

17.14.3 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.

17.14.4 Special finishes

Special finishes shall be as detailed in the Drawings.

17.15 Curing

17.15.1 General

Curing periods shall be in accordance with AS 3600 Table 4.4.

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

17.15.2 Water curing

Surfaces shall be kept moist for the period specified by continuous spraying, ponding, wet hessian or wet sand blankets.

17.15.3 Membrane curing

Membrane curing shall be effected by application of a sprayed curing compound (refer to Clause 17.2.5) or by covering with polythene sheet.

For sprayed curing compounds, two coats shall be applied with each coat at a rate of 0.2 L/m².

17.16 Early loading

No loads including loads from backfilling shall be placed on the structure for seven days and until testing as required by the Designer indicates sufficient strength has been reached.

17.17 Removal of formwork

For cast-in-situ concrete, forms, falsework and centring shall remain in position until 72 hours has elapsed. **Hold Point 13** Precast concrete shall not be removed from the formwork or formwork stripped until 40% of f_c is attained.

17.18 Surface dressing of concrete

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

Concrete surfaces shall be free of honeycombing and pockets and free of voids larger than 20 mm in lateral dimensions or 3 mm deep.

17.18.1 Formed surfaces exposed to view

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) Where specified in the Drawings, surfaces shall achieve the required surface finish to AS 3610.
- c) Where surface finish is not specified in the Drawings, a Class 2 surface finish to AS 3610 is required. Repairs shall be a **Witness Point 9**
- d) Non-structural elements to be covered (such as blinding concrete) shall be Class 3 surface finish to AS 3610.

17.19 Construction joints

Construction joints shown in the Drawings are mandatory.

18 Special-purpose concretes

Concrete designated on the Drawings as one of the following types shall comply with Clause 17 as amended or added to in the following clauses.

These concretes are not normal-class as defined by AS 1379 but are also not considered high risk.

18.1 No-fines concrete

This clause applies to concrete produced with no fine aggregate portion.

18.1.1 Cementitious content

Limits for no-fines concrete are as per Table 18.1.1. For no-fines concrete, the water shall be the minimum amount required for cement hydration, noting that excess water will lead to cement paste not adhering to the aggregates.

Table 18.1.1 - Minimum cementitious contents for no-fines concrete

| Concrete Type | Minimum Cementitious Content (kg/m ³) |
|---------------------------|---|
| No-fines Concrete (10 mm) | 250 |
| No-fines Concrete (20 mm) | 210 |

No-fines concrete is not recommended for use where (potential) acid sulfate soils are present.

18.1.2 Aggregate grading

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 18.1.2.

Table 18.1.2 – Aggregate grading for no-fines concrete

| Test 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 |

18.1.3 Compaction of no-fines concrete

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.

18.2 Kerb and channel concrete

This clause applies to concrete produced for kerb and channel, whether manually placed or machine placed.

18.2.1 General

Kerb and channel shall be supplied in accordance with MRTS03 *Drainage Structures, Retaining Structures and Embankment Slope Protections* and AS 2876.

18.2.2 Compressive strength and cementitious content

The required characteristic compressive strength or minimum cementitious content shall be determined by the Designer.

18.2.3 Acceptance of hardened concrete

Where concrete is specified by compressive strength, acceptance shall be determined in accordance with Clause 17.8.

Where concrete is specified by minimum cementitious content, acceptance shall be on the basis of examination of:

- a) concrete mix design, and
- b) batch records (one per lot).

18.3 Shotcrete

Shotcrete shall comply with MRTS272 *Shotcrete for Aboveground Applications*.

18.4 Controlled low strength material (flowable fill)

Controlled Low Strength Material (CLSM) shall be supplied to meet a specified strength range. Slump shall be nominated as between 180 and 200 mm.

Care shall be taken during placement to avoid floatation or dislodgement of conduits, pipes and formwork.

Technical Note 187 *Controlled Low-Strength Material for Pipe Installation* describes CLSM for pipe installation.

MRTS04 *General Earthworks* nominates what strength is required for different backfill operations.

18.5 Lean mix concrete

Lean mix concrete shall be supplied to meet either a specified strength range or a specified component ratio (e.g. ten parts aggregate to one part cementitious material). Slump shall be nominated to meet the specified or nominated placement procedure.

Concrete shall not be discharged onto the ground for later inclusion into the Works.

Mix designs are not required to be submitted to prove component ratios. These may be checked at batch plant audits.

Appendix A: Acceptance of hardened concrete

This Appendix is an example of assessing strengths in accordance with Clauses 12.3 and 12.5.

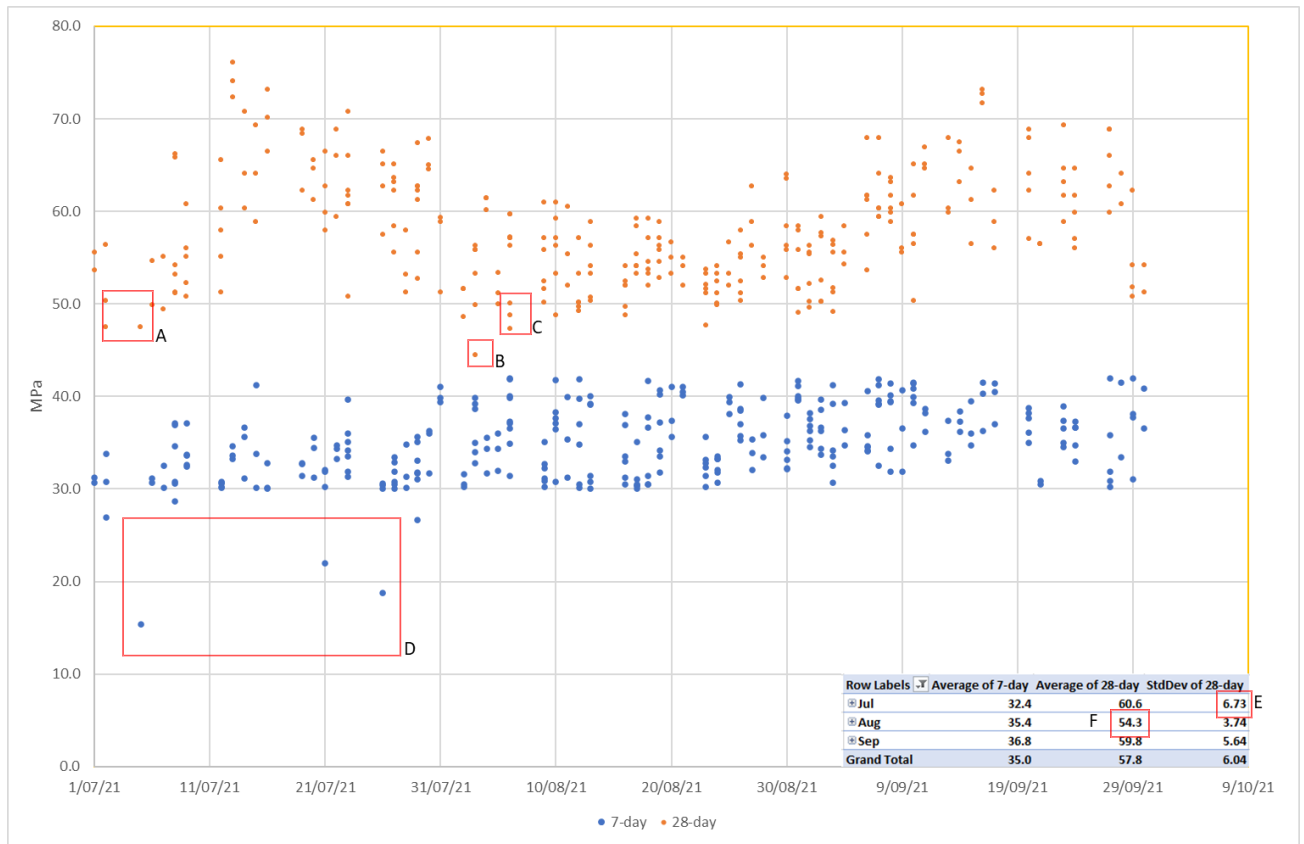
Let $f'_c = 40$ MPa

| Docket | Lot | Date Cast | 28 day Cylinder 1 | 28 day Cylinder 2 | 28 day | Average (3) |
|--------|-----|-----------|-----------------------|----------------------|-----------------------|-------------------------|
| 0001 | 1 | 1/7/2018 | 51 | 56 | 56 | |
| 0002 | 2 | 2/7/2018 | 32 | 35 | 35¹ | |
| 0003 | 3 | 3/7/2018 | 53 | 55 | 54 | 48.3 |
| 0004 | 4 | 4/7/2018 | 54 | 54 | 54 | 47.7 |
| 0005 | 4 | 4/7/2018 | 35² | 41 | 41 | 49.7 |
| 0006 | 4 | 4/7/2018 | 40 | 42 | 41 | 45.3 |
| 0007 | 4 | 4/7/2018 | 37 | 37 | 37 | 39.7³ |
| 0008 | 4 | 4/7/2018 | 52 | 54 | 53 | 43.7 |
| 0009 | 5 | 5/7/2018 | 49 | 54 | 54 | 48 |
| 0010 | 6 | 6/8/2018 | 40 | 43 | 43 | 50.0 |
| 0011 | 6 | 6/8/2018 | 44 | 46 | 45 | 47.3 |
| 0012 | 6 | 6/8/2018 | 43 | 43 | 43 | 43.7 |
| 0013 | 6 | 6/8/2018 | 41 | 41 | 41 | 43.0 |
| 0014 | 7 | 8/8/2018 | 42 | 42 | 42 | 42.0 |
| 0015 | 7 | 8/8/2018 | 50 | 52 | 51 | 44.7 |
| 0016 | 7 | 8/8/2018 | 41 | 43 | 42 | 45.0 |
| 0017 | 7 | 8/8/2018 | 37 | 41 | 41 | 44.7 |
| 0018 | 8 | 10/8/2018 | 38 | 40 | 39 | 40.7 |
| 0019 | 8 | 10/8/2018 | 43 | 46 | 46 | 42.0 |
| 0020 | 8 | 10/8/2018 | 51 | 53 | 52 | 45.7 |

1. Reject Lot 2: $\sigma < 0.9 f'_c$
2. Not a cause of rejection, cylinder is excluded
3. Reject Lot 4: $\bar{\sigma} < f'_c$

Appendix B: Monitoring of concrete strengths

This appendix is an example of monitoring concrete strengths in accordance with Clause 12.4. Data points represent sample (not cylinder) results.



Let specified $f_c = 50$ MPa, $f_t = 59.9$, nominated standard deviation = 6 (default).

For red rectangles:

At (A): Nonconformance. Average of three results below f_c

At (B): Nonconformance. Single result below $0.9 f_c$

At (C): Nonconformance. Average of three results below f_c

At (D): Investigation required. 7 day results are not used for compliance, but these are unusual.

Possible mix or testing issue (noting only one cylinder is crushed for each).

At (E): Standard deviation is above that nominated. Mix design approval can be withdrawn.

At (F): Average 28 day strength closer to f_c than f_t . Mix design approval can be withdrawn.

