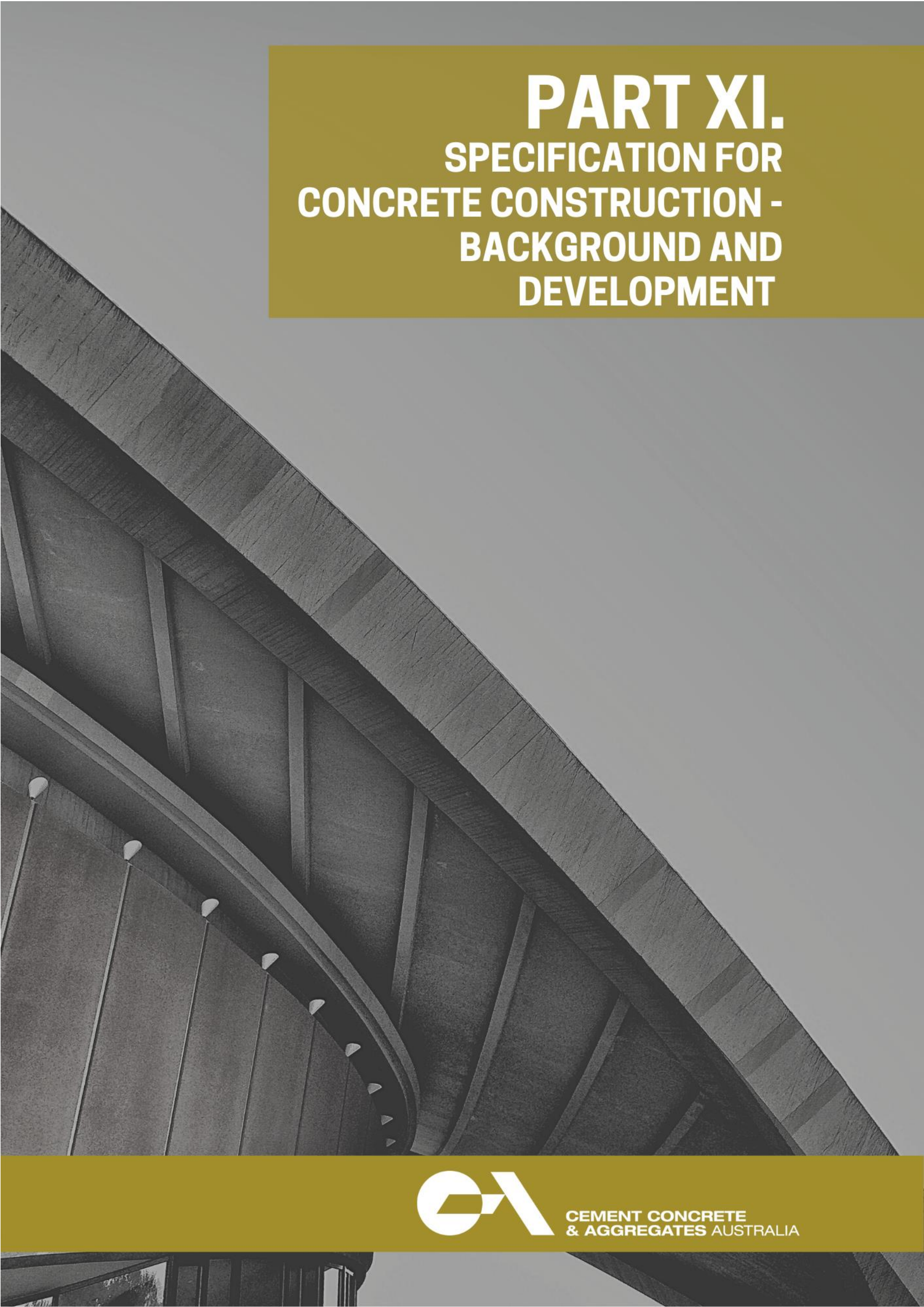
PART XI.
SPECIFICATION FOR CONCRETE CONSTRUCTION - BACKGROUND AND DEVELOPMENT



CEMENT CONCRETE & AGGREGATES AUSTRALIA

CONTENTS

1. INTRODUCTION

1.1 USE OF THIS DOCUMENT

This specification has been developed in good faith and is based on current Standards and industry practices. The use of concrete in structural applications is very broad and the Specification cannot realistically cater for every possible concrete end-use. While every effort has been made to ensure that Specification details are correct and appropriate, there may be certain circumstances where alternative approaches are required. If there is any uncertainty about the applicability of this Specification for any particular project or structure, then additional advice should be sought.

1.2 REFERENCE DOCUMENTS

ASTM defines a specification document as follows:

- An explicit set of requirements to be satisfied by a material, product, system, or service;
- Usually forms part of a contract.

Every project has a unique set of drawings and associated contractual and technical documentation. Similarly, every project needs a unique specification which identifies the project requirements not included on the drawings. Together, the drawings and the specification describe outcomes that the Contractor is expected to deliver for the project. Specifications can either be written as prescriptive – containing all information required for the project – or provide references to the relevant standards and codes of practice to be applied or apply a combination of the two approaches.

There is a general classification of information used in project construction and delivery that has a hierarchy of importance from a legal perspective. The concrete specification forms part of that documentation. In terms of the hierarchy of documents referenced in a specification, the contained information is classified as follows.

Codes (may be referred to as Regulation)

- Top level document sometimes linked to an Act of Parliament;
- Call up Australian Standards: Primary or Secondary.

Examples include:

- Building Code of Australia;
- National Construction Code.

Standards

- These are published documents that generally provide the minimum acceptable standards of a material quality, design method, test method, construction system or finished product;
- Set out procedures designed to ensure products, services and systems are safe, reliable and consistently perform the way they are intended to;
- Can form part of a contract;
- Development of these documents is complex and there are strict procedures involved with their production and review.

Guides

- Published technical reference;
- Industry or issue specific 'best practice';
- Used to support specifier, contractor or supplier position.

This document provides a framework for the development of project-specific specifications for concrete with a checklist detailed below that covers the elements that should be included in the development of the specification:

- General requirements;
- Scope of specification;
- Interpretation;
- Referenced Documents including Codes of Practice;
- Australian Standards;
- International Standards where applicable in Australia;
- Technical Guidance Notes;
- Definitions;
- Inspection, testing and submittals;
- Concrete and Concrete Component Material specifications;
- Reinforcing Steel, Fibres and Post-Tensioning;
- Concrete Supply and Delivery;
- Other materials required in the construction of concrete structural elements;
- Execution;
- Formwork as it relates to the finished concrete in place;
- Placing and Fixing Reinforcing Steel;
- Placing and Fixing Post-Tensioning;
- Concrete Pumping, Placement, Compaction, Finishing and Curing;
- Concrete Testing;
- Other requirements that are specific for a particular concrete application;

In addition to the above, the following items may be nominated in the specification if applicable:

- Portland and blended cement type;
- Concrete temperature limitations;
- Requirements for supplementary cementitious materials;
- Type and properties of reinforcing steel;
- Stripping agent requirements;
- Approval of constituent materials;
- Methods for assessment of finished concrete surfaces.

Concrete is utilised in many different structural applications and so this list cannot cover every application. Additional information may be required to meet specifics of a given project. Similarly, a number of items in this document may not need to be included within a specification if they are not applicable to a specific case. For example, details of post-tensioning would be inappropriate to include for a structure that only utilises conventional reinforcement.

This document may refer to information in other Sections of the Guide. CCAA have also developed technical notes ('Data sheets') that may also be referenced (refer to references list at the end of this document).

The Guide document also contains a '*Glossary'* section that aids the user in providing definition of words or phrases that may be specific to concrete construction and/or have meaning that is not widely understood.

In this document, the relevant elements of a concrete specification are suggested with guidance on what can be included in each section/sub-section. Text included in *italics* is used to demonstrate examples of wording that may be appropriate in the situations defined in the text. Such examples should not be interpreted as being correct or appropriate for all circumstances.

2. DEFINITION OF TERMS

The terms and symbols used in this document will be as defined in the '*Glossary'* section of the Guide to Concrete Construction. It is generally useful to include a glossary or definition of terms in any concrete specification and this can follow a similar, tabular format to that used in the Guide '*Glossary'*.

3. REFERENCE DOCUMENTS

When developing a specification, it is important to define the reference documents and versions used in relation to the specification. These documents can be Codes of Practice, Australian Standards, International Standards, Guides, or possibly other publicly available specifications that are relevant to the construction project (e.g. a Local Government specification).

4. STANDARD TEST METHODS

As there are many ways of testing the same property of concrete there needs to be clarity about the methods that are required to be used. A simple way to do this in a project specification is to tabulate this information as noted in the following example.

*The standard test methods stated in **Table XI.1** shall be used in this Specification.*

Further details of test numbers and test descriptions are given in the following sections of this specification.

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.

5. QUALITY SYSTEM REQUIREMENTS

This section provides a 'roadmap' to the special quality system requirements that relate to the particular project and can include:

- Submittals;
- Hold Points;
- Witness Points;
- Milestones.

It is common practice to highlight these points in the specification document by adding '**HOLD POINT**', '**WITNESS POINT**' or '**MILESTONE**' to the end of a relevant paragraph in the specification document.

These quality system requirements are defined in the following table overleaf.

5.1 SUBMITTALS, HOLD POINTS, WITNESS POINTS AND MILESTONES

Submittals

Submittals are a part of each of Hold Points, Witness Points and Milestones. Submittals include all documentation and records that the contractor, or sub-contractor, must provide to demonstrate compliance with the Drawings and Specification. These requirements will be dependent on the scope of work.

Hold Points

Hold Points are a mandatory verification point beyond which work cannot progress without approval by the designated authority, typically the Engineer or Consultant or Third-Party Inspector. Some common hold points in concrete construction may include:

- Formwork & Falsework design certification;
- Formwork & Falsework execution certification;
- Formwork & Falsework calculations;
- Re-shoring details;
- Formwork removal documentation;
- Special class concrete mix design approval;
- Approval of concrete placing, compaction, finishing and curing procedures;
- In some cases, verification of special class concrete trial mix test results (such as drying shrinkage, creep testing, various durability tests as well as standard tests called for in AS 1379).

Witness Points

Witness Points are identified points in the process where the designated authority, typically the Engineer or Consultant or Third-Party Inspector may review, witness, inspect the method or process of work. The activities, however, may proceed. Some common witness points in concrete construction may include:

- A trial mix of special class concrete;
- Placing and compaction of concrete;
- Finishing and curing of concrete;
- Possibly repair of hardened concrete.

Milestones

Milestones are tools used in project management to mark specific points along a project timeline. These are generally time-based and relate to the critical path of the construction plan. Some common milestones in concrete construction may include:

- Timing of the submission of proposed

concrete mix designs;

- Submission of hot or cold weather concrete placing and finishing procedures;
- Submission of falsework and formwork drawings;
- Submission of underwater concrete placement procedure;
- Submission of concrete curing procedure;
- Submission of heat-accelerated curing procedure.

Table XI.1 – Standard Test Methods

Property to be Tested	***Standard Test Method***
Alkali-Silica Reactivity	*AS 1141.60.1 and AS 1141.60.2*
Chloride ion content (water-soluble)	*AS 1012.20.2*
Crushed particles	*AS 1141.18*
Flakiness index	*AS 1141.15*
Light particles	*AS 1141.31*
Material finer than 2 µm	*AS 1141.13*
Material finer than 75 µm	*AS 1141.12*
Particle density and water absorption	*AS 1141.5 and AS 1141.6.1*
Particle size distribution	*AS 1141.11.1*
Weak particles	*AS 1141.32*
Wet Strength	*AS 1141.22*
Sugar content of Aggregate	*AS 1141.35*
Wet / Dry Strength Variation	*AS 1141.22*
Compressive strength	*AS 1012.8.1 and AS 1012.9*
Slump	*AS 1012.3.1*
Mass per unit volume	*AS 1012.5*
Slump Spread	*AS 1012.3.5*
Visual stability index	*ASTM C1611*

5.2 CONSTRUCTION PROCEDURES

The contractor will be required to submit their quality procedures and related quality plans to the designated authority. A simple way to do this in a project specification is to tabulate the location of the requirements of these procedures in the project specification as noted in the following example.

*The Contractor shall prepare and submit, to the designated authority, documented procedures for construction processes in accordance with the quality system requirements of the Contract. These processes are listed in **Table XI.2**.*

Table XI.2 – Construction Procedures

Procedure	***Specification Clause***
Batching and mixing of concrete	*10*
Hot weather concreting	*13*
Temperature monitoring (large elements and/or high cementitious contents)	*16.6*
Placement under water	*16.7.1*
Curing of concrete	*16.12*
Surface treatment of hardened concrete	*15.17, 16.10, 17.8*

5.3 CONFORMANCE REQUIREMENTS

The specification will cover a number of requirements for conformance in the project specification. It is useful to locate these in the project specification by tabulating the location of the conformance requirements of concrete, concrete constituents and finished concrete in the project specification as noted in the following example.

*The conformance requirements which apply to work covered by this Specification are summarised in **Table XI.3**.*

Table XI.3 – Conformance Requirement

Procedure	***Specification Clause***
Concrete constituent materials	*7, 15.2, 16.2, 17.2*
Plastic concrete properties	*9.1, 9.2, 11, 15.6*
Hardened concrete strength	*12, 15.7*
Concrete temperature	*16.6, 17.4*
Dimensions and levels	*15.12, 16.8, 17.6*
Surface finish of concrete	*15.13, 16.11*
Surface condition	*15.17, 16.10, 17.8*
Heat-accelerated concrete	*17.9.1*

5.4 TESTING FREQUENCY

The concrete specification should detail the minimum testing frequency requirements for concrete and in some cases may require testing frequency of some or all of the concrete constituents. In most cases these frequencies can be guided by the Australian Standards but in some cases of special class concrete used in critical works higher frequencies may be required.

For normal class concrete the testing frequency should be guided by AS 1379 requirements. For all other special class concrete the requirements of AS 1379 may be used but section 12 discusses specifying alternative test frequencies to those in AS 1379.

6. CONCRETE CLASS

This section considers three types of concrete classifications:

- Normal Class concrete as defined in AS 1379;
- Special Class concrete as defined in AS 1379;
- Special Class Precast concrete.

The Special Class Precast concrete is a particular case of Special Class as the curing method and typical mix designs are designed for higher early strength and warrant particular quality plans to manage them.

6.1 MIX DESIGNATION

The specification should give guidance on the designation of concrete mixes to be used.

When normal class concrete is specified it is required to specify the following when ordering in accordance with AS 1379:

- Concrete strength grade (one of N20, N25, N32, N40 or N50). Higher strength grades are deemed to be special class concrete;
- Concrete target slump (between 20 mm and 120 mm in 10 mm increments);
- Maximum aggregate size (one of 10 mm, 14 mm or 20 mm). Other maximum aggregate sizes are deemed to be special class concrete;
- Method of placement and type of equipment (e.g. Pump, crane and bucket, conveyor etc.);
- Target air content up to 5.0% (if specified for freeze/thaw durability).

There are other properties of concrete that are associated with normal class concrete detailed in AS 1379 that are assumed if normal class concrete is specified.

A common method of designating a normal class concrete is 'Strength grade/Max Aggregate size/Target slump/Placing method'. In the case of a normal class concrete with characteristic strength of 32 MPa, a target slump of 80 mm and maximum aggregate size of 20 mm and concrete to be placed by concrete pump, the designation would be '32/20/80/P'.

In many cases the specifier will leave it up to the construction contractor to specify the concrete slump and placing method and in this situation the specification may remain 'silent' on these requirements.

When special class concrete is required the designation will be more complex as the special requirements of the concrete will need to be defined fully by the specifier who will need to develop a suitable designation method. As a guide to this AS 1379 details the following prefixes to strength grade:

- S – Used for compressive strength specified mixes;
- SF – Used for flexural strength grades;
- ST – Used for indirect tensile strength specifications;
- SB – Used for durability exposure classification 'B2' (refer to AS 3600);
- SC – Used for durability exposure classification 'C1 & C2' (refer to AS 3600);
- SU – Used for durability exposure classification 'U' (refer to AS 3600).

6.2 NORMAL CLASS CONCRETE

Concrete designated in the specification as normal class will be required to comply with the requirements of section 15.

6.3 SPECIAL CLASS CONCRETE

Concrete designated in the specification as special class will be required to comply with the requirements of section 16.

6.4 SPECIAL CLASS PRECAST AND PRESTRESSED PRECAST CONCRETE

Concrete designated in the specification as special class precast and prestressed precast will be required to comply with the requirements of section 17.

7. MATERIALS

Concrete is composed of cement or blended cement (including SCM's), fine aggregate, coarse aggregate, admixtures, additives (if approved by the specifier), and water, proportioned and mixed as detailed in accordance with AS 1379 unless varied by this specification for specific special class concrete. All constituent materials will be required to conform to relevant Australian Standards unless varied by the specifier in the concrete specification.

It is general practice that, where a specifier provides or specifies a full or partial mix design for a special class prescription concrete, the mass of coarse and fine aggregates are measured in a saturated surface dry condition (SSD) and usually based on a quantity per cubic metre of concrete.

7.1 CEMENT

This clause should be amended to include the type of cement preferred and the relevant standard that it is required to comply with. Typically, the type of cement may be specified according to AS 3972 from the following list:

- Type GP: General Purpose Portland;
- Type GL: General Purpose, Limestone blend;
- Type GB: General Purpose Blended;
- Type HE: High Early Strength;
- Type LH: Low Heat;
- Type SR: Sulfate Resisting;
- Type SL: Shrinkage Limited.

The most commonly used cement in Australia is Type GP (General Purpose) cement. Type GP cement is often blended with supplementary cementitious materials at the concrete plant to obtain the required mix properties, but blends are also produced by cement manufacturers as Type GB (General Purpose Blended cement). Other cements have special purposes as suggested by the list above and further information on these are available in the Guide, Part II, Sections 1 and 2.

A simple wording of a clause for this section is given in the following:

General purpose and blended cement shall comply with the requirements of AS 3972 or NZS 3122, 3123 or 3125. Type GP or GB cements shall be used unless otherwise specified or approved by the specifier.

Supplementary cementitious materials used in Type GB, Type LH, Type SR or Type SL cements shall comply with AS/NZS 3582.1, AS 3582.2 or AS/NZS 3582.3.

Acceptable cementitious products must hold a valid registration number issued by CemAssure Limited, or other third-party cementitious materials conformance assessment system as shall be demonstrated to be directly equivalent to CemAssure, endorsed by JAS-ANZ or equivalent, and approved as such in writing by the specifier.

Evidence of compliance with this clause must be obtained when contract bids are received.

Where 'special purpose' cements required in specialised concrete mixes (such as Type HE used in Special Class precast concrete) are to be supplied to a project then this is best tabled as noted in section 9.

7.2 SUPPLEMENTARY CEMENTITIOUS MATERIALS

Concrete mixes often use supplementary cementitious materials (SCM's) as part of a mix binder combination with cement. The common SCM's used in Australia are:

- Fly ash;
- Ground Granulated Blast Furnace Slag;
- Amorphous Silica;
- A blend of two or three of the three SCM types.

The following examples provide guidance on the compliance requirements for these materials. In each case their use may be required for various special purposes such as:

- Improve durability for concrete in aggressive environments;
- Reduce temperature rise in placed concrete;
- Reduce the risk of Alkali-Silica Reaction;
- Improve the plastic properties of concrete.

In each case there is a need to demonstrate that the performance characteristics of the concrete will be achieved. This can be achieved by verifying the results of trial mixes on concrete using these SCM's or verification of concrete supplier production data where the particular mix is routinely supplied and tested.

Examples of wording of clauses for use of SCM's are provided in sub-sections 7.2.1 to 7.2.4.

7.2.1 Fly Ash

Fly ash used shall comply with AS/NZS 3582.1 and be Special Grade or Grade 1 as defined by the Australian Standard. In addition to this, the achievement of AS 1379 minimum seven-day strength requirements and any specified properties of concrete mixes containing the design fly ash proportion of binder must be demonstrated by trial mixes or production test data for this concrete mix. Tests verifying compliance of the fly ash to the Standards shall be submitted to the designated authority with the proposed mix designs.

7.2.2 Ground Granulated Blast Furnace Slag

Ground granulated blast furnace slag shall conform to AS 3582.2. In addition to this, the achievement of AS 1379 minimum seven-day strength requirements and any specified properties of concrete mixes containing the design slag proportion of binder must be demonstrated by trial mixes or production test data for this concrete mix. Tests verifying compliance of the slag to the Standards shall be submitted to the designated authority with the proposed mix designs.

7.2.3 Amorphous Silica

Amorphous silica shall conform to AS/NZS 3582.3. In addition to this, the achievement of AS 1379 minimum seven-day strength requirements and any specified properties of concrete mixes containing the design amorphous silica proportion of binder must be demonstrated by trial mixes or production test data for this concrete mix. Tests verifying compliance of the amorphous silica to the Standards shall be submitted to the designated authority with the proposed mix designs.

7.2.4 Cementitious Blends

Where a blend of two or more of the SCM's are used, each component of the blend shall conform to the relevant Standard as noted in sub-sections 7.2.1 to 7.2.3. In addition to this, the achievement of AS 1379 minimum seven-day strength requirements and any specified properties of concrete mixes containing the *design SCM blend proportion of binder must be demonstrated by trial mixes or production test data for this concrete mix. Tests verifying compliance of the SCM blend to the Standards shall be submitted to the designated authority with the proposed mix designs.*

Acceptable cementitious products must hold a valid registration number issued by CemAssure Limited, or other third-party cementitious materials conformance assessment system as shall be demonstrated to be directly equivalent to CemAssure, endorsed by JAS-ANZ or equivalent, and approved as such in writing by the specifier.

7.3 WATER

Mixing water shall be deemed to be of acceptable quality if (a) test results and service records of concrete made with that water indicate that it is not injurious to the strength or durability of the concrete or of the materials embedded in it; or (b) it has been suitably tested in a laboratory and the test results are within limits given in AS 1379.

Further information on water quality is available in the Guide, Part II, Section 4.

A simple wording of a clause for this sub-section is given in the following:

Water used in the manufacture of concrete shall meet the requirements of AS 1379. Tests verifying compliance of the water to AS 1379 shall be submitted to the designated authority with the proposed mix designs.

7.4 CHEMICAL ADMIXTURES

Chemical admixtures are used in concrete with the aim of benefitting placement and strength development of the concrete. For example, in climates subjected to freezing and thawing, air-entraining agents are recommended to improve the durability of the exposed concrete surfaces.

Appropriate admixture use should be proposed by the Contractor and these should be permitted provided the placed concrete meets design requirements. In some cases, a specifier may require a particular type of admixture or admixture combination where it is used to achieve proven properties of the concrete.

An example of simple wording for this clause is given in the following:

Chemical admixtures shall comply with the requirements of AS 1478.1 and shall be used in accordance with Appendix B of that Standard. Admixtures shall not contain chlorides, or any other substance detrimental to concrete or reinforcing steel. Technical data sheets for each chemical admixture shall be submitted to the designated authority with the proposed mix designs.

7.5 CONCRETE AGGREGATES

This clause should specify the compliance of aggregates for the concrete mix, the test procedure and the associated limits where alternatives are provided in AS 2758.1.

For coarse aggregate, the maximum aggregate size must be specified.

Where the potential for Alkali-Aggregate Reaction risk is suspected, strategies to minimise the risk should be specified in accordance with AS HB 79 '*Alkali-Aggregate Reaction – Guidelines on Minimising the Risk of Damage to Concrete Structures in Australia*'. This publication will help a specifier to understand the practical issues raised by this phenomenon.

Typical strategies will depend on the relative risk of failure in the structure and may include:

- Limits to the total mass of reactive alkali in the concrete;
- Use of minimum levels of supplementary cementitious materials; and/or
- Testing of proposed aggregates and/or mix designs.

Detailed information on aggregates is available in the Guide, Part II, Section 3. Examples of wording of clauses for specification of aggregates are provided in sub-sections 7.5.1 and 7.5.2

7.5.1 Coarse Aggregates

*Coarse Aggregate shall conform to AS 2758.1 unless specified otherwise. Each type and source of aggregate shall be tested separately. Testing of coarse aggregate for use in concrete shall be carried out as detailed in **Table XI.4** and preliminary test results on coarse aggregates submitted to the designated authority with the proposed mix designs.*

Table XI.4 – Coarse Aggregate Testing

Test Method	***Testing Standard***	***Acceptable Limits***
Grading	*AS 1141.11.1*	*AS 2758.1 App. B*
Flakiness Index	*AS 1141.15*	*<35%*
Particle Density	*AS 1141.6.1*	*2.1-3.2 T/ m^3*
Water Absorption	*AS 1141.6.1*	*<3.0%*
Wet Strength	*AS 1141.22*	*>100 KN*
Wet/Dry Variation	*AS 1141.22*	*<25%*
Alkali Reactive Materials	*AS 1141.60.1 AS 1141.60.2*	*AS HB 79 Non-reactive*
Weak Particles	*AS 1141.32*	*<0.5%*

7.5.2 Fine Aggregates

*Fine Aggregate shall conform to AS 2758.1 unless specified otherwise. Each type and source of aggregate shall be tested separately. Testing of fine aggregate for use in concrete shall be carried out as detailed in **Table XI.5** and preliminary test results on fine aggregates submitted to the designated authority with the proposed mix designs.*

Table XI.5 – Fine Aggregate Testing

Test Method	***Testing Standard***	***Acceptable Limits***
Grading	*AS 1141.11.1*	*AS 2758.1 App. B*
Material finer than 75 microns	*AS 1141.12*	*<5% Nat. Sand <20% Man. Sand*
Particle Density	*AS 1141.6.1*	*2.1-3.2 T/ m^3*
Water Absorption	*AS 1141.6.1*	*<3.0%*
Chloride Content	*AS 1012.20.2*	*<0.008%*
Sulfate Soundness	*AS 1141.24*	*<6.0% Loss*
Alkali Reactive Materials	*AS 1141.60.1 AS 1141.60.2*	*AS HB 79 Non-reactive*
Deleterious Fines Index	*AS 1141.66*	*<150*
Organic Impurities	*AS 1141.34*	*Lighter than standard*

7.6 CONCRETE ADDITIVES, COLOURS AND FIBRES

Some Special Class concrete mixes may be required to contain various forms of solid additives that are not covered by sub-sections 7.1 to 7.5. These may include, but are not limited to:

- Solid mineral additives such as clays, chemical additives not covered by AS 1478.1 and cementitious materials not detailed in sub-sections 7.1 and 7.2;
- Colouring Oxides;
- Fibres – both steel and synthetic types.

The specifications of these are discussed in the following sub-sections.

7.6.1 Solid Mineral Additives

In some circumstances, materials are added to concrete to produce an enhancement of the concrete plastic properties or hardened properties. In the case that these materials do not have a relevant Standard for their use in concrete then the supplier will be required to warrant their use and recommend appropriate dose rates for the material in the concrete mix. This recommendation should be supported by trial mix and test data.

7.6.2 Colours

If coloured concrete is required and the colour is achieved through cement colour, the type of cement to be used (e.g. Off-White, White or grey) and possibly the cement source should be specified. The availability of colours should be checked prior to specification. Normally it is sufficient to nominate a particular manufacture's colour without specifying a dosage rate. Often a particular cement colour is combined with pigments to produce the required colour. The responsibility for producing the colour with the specified concrete mix then rests with the concrete supplier. For colours outside the standard range, a dosage rate for the specific concrete mix may need to be established via test panels. Acceptance of test panels will be subject to approval by the specifier or the designated authority.

Examples of simple wording for this clause are given in the following:

The concrete shall incorporate [specify colour of cement] from [specify producer] and shall incorporate [specify pigment product and supplier] pigment at a dosage rate of [quantity % by weight of cement].

The concrete shall incorporate [specify colour of cement] from [specify producer] and [specify pigment product and supplier] pigment at a dosage rate of [quantity % by weight of cement].

7.6.3 Fibres

In some forms of special class concrete fibres are incorporated to provide improved properties of the plastic or hardened concrete. Care should be taken to ensure that the fibres most appropriate for the application are used. The supplier, fibre type and dose rate or concrete fibre reinforced concrete performance requirements should be specified in addition to the relevant material standards for the fibres.

In the case of structural synthetic fibres or steel fibres the expected minimum properties of the concrete incorporating these fibres may be specified. These properties may include minimum tensile strength at various CMOD values (refer AS 3600 or EN 14651).

Information regarding specification of fibres is available in the Guide, Part I and Part II, Section 7.

Examples of typical wording for this clause are given in the following:

The concrete shall incorporate [specify fibre product and supplier] at a dosage rate of [quantity kg per m^3 of concrete].

Properties of synthetic fibre reinforced concrete:

Synthetic fibre reinforced concrete shall possess the following properties:

- *Average residual strength (ASTM C1399) > [X] MPa;*
- *Flexural toughness (ASTM C1609) > [Y] MPa;*
- *The % of flexural strength at 3 mm deflection of standard beam test (Flexural toughness factor to ASTM C1609) > [N]%.*

7.7 CURING COMPOUNDS

Spray-on liquid membrane curing compounds are one common method of curing concrete exposed surfaces after finishing. Where curing compounds are used, the properties need to be defined to ensure compatibility of the curing compounds with any other applied finishes that are proposed to be used. Discoloration of the concrete surface may or may not be a major concern.

Of the many types of liquid membrane-forming curing compounds available, the wax-based emulsions and chlorinated rubber types are preferred and recommended. Recent research has shown that special safety precautions are necessary for the use of chlorinated rubber compounds. A white pigmented dye is recommended to facilitate checking that the concrete surface has been fully sprayed.

Wax-based curing compounds are generally efficient in terms of moisture retention but can create safety concerns by producing a slippery surface on the concrete. For this reason, it is recommended that they not be used on surfaces subject to early foot or vehicular traffic.

Liquid membrane curing compounds need to be effective and appropriate test methods to assess this are provided in AS 3799. An example of simple wording for this clause is given in the following:

Liquid membrane-forming curing compounds shall comply with the requirements of AS 3799 and be applied at a dosage rate as per the manufacturer's specifications. The supplier shall provide a certificate of compliance and NATA-endorsed test certificate showing compliance to the Australian Standard.

8. STORAGE OF MATERIALS

While much of the concrete produced in Australia is sourced from fixed location premixed concrete plants that generally have material storage facilities that are fully compliant with the requirements of AS 1379, this is not always the case where concrete may be produced from temporary 'project' plants. This may require a section of the concrete specification detailing storage requirements. Two key areas where appropriate storage of materials has a direct impact on the quality assurance of the concrete are the binder storage and the aggregate storage. Examples of suitable wording for specification of storage for these two material types are provided in the following sub-sections.

8.1 CEMENTITIOUS MATERIALS

Bulk cement and SCM's shall only be stored in watertight silos. Bagged cement and SCM's 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.

8.2 AGGREGATES

Aggregates shall be stored on a hardstand or in silos. Aggregates shall be stored in such a manner as 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 to allow free drainage of rainwater.

9. CONCRETE MIX DESIGN AND ACCEPTANCE

The specifier or the designated authority will generally be required to review the proposed concrete mix designs for a project. This is particularly so in the case of special class concrete. In the case of normal class concrete the specifier may seek to sight and verify production assessment reports for the supply plant only. In either case, the provision of documented mix designs, concrete constituent material test reports and concrete test reports is likely to be a 'Hold Point' as noted in section 5 of this document.

It is important that the construction contractor is responsible for (a) the management of concrete mixes on the construction site, (b) what approved concrete mixes are used and (c) where they are to be used on the site. The contractor will typically need to submit the following detail for each special class concrete to be used on site:

- Mix code and version;
- Intended application (e.g. in-situ, precast, sprayed, extruded, piling (dry), or piling (wet) etc.);
- Strength grade of concrete;
- Nominated slump or slump spread;
- Name of the concrete supplier;
- Location of batch plant;
- Types, proportion by mass, sources of the various constituent materials;
- Test results on aggregate product test properties (sub-section 7.5);
- Average 28-day strength with standard deviation (sub-section 9.3);
- Chloride content of hardened concrete (sub-section 9.7);
- Concrete durability test values (sub-

section 9.6);

- Other test information – for example drying shrinkage testing (sub-section 9.9), sulfate testing (sub-section 9.8) and/or other material test certificates may be required on a mix or project basis.

As well as submitted mix designs there are also controls required on the testing of concrete used on the project to ensure that at least the minimum requirements of AS 1379 are being maintained.

9.1 SLUMP AND SLUMP SPREAD

The specification of slump by the design engineer is not generally recommended as this may restrict methods used by the contractor. AS 1379 states that the concrete shall be deemed to comply with the specified slump, if the measured slump is within the tolerance for slump given in ***Table XI.6***.

Table XI.6 – Permissible Tolerance on Slump (AS 1379)

Specified Slump Range (mm)	Tolerance (mm)
< 60	+/-10
≥60 ≤80	+/-15
>80 ≤110	+/-20
>110 ≤150	+/-30
>150	+/-40

Where Super-workable concrete is specified there may be a need to carry out a number of tests on the concrete that may not apply to normal class or special class concrete with a specified slump under 220 mm (refer to the Guide, Part VI, Section 22 and Part VIII, Section 25 for more information on Super-workable Concrete). A common test for Super-workable Concrete consistency is the slump flow test. Typical specified Slump Flow values will range from 550 mm to 700 mm. Common acceptance tolerances on slump flow are provided in ***Table XI.7***.

Table XI.7 – Typical Tolerance on Slump Flow (AS 1012.3.5)

Specified Slump Flow (mm)	Tolerance (mm)
550	+/-50
600	+/-50
650	+/-50
700	+/-50

Other values can be obtained from the slump flow test including T_{500} (AS 1012.3.5) and Visual Stability Index or VSI (ASTM C1611). Refer to the Guide, Part VI, Section 22 and Part VIII, Section 25 for more information on these tests and references.

The frequency of slump or slump flow testing should be specified at least at the same frequency of compressive strength testing. In the case that Production Assessment in accordance with AS 1379 is provided then the minimum frequency is 1 per 100 m^3 of concrete supplied. If Project Assessment is specified at the project site, then the frequency is at least 1 per 50 m^3. In some cases of special class concrete or a critical element or group of elements in a structure it may be justified to increase the frequency of testing to more than that required by AS 1379.

9.2 AIR CONTENT COMPLIANCE

Where air content is specified for concrete the frequency of sampling and testing is recommended to be in every alternate test sample for compressive strength. This suggests a test frequency of 1 sample per 100 m^3 of concrete. In some cases, this will be adequate but it may be useful to assess the first two batches of concrete in every day's supply to ensure that adjustments to air entraining agent can be made early in a supply if required.

Compliance to specified air content is recommended to be within a tolerance of +/- 1.5% of the target value. Where air content control is critical this tolerance may be reduced to +/- 1.0% of the target with an increased frequency of testing.

An example of simple wording for this clause is given in the following:

Where the concrete mix air content is specified the air content shall be sampled and tested at a frequency of 1 sample per 100 m^3. The concrete shall be deemed as conforming if measured air contents are within 1.5% of the specified value.

9.3 COMPRESSIVE STRENGTH COMPLIANCE

Concrete compressive strength compliance is generally assessed at 28 days after casting. Compliance assessment methods are provided in AS 1379 and these expect that sampling and testing will be carried out in accordance with AS 1012.8.1 and AS 1012.9. The details of assessment are provided in the Guide, Part VIII, Section 26.

Examples of simple wording for this clause are given in the following:

The concrete compressive strength shall be sampled and tested in accordance with AS 1012.8.1 and AS 1012.9. Test data from the project site will be assessed using 'Project Assessment' in accordance with AS 1379. The concrete supplier shall carry out 'Plant Assessment' in accordance with AS 1379 for all strength grade concrete supplied from the plant supplying concrete to the project site. If requested by the construction contractor, the concrete supplier shall provide a Production Assessment report in accordance with AS 1379 for verification.

In some cases of special class concrete strengths at earlier ages (for post tensioning, stripping forms or lifting precast elements) or a later age strength than 28-days (such as 90-day strength for low heat mass concrete) may be specified as a characteristic strength. It is recommended that testing and assessment of these alternative age test specimens is specified using the same method and formulae as for 28-day strength in AS 1379 except with variation for the period of curing the test specimens.

The frequency of compressive strength testing should be specified as 'in accordance with AS 1379' for Production Assessment (1 sample per 100 m^3 of concrete supplied) or for Project assessment (1 sample per 50 m^3). In some cases of special class concrete or a critical element or group of elements in a structure it may be justified to increase the frequency of testing to more than that required by AS 1379.

An example of simple wording for this clause is given in the following:

Compressive strength concrete samples shall be taken on site at a frequency in accordance with AS 1379 for Project Assessment. From each sample at least 3 test cylinders will be cast (1 cylinder for 7-day assessment and 2 cylinders for 28-day assessment). Specimens will be cast, cured and tested in accordance with AS 1012.8.1 and AS 1012.9.

9.4 TENSILE STRENGTH COMPLIANCE

Concrete tensile strength can be specified in lieu of compressive strength or in conjunction with compressive strength. Typically, this will be either Indirect Tensile Strength or Flexural Tensile Strength. More details are provided for these tests in the Guide, Part VIII, Sections 25 and 26.

In AS 1379 two methods of assessing compliance of tensile strengths are provided:

- Using an equivalent target flexural strength and compressive strength so as to use compressive strength assessment as a means of controlling tensile strength;
- Using the same methods and formulae as for compressive strength assessment except applying these to a specified characteristic tensile strength (Flexural or Indirect) and with standard deviation measured from the tensile strength at 28-days or nominated assessment curing age.

The reason for the first assessment option in AS 1379 is recognition of the extremely high variability of tensile tests (particularly flexural strength testing which typically has a coefficient of variation between 50% and 100% greater than that of compressive strength for the same concrete).

One flaw in using the second assessment method is that while AS 1379 has guidance on maximum pair differences for compressive strength at 28 days (for pairs of compressive strength tests from the same sample of concrete and tested at 28 days), no such guidance is provided for flexural or indirect tensile strength pair differences. The very high variability of tensile strength tests is partly attributable to weaknesses in the test methods that lead to the effects of any inconsistency in the test sample significantly impacting on the test value.

An example of simple wording for this clause is given in the following:

Flexural tensile strength concrete samples shall be taken on site at a frequency in accordance with AS 1379 for Project Assessment. From each sample at least three test beams will be cast (1 beam for 7-day assessment and 2 beams for 28-day assessment). Specimens will be cast, cured and tested in accordance with AS 1012.8.2 and AS 1012.11. Assessment of the strength of conforming test beams cured to 28 days may be carried out using the method applied to compressive strength production assessment and project assessment in AS 1379. The standard deviation for flexural strength of a concrete mix will be calculated from a minimum of 15 conforming samples. Any samples with a pair difference greater than 15% of the average strength of the pair at 28 days will be deemed as non-conforming and rejected for the purpose of assessment.

9.5 SPECIFIC EXPOSURE CLASS REQUIREMENTS

Concrete structures designed in accordance with AS 3600 will require that the concrete meets certain durability requirements in accordance with exposure classifications relevant to the environment in which the concrete is placed. AS 3600 directs six of the seven exposure classes to using minimum strength grade concrete along with minimum curing requirements. These classes, minimum strength grade and relevant minimum curing are summarised in **Table XI.8**.

Table XI.8 – AS 3600 Concrete Exposure Requirements

Exposure Classification	Minimum Strength Grade of Concrete (MPa)	Minimum average strength at the time of removing forms (MPa)	Minimum period of curing (Days)
A1	20	15	3
A2	25	15	3
B1	32	20	7
B2	40	25	7
C1	50	32	7
C2	50	32	7
U	Not Specified	Not Specified	Not Specified

The AS 2758.1 concrete aggregate testing assessment requirements also vary for concrete in the same exposure classes as used in AS 3600. Acceptable test values for coarse and fine aggregate vary from classes A1 & A2 to B1 & B2 and again to C1 & C2 and impact on Sulfate Soundness, Wet/Dry Strength and Los-Angeles Abrasion Resistance test requirements. More information on these requirements can be found in the Guide, Part II, Section 3.

When designs are carried out for concrete piles (AS 2159), concrete bridges (AS 5100.5), concrete liquid retaining structures (AS 3735) or concrete maritime structures (AS 4997), each Standard has a similar (but different) set of exposure classifications that are specific to design for durability in their specific environments. Care needs to be exercised when specifying concrete mixes in these environments as each case where concrete in excess of N32 grade concrete is specified, it may become a special class concrete by virtue of the definition of special class concrete in AS 1379 (minimum binder content, recommended binder compositions and maximum water/binder ratios may apply). Where special class concrete requirements need to be specified, these will be detailed in additions to section 7 clauses and noted in sub-section 16.1.

9.6 TESTING FOR CONCRETE DURABILITY

Where concrete is required to meet specific durability requirements it will automatically become a special class concrete by the definition of special class concrete in AS 1379. There are many test methods for various aspects of concrete durability. These can include but are not limited to:

- Water permeability;
- Gas permeability;
- Surface absorption rate;
- Pore size and volume;
- Volume of permeable voids;
- Chloride diffusion;
- Carbonation rate;
- Concrete electrical resistivity.

For each of these general properties there may be a single test method or many test methods. Most of the test methods have not been incorporated into Australian Standards but are easily found as international standards and referenced. Many related documents and papers can provide useful advice on the use and assessment of test data.

If a special class concrete cast into a structural element is placed into an environment where a single or multiple durability property of the concrete is critical to achieving a design life that is not adequately covered by the design standards prescriptive requirements, then the specifier may need to specify a test method, assessment method, testing frequency and compliance details for this property.

An example of simple wording for this clause is given in the following:

Type SC50/20/120 special class concrete will be assessed for chloride diffusion coefficient using test method ASTM C1556. Test frequency will be testing the trial mix at least three months prior to supply and then testing samples every three months during supply. The trial mix Diffusion Coefficient at 56 days shall be less than 3.0 × 10^{-12} m^2/s. During supply of SC50/20/120, test values exceeding 3.9 × 10^{-12} m^2/s will be deemed to be non-conforming.

9.7 CHLORIDE CONTENT TESTING

AS 1379 requires concrete production from a supply plant to be assessed for its chloride content by assessing the most frequently sampled concrete at a frequency of at least 1 test every 6 months. In the case of project assessment of concrete, the specifier may choose to target testing of more critical special class concrete for chloride content at stages during the supply of concrete to the construction site. The limit on chloride content of normal class concrete in AS 1379 is calculated as a mass of chloride ions per unit volume of concrete with a maximum limit of 0.80 kg/m^3. The frequency of testing will be increased if any changes of concrete constituent materials are made by the supplier or detected (e.g. a new source of sand).

Because low chloride content is critical for protection of reinforcing steel and that pre-stressing steel may require even lower limits of chloride in the concrete than normal reinforcement, it is possible that the limits on chlorides may be reduced on some special class concrete mixes used in particular concrete elements.

Two methods for testing the chloride content are now available (i.e. AS 1012.20.1 and AS 1012.20.2). The original method, AS 1012.20.1, uses acid extraction of chlorides from the concrete, whereas AS 1012.20.2 uses water extraction of chlorides from the concrete. The compliance limits for chlorides in AS 1012.20.2 will be lower than those currently provided in AS 1379. Guidance on AS 1012.20.2 limits for aggregates are provided in AS 2758.1 and if AS 1012.20.2 is used for normal class concrete it would be expected that a limit of water-soluble chlorides will be reduced to 0.60 kg/m^3. The reason for using the water-soluble method relates to certain aggregates (rare) that have chloride ions 'locked' in some of the minerals forming that aggregate. It has been determined that in these cases, the acid extraction will liberate these chlorides that would not generally be available to the concrete pore water solutions and therefore not be harmful to reinforcement. The water extraction method avoids picking up these 'locked' chlorides.

AS 1379 requires expression of chlorides as a mass (kg) in a cubic metre of concrete. AS 1012.20.1 and AS 1012.20.2 express the chloride as a percentage of the dry mass of concrete. In order to calculate the mass of chloride ions per m^3 of concrete, the percentage value from AS 1012.20.1 (or AS 1012.20.2) are multiplied by the density of that concrete in oven dry condition. This can be assessed on an un-cured test specimen where the specimen is oven dried at 105ºC to a constant mass (less than 1 gram change over 24 hours) and density measured using the method in AS 1012.12.1 before being submitted for chloride testing. The dry density may also be estimated from the mix design by summing up the dry mass of each solid ingredient in a cubic metre of concrete. The calculation is simple – multiply the % by weight of concrete by the dry density (in kg/m^3). For example: a concrete test specimen has a dry density of 2,260 kg/m^3 and a chloride content of 0.021% – then the chloride content = 2,260 × 0.021/100 = 0.47 kg/m^3.

The concrete supplier or testing authority will provide a report containing these results and supporting test certificates where more than one laboratory has carried out this assessment.

Examples of simple wording for this clause are given in the following:

Normal class concrete will be assessed for chloride content of concrete using test methods AS 1012.20.1 or AS 1012.20.2 every 6 months. Any approved change of concrete constituent materials during supply will initiate re-testing. A report verifying the chloride content of the concrete in kg/m^3 shall be submitted to the construction manager. Chloride content of concrete in excess of the limit set in AS 1379 will be deemed as non-conforming.

Special class concrete mix SB40/20/80 will be assessed for chloride content of concrete using test method AS 1012.20.1 every 1,000 m^3 of supply of this mix. Any approved change of concrete constituent materials during supply will initiate re-testing. A report verifying the chloride content of the concrete in kg/m^3 shall be submitted to the construction manager. Chloride content of concrete in excess of 0.40 kg/m^3 will be deemed as non-conforming.

9.8 SULFATE CONTENT TESTING

AS 1379 requires concrete production from a supply plant to be assessed for its sulfate content by assessing the most frequently sampled concrete at a frequency of at least 1 test every 6 months. In the case of project assessment of concrete, the specifier may choose to target testing of more critical special class concrete for sulfate content at stages during the supply of concrete to the construction site. The limit on sulfate content of normal class concrete in AS 1379 is calculated as a mass of sulfate (as SO_3) per mass of cement (binder) in the concrete with a maximum limit of 50 gm/kg. The frequency of testing will be increased if any changes of concrete constituent materials are made by the supplier or detected (e.g. a new source of sand).

In this case the sulfate content is again assessed by the test method of AS 1012.20.1. The reported value of sulfate will be expressed as a percentage of the dry concrete sample. To convert this to a proportion by weight of cement the following formula is used:

Mass of sulfate (gm) per kg of binder = [% Sulfate per mass of dry concrete × Dry density of concrete (kg/m^3)/ Mass of binder (cement + SCM) (kg/m^3) × 1,000].

For example, if the sulfate content of the concrete = 0.35% of dry concrete, the concrete dry density equals 2,260 kg/m^3 and the binder content equals 380 kg/m^3, then the mass of sulfate (gm) per kg of binder = 0.35/100 × 2,260/380 × 1,000 = 20.8 gm/kg.

An example of simple wording for this clause is given in the following:

Normal class concrete will be assessed for sulfate content of concrete using test method AS 1012.20.1 every 6 months. Any approved change of concrete constituent materials during supply will initiate re-testing. A report verifying the sulfate content of the concrete in gm per kg of total binder shall be submitted to the construction manager. Sulfate content of concrete in excess of the limit set in AS 1379 will be deemed as non-conforming.

9.9 DRYING SHRINKAGE TESTING

AS 1379 requires concrete production from a supply plant to be assessed for its drying shrinkage by assessing the most frequently sampled concrete at a frequency of at least 1 test every 6 months. In the case of project assessment of concrete, the specifier may choose to target testing of more critical special class concrete for drying shrinkage at stages during the supply of concrete to the construction site. The (maximum) limit on drying shrinkage for normal class concrete in AS 1379 is 1,000 micro-strain at 56 days. It is important to note that the maximum drying shrinkage for normal class concrete is applied to individual test sample results and not to the mean or average test result. The coefficient of variation of drying shrinkage testing on a single mix can be around 10% of the tested value. In view of this 90% of tests on concrete with an average drying shrinkage of 850 micro-strain will be likely to range between 700 and 990 micro-strain. In view of this the upper limit of 1,000 micro-strain for an individual test is a reasonable method of controlling the drying shrinkage of normal class concrete and suggests a maximum average drying shrinkage of approximately 850 micro-strain at 56 days.

The frequency of testing will be increased if any changes of concrete constituent materials are made by the supplier or detected (e.g. a new source of aggregate or cement).

In some projects the specifier will determine that a lower drying shrinkage limit will be specified for a special class concrete. In this case the specifier will need to determine a method of assessing the concrete compliance based on the testing frequency. Based on this information, the mix designer can establish a mix design that will provide a suitable target average shrinkage to comply.

An example of simple wording for this clause is given in the following:

Special class concrete mix 'S40/20/80/700µm' shall be designed to provide a maximum individual sample drying shrinkage of 700 micro-strains at 56 days when sampled and tested in accordance with AS 1012.8.4 and AS 1012.13. The basis of assessment of this mix will be a trial mix with drying shrinkage less than 600 micro-strains at 56 days prior to use of this concrete on site. The sampling and testing frequency on this mix will be one sample for every 200 m^3 of 'S40/20/80/700µm' concrete on site. Compliance of this supply will be verified by monitoring the average shrinkage value of 5 consecutive samples tested for drying shrinkage at 56 days. Concrete represented by these 5 consecutive samples will be deemed not to comply if any single test sample shrinkage exceeds 700 micro-strains at 56-days or if the average of the 5 consecutive samples exceeds 660 micro-strains at 56 days.

10. BATCHING, MIXING AND TRANSPORT OF CONCRETE

Concrete may be provided by a concrete supplier with a fixed plant off the project site or may be produced through a concrete plant on site. In either case the requirements for batching concrete, mixing and transport of the concrete should conform to requirements detailed in AS 1379.

10.1 BATCHING

An example of simple wording for this clause is given in the following:

Aggregates and all cementitious material shall be batched by mass in accordance with the tolerances provided in AS 1379. Approved liquid admixtures may be batched by weight or volume in accordance with the tolerances provided in AS 1379. Water may be batched by mass or by volume in accordance with the tolerances provided in AS 1379. Batch records for each batch must be available at the plant for at least 12 months should they be required for auditing. Each batch of concrete will be accompanied with a certificate (docket or ticket) with details of the batch as required by AS 1379.

10.2 MIXING

An example of simple wording for this clause is given in the following:

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. Mixing time shall be in accordance with testing of the prototype mixer to determine a mixing time that achieves mixer uniformity as detailed in AS 1379 Appendix A.

10.3 TRANSPORT AND DELIVERY

An example of simple wording for this clause is given in the following:

The timing of deliveries shall be such as to ensure an essentially continuous placing operation. Concrete shall be placed and compacted within the 90 minutes of the batched load leaving the batch plant. This time may be extended if the supplier and construction contractor agree that a slump loss control admixture or set-retarding admixture can be used to maintain mix consistency without the addition of excess water.

11. ACCEPTANCE AND REJECTION OF PLASTIC CONCRETE

The consistency and workability of concrete needs to be selected so that it can be handled and transported without segregation and can be placed, worked and compacted into the forms and around all reinforcement.

The consistency of concrete will generally be checked by means of the slump or slump spread test. Some very low slump, special class concrete may be assessed by compacting factor tests. Sampling is carried out in accordance with AS 1012.1 and testing by AS 1012.3.1 or AS 1012.3.5. Sampling and testing should be conducted by a NATA-accredited laboratory and reported as a NATA-endorsed test report.

The assessment of conformance will be the measured slump being within the tolerances of the specified slump (refer to **Tables XI.6** and **XI.7** in sub-section 9.1).

Action on non-conformance is generally to reject batches of concrete with out-of-tolerance slump but if the measured slump is below the lower tolerance it may be possible to add water to raise the slump within permissible tolerances provided the concrete supplier can demonstrate that the additional water will not exceed a water/cement ratio requirement or cause the mix to be non-conforming in any other hardened concrete properties (strength, durability, shrinkage or others) and that the construction contractor or specifier approve this adjustment.

An example of simple wording for this clause is given in the following:

*The consistency of concrete shall be sampled and tested in accordance with AS 1012.3.1 (for concrete other than super-workable concrete) or AS 1012.3.5 (for super-workable concrete). The testing frequency shall be in accordance with 'Project Assessment' testing in AS 1379. Concrete will be subject to rejection if the measured slump exceeds the relevant tolerance provided in **Tables XI.6** and **XI.7** in sub-section 9.1.*

Plastic concrete may be rejected on the basis of the air content being outside the tolerances required of specified target air content. Details of this are provided in sub-section 9.2.

A batch of plastic concrete may also be rejected if its colour or general appearance is very different to that of prior batches of the same mix.

12. ACCEPTANCE AND REJECTION OF HARDENED CONCRETE

The general requirements for testing and acceptance of hardened concrete have been provided in sub-sections 9.3, 9.4, 9.6, 9.7, 9.8 and 9.9. More specific requirements are listed in sections 16 and 17.

13. ENVIRONMENTAL LIMITS FOR CONCRETING OPERATIONS

The ambient environment in which concrete is manufactured, transported and placed has a significant impact on the hardened properties of concrete and potential for cracking of exposed surfaces of concrete. Factors such as ambient temperature, humidity and wind speed are part of these effects as is the temperature of the concrete on delivery and in its final state. To assist in controlling this AS 1379 places limits on the delivered temperature of concrete. In addition to this the effects of evaporation from the exposed surface of concrete during placement (such as foundations and slabs) may lead to cracking and durability issues (refer to the Guide, Part V, Section 18 and Part V, Section 17 for more information).

13.1 TEMPERATURE LIMITS

An example of simple wording for this clause is given in the following:

No concrete shall be placed on the project that has a measured temperature less than 5°C or greater than 35°C. Where the maximum air temperature is likely to exceed 30°C or be less than 10°C the construction contractor shall take action to ensure that the temperature limits will be adhered to.

13.2 ENVIRONMENTAL LIMITS

High rates of evaporation of bleed water from the surface of concrete can lead to premature stiffening of the concrete surface as well as setting up of stresses within the concrete surface that can lead to early cracking (plastic cracking) of the finished surface and potential for related longer term durability problems. The evaporation rate is linked to a combination of concrete temperature, air temperature, air relative humidity and wind speed. ***Figure XI.1*** provides a graphical method of estimating the likely evaporation rate of bleed water from the concrete surface. The following sub-sections explore assessment of evaporation and its control.

13.2.1 Estimation and Control of Evaporation Rates

When the predicted evaporation rate during the intended period of placement and finishing exceeds 0.50 kg/m²/h there is a reasonable probability that the exposed surface of a concrete slab (particularly strength grades in excess of 32 MPa) will dry too quickly and increase the risk of plastic cracking. When the evaporation rate exceeds 1.00 kg/m²/h plastic cracking of all concrete slabs is almost certain.

The evaporation rate can be calculated using the following parameters measured at the site:

- Air temperature (measured with a calibrated thermometer);
- Wind velocity (measured with a handheld or fixed anemometer);
- Relative humidity of the air (measured with a handheld or fixed psychrometer);
- Concrete temperature (Measured with a calibrated thermometer).

Figure XI.1 can be used for estimating the evaporation of surface moisture from the concrete for the construction site.

Control measures that can be used to reduce the evaporation rate include:

- Reducing the concrete temperature (adding ice to the mix, shading or cooling aggregates etc.);
- Erecting protective barriers around the construction area where the slab is being

placed to reduce the wind velocity;

- Application of water mist sprays to increase humidity above the slab surface;
- Application of surface evaporation retardant (e.g. aliphatic alcohol) sprays to the concrete surface.

An example of simple wording for this clause is given in the following:

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.

13.2.2 Application of Evaporation Retarding Compound

The use of an evaporation retarding compound on the top surface of the concrete is recommended during placing of concrete slabs. It should be applied within 10 minutes of concrete placement and initial levelling. The compound is applied again following any subsequent floating.

Evaporation retardant compounds will consist primarily of aliphatic alcohol suitable for use on concrete.

Evaporation retardants do not replace curing compounds.

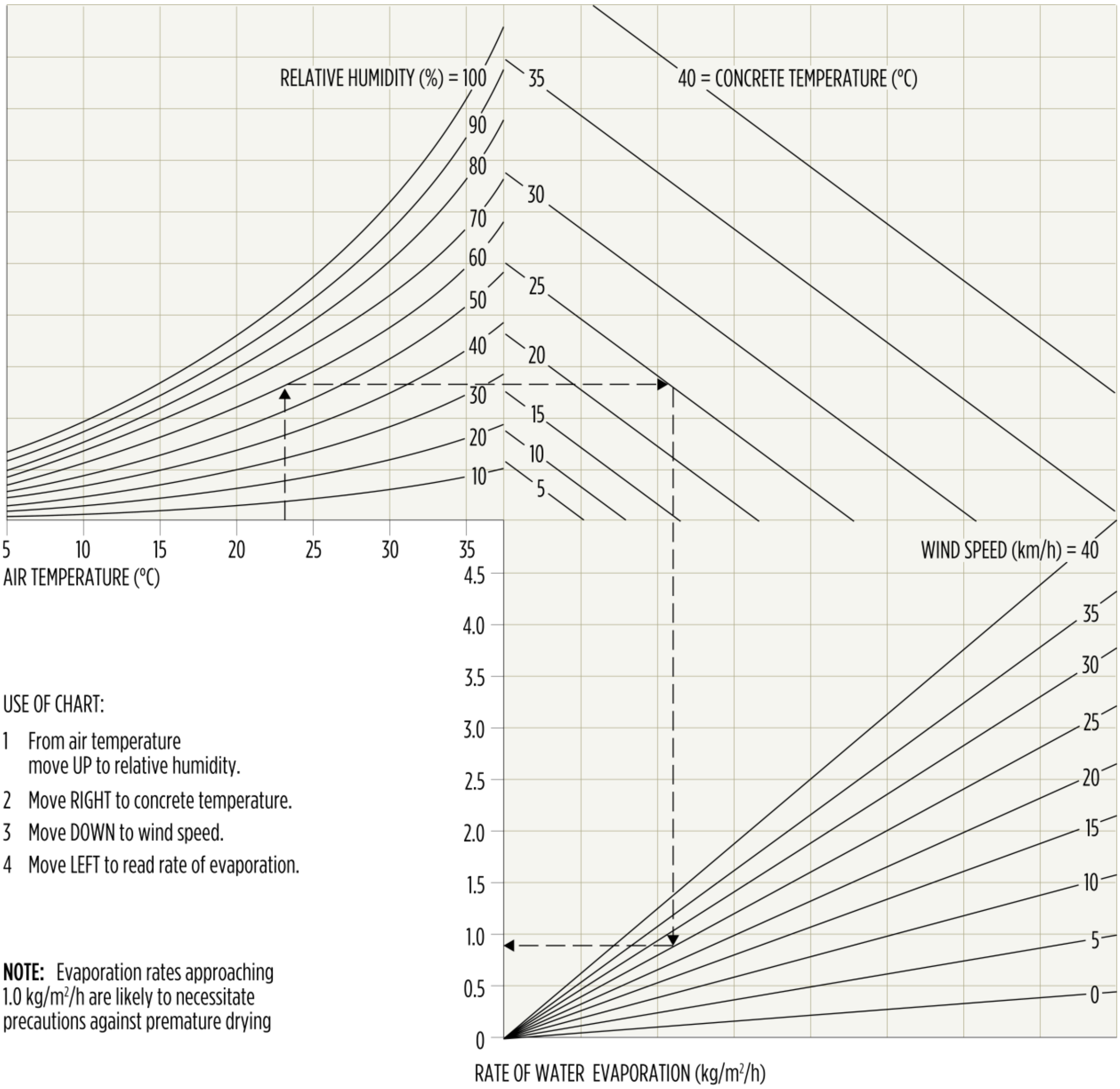


Figure XI.1 – Effect of concrete and air temperatures, relative humidity and wind velocity on the rate of evaporation of surface moisture from concrete (after ACI 305 (1999) [2])

An example of simple wording for this clause is given in the following:

Where weather conditions on site indicate an evaporation rate from the concrete surface is likely to exceed 0.50 kg/m²/h, the use of evaporation retardant mist sprays on the concrete slab exposed surface are mandatory. Sprays must be mixed in accordance with the manufacturer's instructions and applied within 10 minutes of concrete placement and initial levelling. Sprays are then applied again following any subsequent floating operation on the concrete surface.

13.3 PROTECTION FROM RAIN

Concrete should not be poured in the rain or if rain is imminent, unless adequate measures are taken to protect the plastic concrete from the damage caused by rain. Suitable protection may include a waterproof covering to protect all exposed surfaces of the concrete. All water should be removed from the forms before concrete is poured.

The effects of significant rainfall during concrete placement may include:

- Increased consistency of the concrete;
- Ponding of water on the surface;
- Disturbance (cratering) of concrete surface.

Concrete which is exposed to significant rain from the time of commencement of placement to the commencement of curing may be subject to rejection.

An example of simple wording for this clause is given in the following:

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 damage caused by rain. Suitable protection may include a waterproof covering to protect all exposed surfaces of the concrete. All water should be removed from the forms before concrete is poured. Concrete which is exposed to significant rain from the time of commencement of placement to the commencement of curing will be subject to rejection.

13.4 CURING OF CONCRETE

All concrete must have a planned method for curing. Generally, the construction contractor will need to provide a method statement detailing the proposed methods to be used on site that ensure that the requirements for curing set out in sections 15 to 17 can be achieved.

Curing can be achieved through the application of water. The two difficulties with water curing are a) the ability to maintain the water in place for the curing period and b) the potential of excessive water running into foundations and causing damage. One method of keeping water on a concrete slab surface is using wet hessian on the surface as this takes less water to maintain the curing in place.

It is common practice to use liquid membrane-forming curing compounds which are defined in AS 3799. Where curing compounds are used, the properties need to be defined to ensure compatibility of the curing compounds with other applied finishes. Discoloration of the concrete surface may or may not be a major concern with this form of curing.

Impermeable sheet materials can be used to cure concrete and will need to meet the requirements of ASTM C171. When impermeable sheet materials are used, they must be anchored down and joints in material taped to ensure effectiveness. On large flat surfaces they may present a safety hazard for slipping for foot traffic.

Curing can be achieved by retention of formwork. In this case it is important that the formwork is not moved or removed during the curing period.

Curing needs to commence as soon as practicable, but no more than three hours after completion of the finishing operations of any unformed finishes.

Further details on curing of concrete are provided in the Guide, Part V, Section 15.

14. DEFECTS AND RECTIFICATION

The following wording is a common approach to rectification, but the precise responsibility and wording is up to the specifier:

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

- *The concrete, and any portion of the structure built on the non-conforming concrete shall be removed and replaced with conforming concrete; or*
- *The non-conforming concrete, and any product containing that concrete, shall be replaced; or*
- *The non-conforming concrete may remain in place and additional works, approved by the Specifier, shall be undertaken to achieve adequate appearance, strength and durability.*

15. NORMAL CLASS CONCRETE FOR IN-SITU, PRECAST AND PRECAST-PRESTRESSED APPLICATIONS

This section applies to in-situ and precast concrete elements, where the drawings require normal class concrete. Normal class concrete is defined in AS 1379.

15.1 CONCRETE CLASS

The strength grade of concrete and maximum nominal aggregate size used shall be as specified on the Drawings. The specified concrete slump for any structural element is to be a default of 80 mm, or as recommended by the construction contractor to the specifier.

15.2 MATERIALS

15.2.1 Cement

All cement used in normal class concrete shall comply with AS 3972.

15.2.2 Supplementary Cementitious Materials

All supplementary cementitious materials used in normal class concrete shall comply with their relevant standards:

- *Fly ash shall comply with the requirements of AS 3582.1;*
- *Ground Granulated Blast Furnace Slag shall comply with the requirements of AS 3582.2;*
- *Amorphous Silica shall comply with the requirements of AS 3582.3.*

15.2.3 Chemical Admixtures

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

15.2.4 Concrete Aggregates

Concrete coarse and fine aggregates shall conform to AS 2758.1 and must satisfy the requirements for exposure class as specified for the concrete application.

15.2.5 Alkali Reactive Aggregates

Where an aggregate is identified as having potential for alkali-aggregate reaction (i.e. it is either reactive or slowly reactive) in accordance with AS 2758.1 treatment to control the effects shall be in accordance with SA HB 79.

15.2.6 Curing Compounds

Where a liquid membrane forming curing compound is used as the method of curing concrete it shall comply with the requirements of AS 3799 and its application rate will be as recommended by the Supplier. The construction contractor will also need to demonstrate that any curing method used will not damage the appearance or the function of the structure.

15.2.7 Other Methods of Curing Concrete

Where other methods of curing concrete are used (such as formwork retention, water sprays, wet hessian or impermeable sheet) the construction contractor must develop a method statement that supports the method is capable of remaining in place for the curing periods defined in Table XI.8 according to the concrete strength and durability class. The construction contractor will also need to demonstrate that any curing method used will not damage the *appearance of the concrete or the function of the surrounding structures during construction.*

15.3 STORAGE OF MATERIALS

Materials shall be stored as detailed in section 8 of this document.

15.4 CONCRETE MIX DESIGNS

The Contractor shall recommend mix designs to the Specifier for all normal class concrete used in the project for the Specifier's approval. The Contractor shall ensure that the mix design is suitable for the particular application. Concrete slump shall be nominated by the Contractor as appropriate for the intended application.

15.5 BATCHING, MIXING AND TRANSPORT

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

15.6 ACCEPTANCE AND REJECTION OF PLASTIC CONCRETE

Refer to section 11 of this document.

15.7 ACCEPTANCE AND REJECTION OF HARDENED CONCRETE

Refer to sub-sections 9.3, 9.4, 9.6, 9.7, 9.8, 9.9 and 12 of this document.

15.8 DEFECTS AND RECTIFICATION

Refer to section 14 of this document.

15.9 FALSEWORK

Falsework shall conform to AS 3610.1. 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 Specifier. The Specifier's approval of the use of completed sections of the project 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.

15.10 FORMWORK

All formwork shall be subject to inspection and approval by the Specifier. Formwork shall conform to AS 3610.1 and provide a surface Finish Class as noted on the drawings.

15.10.1 Supports (Bar-Chairs and Spacers)

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

15.11 PLACING AND COMPACTING CONCRETE

No concrete shall be placed in the project site until:

a) The formwork and reinforcement have been inspected, and

b) All foreign material has been completely removed from the forms.

Reference can be made to the Guide, Part V, Sections 12 and 13 for more information on placing and compaction. It is often assumed that the concrete placing sub-contractor knows how to meet the objectives of this specification, but it is useful to provide a summary of these requirements.

An example of wording this sub-section is in the following:

Concrete placing shall be carried out continuously between forms and/or construction joints and in such a manner that a plastic concrete face is maintained. Placing and compaction shall be carried out so that the finished concrete thickness, its surface shape and level shown on the drawings will be obtained within the specified tolerances.

Concrete shall be deposited using suitable conveyors, concrete pumping equipment, clean chutes, troughs, hoppers or pipes so as to require a minimum of handling and redistribution.

The concrete shall be placed so that its working face is normal to the direction of placing. It shall be in such a manner as to minimise segregation. Hand spreading of concrete in a slab shall be done with shovels, not rakes. Vibrators are to be used for compaction of concrete and shall not be used to spread concrete.

Horizontal elements shall be placed with concrete in layers not more than 300 mm thick for compaction. Compact the following layer into the previous layer before the previous layer has taken initial set. The interval between successive layers of concrete shall be limited to be less than the time taken for the initial set of the previous layer to occur in the ambient conditions.

Vertical elements shall be placed to limit the free fall of concrete to maximum of 2 m.

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

The Contractor shall ensure that the concrete placing sub-contractor has the correct number and type of compaction equipment (vibrators, vibrating screeds or other approved equipment) to complete the placement.

15.12 TOLERANCES

Specified dimensional and surface tolerances for concrete should realistically reflect the requirements for the appearance and function of the concrete element. The practice of specifying more stringent tolerances than required to cover unforeseen circumstances should be avoided. The more stringent the tolerances, the more sophisticated (and therefore costly) are the construction and measurement methods needed to achieve and check them.

The following design standards for concrete structures can potentially be able to utilise normal class concrete:

- AS 3600 – Concrete Structures;
- AS 2870 – Residential Slabs and Footings;
- AS 3850.2 – Prefabricated concrete elements – Part 2: Building Construction.

Other concrete design standards, by virtue of their specified properties required of concrete, will automatically require special class concrete (refer to sub-section 16.7).

In AS 3600 and AS 2870, the tolerance requirements are as detailed in AS 3600 section 17 as well as the requirements of the formwork standard AS 3610.1. In addition to these standards, the CCAA Data sheet 'Tolerances for Concrete Surfaces' provides useful guidance on specifying tolerances.

An example of simple wording for this clause is given in the following:

Construct formwork so that finished concrete dimensional tolerances of the cast concrete element conform to requirements of AS 3600 and AS 3610.1.

15.13 FINISHING OF CONCRETE

All unformed surfaces must be finished to line and level as indicated on the drawings and within the tolerances specified.

All finishing operations must be completed prior to the application of any curing. The finishing operations will be carried out in a manner so as to provide a dense surface free from non-conforming surface cracking.

15.13.1 Prevention of Cracking

The concrete placing sub-contractor will need to plan and control the placing, compacting, curing and finishing operations to prevent cracking in the various concrete elements. In the case of slab placement or foundations with large exposed surface areas, it is recommended that evaporation retardants are applied to the levelled exposed surface as detailed in sub-sections 13.2.1 and 13.2.2.

The specification must make this requirement clear to the concrete placing sub-contractor. An example of wording this sub-section is in the following:

The concrete placing sub-contractor shall plan and control the placing, compacting, curing and *finishing operations to prevent cracking in the various concrete elements. In the case of slab placement or foundations with large exposed surface areas, an evaporation retardant shall be applied to the levelled, exposed surface when ambient conditions require this protection as detailed in sub-sections 13.2.1 and 13.2.2 of this specification.*

15.13.2 Finish Type

The type and quality of concrete surface finish should generally be detailed on the drawings.

An example of wording this sub-section is in the following:

The concrete finish type and quality applicable to exposed surfaces and off-form finish shall be as specified on the drawings.

15.14 CURING OF CONCRETE

An example of wording this sub-section is in the following:

All concrete shall be cured in accordance with a suitable method as detailed in sub-section 13.4. The selected method for each concrete element shall be detailed in a work method statement by the Construction Contractor and submitted to the Specifier for approval prior to application.

15.15 EARLY LOADING

An example of wording this sub-section is in the following:

No loads including loads from backfilling shall be placed on the concrete structure for at least seven days after placement of concrete and until testing indicates that the required strength of the concrete has been achieved and approved by the Design Engineer.

15.16 REMOVAL OF FORMWORK

Forms, falsework and centring should remain in position until the times stated in AS 3600 clause 17.6 have elapsed after completion of concreting.

In addition, the curing requirements of AS 3600 clauses 4.4 and 4.5 should be considered before stripping the forms. If forms have to be stripped under 7 days then an appropriate curing method will be applied to the stripped surface within an hour of stripping.

Forms should be removed with care, without hammering and wedging, and in a manner which will not injure the concrete or disturb the remaining supports.

15.17 SURFACE TREATMENT OF CONCRETE

Prior to commencing concreting operations, the Contractor should document procedures and standards for surface dressing and repair of concrete. These procedures should be subject to the approval of the Specifier.

Concrete surfaces should be free of honeycombing and pockets and free of voids larger than 20 mm in lateral dimensions or greater than 3 mm depth from the surrounding surface.

The repair material should also be approved by the specifier.

15.17.1 Formed Surfaces Exposed to View

Following the removal of formwork, the following operations should be carried out to the standard approved by the Specifier:

- Unwanted projections shall be ground off or removed to provide a smooth surface;
- Where specified in the Drawings, surfaces shall achieve the required surface finish to AS 3610.1;
- Where surface finish is not specified in the Drawings, a default class of surface finish to AS 3610.1 is required to be nominated in this specification (e.g. Class 2).

15.18 CONSTRUCTION, ISOLATION, EXPANSION AND CONTRACTION JOINTS

All planned joints should be marked on the project drawings along with specific details of their construction and relationship to the continuity or otherwise of reinforcement through the joint.

The location of unplanned joints should be approved by the Contractor and Specifier.

Further details on the various types of joints are provided in the Guide, Part V, Section 17.

15.18.1 Construction Joints

Construction joints should be on a single plane and at right angles to the main reinforcement. They should preferably be vertical or horizontal to the member.

In jointed pavement construction, unplanned joints should be constructed at the planned location of contraction or isolation joints. For pavements, the proper location of construction joints is critical to the functioning of the pavement. The Specifier should be consulted before giving any approval to the relocation of construction joints or the inclusion of additional ones.

AS 3600 requires that in columns and walls a construction joint be formed logically at the soffit of the beams and slabs they support.

During placement the concrete adjacent to the joint should be well compacted. The joint should be stripped when the concrete has set and hosed down to expose the coarse aggregate to aid the shear connection across the joint. Any problems in stripping of the joint will be eased if it is located away from regions of high moment and reinforcement congestion.

An example of wording is in the following:

Construction joints shall be located as documented. Joints shall not change the requirement for the concrete surface to achieve specified tolerances.

If a delay in concrete supply to a continuous pour occurs and the previous concrete has started setting at the point of commencing the pour, then a construction joint shall be formed at that point. Prior to recommencement of placement the surface of the placed concrete will be roughened at the construction joint to a pronounced profile with a surface roughness not less than 3 mm. Remove loose aggregate particles and laitance. Saturate the concrete surface then remove all excess water prior to placing the adjoining concrete. Where applicable, provide temporary openings in formwork to allow contaminated water to be removed.

15.18.2 Isolation and Expansion Joints

An example of wording this sub-section is in the following:

Isolation joints shall be formed about structures and features that project through, into or against the base, using joint filler of the type, thickness and width as indicated, and installed in such a manner as to form a complete, uniform separation.

Isolation joints shall be formed by means of an approved preformed filler material which shall be installed only after the concrete on one face of the joint has hardened. The strips of filler shall be fitted tightly together, attached to the hardened concrete with approved adhesive, and held in line to ensure continuity and prevent any concrete from entering the joint.

Expansion joints shall be provided as detailed on the drawings.

Isolation and expansion joints shall be sealed along the top surface and any exposed sides.

15.18.3 Contraction Joints

Transverse contraction joints are constructed as either tooled joints, wherein a groove is formed in the plastic concrete, or sawn joints, wherein a groove is sawn in the hardened concrete, or an approved regular combination of the two.

An example of wording for a sawn joint is in the following:

Sawn contraction joints shall be constructed by sawing a groove not less than 3 mm and not more than 5 mm in width for the entire depth of the cut. The depth of the cut shall be between one-quarter and one-third of the base depth unless otherwise indicated in the drawings.

Sawing of the joints shall commence as early as possible and be carried out when the concrete has hardened sufficiently to permit cutting without excessive chipping, spalling or tearing.

A chalk line or other suitable guide shall be used to mark the alignment of the joint. The saw cut shall be straight from edge to edge of the panels and shall not vary more than 15 mm from the true joint alignment.

Before sawing a joint, the concrete shall be examined closely for any cracking; the joint shall not be sawn if a crack has occurred near the location chosen for a joint. In these instances, the proposed joint shall be relocated away from the crack and remedial treatment may be required. Sawing shall be discontinued if a crack develops ahead of the saw cut.

16. SPECIAL CLASS CONCRETE FOR IN-SITU APPLICATIONS

This section applies to cast in-situ concrete elements, where the drawings require special class concrete. Special class concrete is defined in AS 1379. The need for special class concrete will largely be dependent on the type of structure that the concrete is used in and the environment that the concrete structure is located in. A number of Australian concrete structural design Standards or Guidelines describe concrete requirements where it is likely that special class concrete will be required due to the mix design requirements or special properties being nominated. These include:

- AS 3600 for exposure classifications B2, C1 and C2;
- AS 3850.2 for required early strength outside of AS 1379 normal class requirements in precast concrete;
- AS 2159 for particular requirements relating to piling mix properties;
- AS 3735 for special shrinkage, binder and W/B ratio requirements for water retaining structures;
- AS 4997 for special shrinkage, binder and W/B ratio requirements for structures in a maritime environment.

16.1 MIX DESIGNS

Each special class mix to be utilised in a construction project must be itemised along with any special requirements for the mix, its testing and its constituent materials. A useful method of presenting this is to set up a schedule of all special class mixes (refer to sub-section 16.1.1).

An example of wording for this sub-section is as follows:

The Contractor shall recommend mix designs to the Specifier for all special class concrete used in the project for the Specifier's approval. The Contractor shall ensure that the mix design is suitable for the particular application and that required trial mixes have been carried out and reported to the Specifier. Concrete slump shall be nominated by the Contractor as appropriate for the intended application.

16.1.1 Special Mix Schedule

It is useful to summarise the special class concrete mixes along with their special requirements in the specification so that the users of the specification can verify that all of the requirements have been understood and that a common designation for each mix can be introduced to assist quality assurance requirements.

One method to achieve this is to develop a Special Class Concrete Mix Schedule that is part of the concrete specification. An example of such a schedule is given in ***Table XI.9***.

16.1.2 Trial Mixes

Where extensive performance data is not available regarding a concrete mix, mix design acceptance will be on the basis of trial mixes.

'Extensive performance data' refers to test results for the proposed or similar mixes over a recent timeframe. Trial mixes will be made using all constituent materials proposed for the project. The trial mix may be carried out in a NATA-certified laboratory or through the intended concrete plant for the project. When using a batch of concrete from the concrete plant for a trial, the minimum volume of the trial mix should not be less than 25% of the rated capacity of the mixer. 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 mix design including compliance with any specified plastic properties or maximum water content allowable (unless slump or other consistency limits are exceeded).

Each trial mix shall be tested for slump or spread, plastic unit weight (yield), air content and strength as well as any specialist testing required by this specification.

When supplying a trial mix from the proposed concrete plant, the trial mix will be batched and delivered in a manner as per the anticipated final procedures used, including any admixtures added on site.

Table XI.9 – Example of a Special Class Concrete Mix Schedule

Mix Designation	***Standard/ Design Life (Yrs)***	***Minimum Binder Content (kg/m^3)***	***Max. W/B Ratio / Binder Composition***	***Special Testing Requirement***	***Frequency of Special Testing***
S40/20/200/Piling	*AS 2159 / 100*	*-*	*-*	*See Note 2*	*Trial mix only*
SB40/20/100/P	*AS 3600 / 50*	*-*	*- / >25% Fly ash*	*ASTM C1556 / <5.0×10^{-12}*	*Trial mix only*
SC50/20/100/P	*AS 4997 / 100*	*450*	*0.40 / >25% Fly ash*	*AS1012.13 / See Note 1*	*Trial mix plus 1 sample per 1,000 m^3*
S40/20/80/P – LH	*AS 3600 / 50*	*400*	*0.45 / Type LH Cement*	*See Note 3*	*Trial mix only*

NOTES:

1) *Drying shrinkage testing at 56 days for SC50/20/100/P with compliance trial mix <560 μm; maximum individual sample value <600 μm and the average of 5 consecutive samples <585 μm;*
2) *Concrete for piles will be S40/20/200/Piling and shall be suitable to be placed by tremie with a target slump of 200 mm and the trial mix shall be tested for Bauer Filtration to 'EFFC/DFI Task Group' test method. Maximum value <23 mL;*
3) *The trial mix concrete mix S40/20/80/P – Type LH used in mass foundations will be tested for semi-adiabatic temperature rise using test method from CIRIA C660 '1 m^3 Hot box test'. The maximum temperature rise from the target initial temperature of the concrete mix shall be less than 32^{o}C and the target initial concrete temperature shall not exceed 28^{o}C.*

The slump or slump spread measured shall be within tolerance (see Tables XI.6 and XI.7). At least two cylinders will be cast from each trial mix for compressive strength testing at 28 days and additional cylinders (a minimum of two per age and at least 7 days must be assessed) shall be required if strength gain is to be assessed for early stripping or loading.

Timing of trial mixes for acceptance of mix designs will always be a consideration as part of the project critical path (milestones) as some testing can take up to 12 months from the trial mix to complete and at least three months for early indication of the likelihood of conformance.

Conformance of trial mix hardened properties needs careful consideration due to the risks associated with limited data. In the case of compressive strength, it is useful to ensure that the trial mix strength is equal to or greater than the intended target strength of the mix at 28 days. For other tests, the specifier will need to use judgement as to conformance of a single trial mix while taking account of the likely test value variability.

16.2 MATERIALS

Materials for special class concrete are generally specified in the same manner as is given in sub-section 15.2. It is possible that special materials or more restricted materials may be required in the case of special class concrete.

16.2.1 Special Materials

More restrictions may apply to certain special class concrete materials. For example:

- A particular type or source of cement (e.g. Types SR, SL, LH, HE could be chosen specifically from those covered by AS 3972) or can be White or Off-White cement;
- Stronger limitations on the maximum or minimum proportions of various SCM's may be applicable for certain mixes or all special class mixes;
- Aggregates may have further restrictions or test types and/or conformance requirements that are outside those of AS 2758.1 for a particular concrete mix;
- Requirements (e.g. fire resistance properties, exclusion of particular mineral compositions etc.);
- Water requirements may be different to AS 1379 with lower levels of certain chemical components;
- Admixtures or additives that are allowed to be used may be more limited than those allowed by AS 1478.1 or may be restricted to one or a few admixture types or sources.

Where possible, these restrictions are best noted in the special mix schedule.

16.3 TESTING PROCEDURES

An example of wording for this sub-section is in the following:

Sampling, testing and acceptance of concrete for in-situ placement shall be undertaken in accordance with sections 9, 11 and 12 unless stated otherwise in this sub-section.

In some cases, there is a need to clarify the methods of more specialised tests or alternative acceptance criteria for the standard tests. Where possible, test methods, the mix designations that they apply to and the testing frequency are best summarised in this sub-section in a table form and referenced by this sub-section number and table number in the 'special class concrete mix schedule'.

An example of this is provided in ***Table XI.10***.

16.3.1 Early Stripping

Where early stripping of concrete formwork is required refer to sub-sections 15.15 and 15.16 in this document.

16.3.2 Early Loading

If concrete is to be placed over or adjacent to and connected with a previous section prior to 28-day testing and acceptance, additional sampling and early age testing shall be undertaken for verification of structural adequacy by the Design Engineer prior to loading the previous section.

Table XI.10 – Special Concrete Testing Schedule

Mix Designation	***Test Method***	***Test Standard***	***Compliance Criteria***	***Frequency of Special Testing***
S40/20/200/Piling	*Bauer Filtration*	*EFFC/DFI Task Group*	*Maximum value <23 mL*	*Trial mix only*
SB40/20/100/P	*56-day Chloride diffusion coefficient*	*ASTM C1556*	*<5.0×10^{-12}*	*Trial mix only*
SC50/20/100/P	*Dying Shrinkage*	*AS 1012.13*	*Average of 5 consecutive samples <585 μm*	*1 sample per 1,000 m^3*
S40/20/80/P – LH	*Semi-adiabatic temperature rise*	*CIRIA C660*	*<32^{o}C*	*Trial mix only*

16.4 FALSEWORK

Refer to sub-section 15.9

16.5 FORMWORK

Refer to sub-section 15.10.

16.5.1 Supports (bar-chairs and spacers)

Refer to sub-section 15.10.1.

16.6 CONCRETE TEMPERATURE

The requirements for the temperature on delivery of normal class concrete are provided in sub-section 13.1. In some special class concrete and particularly in concrete that is placed at a thickness of 500 mm or greater and has higher strength requirements, the maximum temperature that the concrete reaches in its forms may need to be accounted for. This may be achieved through a number of methods including:

- Reducing the maximum allowable temperature of concrete as delivered to the site;
- Modifying the mix constituents to control the temperature rise in forms;
- Designing higher reinforcement ratios in the structure where there is a concern about cracking;
- A combination of all these methods to control the risks that have been identified (e.g. cracking due to thermal movement or the risk of Delayed Ettringite Formation or “DEF”).

The specification of control measures will depend on the structural element dimensions as well as the combination of exposures related to the element.

16.7 PLACING AND COMPACTION OF CONCRETE

Where the consistency of the plastic concrete is as per normal class concrete then reference should be made to sub-section 15.11. Where the specified consistency of the special class concrete is outside of this range (such as roller-compacted concrete, low slump paving machine concrete at the lower end of consistency or Super-workable concrete at the higher end of consistency), the placing and compaction methods intended must be specified (type of placing equipment and method of compaction (if any).

16.7.1 Placing Under Water

A common method of placing concrete under water (e.g. wet piles) is to use a tremie tube delivery. More information on this method is available in the Guide, Part VI, Section 21. In general, the concrete mix used in this method of delivery will require specialist design and the placing procedure needs to be proposed by the Construction Contractor. An example of wording for this sub-section is in the following:

The Contractor shall submit a procedure for underwater concreting to the Specifier which includes placement of concrete in wet cast-in-place piles using a tremie tube method.

16.8 TOLERANCES

Refer to sub-section 15.12.

16.9 REMOVAL OF FORMWORK

Refer to sub-section 15.16.

16.10 SURFACE TREATMENT OF CONCRETE

Refer to sub-section 15.17.

16.11 FINISHING OF CONCRETE

Refer to sub-section 15.13.

16.12 CURING OF CONCRETE

Refer to sub-section 15.14.

16.13 CONSTRUCTION, ISOLATION, EXPANSION AND CONTRACTION JOINTS

Refer to sub-section 15.18.

16.13.1 Construction Joints in Marine or Other Aggressive Environments

An aggressive environment such as the spray zone or splash/tidal zone in AS 3600 requires special class concrete and will require a suitable procedure for forming a construction joint. An example of wording for this sub-section is in the following:

Construction joints in AS 3600 exposure class C1 or C2, environments shall be prepared as follows:

1) *The surface of the joint shall be prepared as in sub-section 15.18.1 immediately prior to casting concrete against the joint. The surface and any projecting steel shall then be washed with clean fresh water to remove any salt deposits or other contaminants, and either blown dry with oil-free air or allowed to dry while protected from further contamination;*
2) *The concrete surface shall be coated with a wet-to-dry epoxy resin, as approved by the Specifier, followed by placement of the fresh concrete before the epoxy on the interface has hardened.*

17 SPECIAL CLASS CONCRETE FOR PRECAST AND PRECAST-PRESTRESSED APPLICATIONS

This section applies to precast and precast-prestressed concrete elements, where the drawings require special class concrete. Special class concrete is defined in AS 1379.

17.1 MIX DESIGNS

Each special class mix to be utilised in a construction project must be itemised along with any special requirements for the mix, its testing and its constituent materials. A useful method of presenting this is to set up a schedule of all special class mixes (refer to sub-section 16.1.1).

The Contractor shall recommend mix designs to the Specifier for all special class concrete used in the project for the Specifier's approval. The Contractor shall ensure that the mix design is suitable for the particular application and that required trial mixes have been carried out and reported to the Specifier. Concrete slump shall be nominated by the Contractor as appropriate for the intended application.

17.1.1 Special Mix Schedule

Refer to sub-section 16.1.1.

17.1.2 Trial Mixes

Refer to sub-section 16.1.2.

17.2 MATERIALS

Materials for special class concrete are generally specified in the same manner as is given in sub-section 15.2. It is possible that special materials or more restricted materials may be required in the case of special class concrete.

17.2.1 Special Materials

More restrictions may apply to certain special class concrete materials when used in pre-cast concrete applications. It is common that high early strength is required from the concrete so that better mould or formwork utilisation can be achieved, for example:

- A particular type or source of cement (e.g. Type GP or Type HE cement could be chosen specifically from those covered by AS 3972) or can be White or Off-White cement for decorative/colour reasons;
- Stronger limitations on the maximum proportions of various SCM's may be applicable to achieve higher early strength;
- Aggregates may have further restrictions or test types and/or conformance requirements that are outside those of AS 2758.1 for particular concrete mix requirements (e.g. fire resistance properties or ruling out aggregates with potential for ASR due to the use of accelerated curing and lower SCM proportions);
- Water requirements may be different to AS 1379 with lower levels of certain chemical components;
- Admixtures or additives that are allowed

to be used may be more limited than those allowed by AS 1478.1 or may be restricted to one or a few admixture types or sources.

Where possible, these restrictions are best noted in the special mix schedule.

17.3 TESTING PROCEDURES

An example of wording for this sub-section is in the following:

Sampling, testing and acceptance of concrete for in-situ placement shall be undertaken in accordance with sections 9, 11 and 12 unless stated otherwise in this sub-section.

In some cases, there is a need to clarify the methods of more specialised tests or alternative acceptance criteria for the standard tests. Where possible, test methods, the mix designations that they apply to and the testing frequency is best summarised in this sub-section in a table form and referenced by this sub-section number and table number in the 'special class concrete mix schedule'.

An example of this is provided in ***Table XI.11***.

Table XI.11 – Special Concrete Testing Schedule

Mix Designation	***Test Method***	***Test Standard***	***Compliance Criteria***	***Frequency of Special Testing***
S40/20/80/HAC	*Compressive Strength*	*AS 1012.8.1 and AS 1012.9, See Note 1*	*See Note 1*	*1 per 25 m^3 minimum 3 samples per day of production*
SC50/20/120/HES	*Compressive Strength*	*AS 1012.8.1 and AS 1012.9*	*See Note 2*	*1 per 50 m^3*

NOTES:

1) *Concrete mix S40/20/80/HAC will be cured by heat accelerated curing. Standard concrete sampling and testing in accordance with AS 1012.8.1 and AS 1012.9. Curing of test specimens will be as for the precast segment curing using Heat Accelerated Curing for the first 16 hours followed by cooling and standard curing thereafter. The 24-hour strength assessed by the average of 3 consecutive samples shall exceed 35 MPa and no single sample strength shall be less than 30 MPa. Test samples assessed at 28 days shall comply with the requirements of AS 1379 for the specified characteristic strength (40 MPa);*
2) *Concrete mix SC50/20/120/HES will be cured in ambient conditions. Standard concrete sampling and testing in accordance with AS 1012.8.1 and AS 1012.9. The 3-day strength assessed by the average of 3 consecutive samples shall exceed 25 MPa for demoulding. Test samples assessed at 28 days shall comply with the requirements of AS 1379 for the specified characteristic strength (50 MPa).*

17.4 CONCRETE TEMPERATURE

The requirements for the temperature on delivery of normal class concrete are provided in sub-section 13.1. In some special class precast concrete and particularly in concrete that is placed at a thickness of 500 mm or greater and has higher strength requirements, the maximum temperature that the concrete reaches in its forms may need to be assessed to ensure the concrete temperature does not exceed the specified maximum. The maximum allowable temperature will depend in the binder composition and reinforcement ratios in most cases (refer to sub-section 16.6).

17.5 PLACING AND COMPACTING CONCRETE

The method of compaction will need to be specified to suit the consistency of the specified mix, type of forms or moulds used and accessibility for vibrators around the reinforcement. In some cases, form vibration may be a suitable method. In all cases, the compaction must be sufficient to produce an adequate consolidation of the concrete as well as the specified surface finish.

17.6 DIMENSIONAL TOLERANCES

Dimensional tolerances shall be in accordance with AS 3850.2.

17.7 REMOVAL OF FORMS OR DEMOULDING

Removal of forms or moulds shall only take place where the concrete strength is demonstrated to have achieved the minimum average strength required by the Design Engineer.

17.8 SURFACE TREATMENT OF CONCRETE

Refer to sub-section 15.17 in this document.

17.9 CURING OF CONCRETE

Refer to sub-section 13.4 for ambient curing of precast concrete. For Heat Accelerated Curing refer to the Guide, Part V, Section 15.

17.9.1 Heat Accelerated Curing (HAC)

Heat accelerated curing can be carried out using either steam or hot water curing methods.

Steam curing of precast and precast prestressed concrete units should be carried out within an appropriately designed 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 needs to be monitored and controlled within specified limits.

Steam curing of precast and precast prestressed concrete units should be carried out within an appropriately designed 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 needs to be monitored and controlled within specified limits.

Hot water curing of precast and precast prestressed concrete units can be carried out 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. The difference between the inlet temperature and the outlet temperature of the hot water curing system needs to be monitored and controlled. The free concrete surface of the units being cured should ensure that the minimum average relative humidity in the enclosure shall be maintained at 90% and that the free surface temperature is within specified limits of the maximum concrete temperature in the mould at any time during the curing process.

The maximum surface temperature of concrete within the enclosure (steam curing), or the maximum water temperature (hot water curing) should not exceed 70°C. The maximum temperature at any point within the concrete shall not exceed 75°C at any point during or after the heating or curing process. This temperature may be reduced where concern exists for a particular cement combination in regard to delayed ettringite formation ('DEF').

In general, the HAC cycle will involve four stages:

- Pre-set or delay period at ambient temperature prior to heating;
- The heating period (at a controlled rate of temperature rise;
- Curing period during which the maximum temperature is reached and maintained;
- Cooling period prior to form or mould removal (at a controlled rate of temperature drop to avoid too large a temperature gradient inside the concrete element leading to cracking).

The complete HAC process typically will take at least 16 hours but may vary. The precast sub-contractor should provide the Contractor and Specifier with details of the intended curing process including the target temperature against time for each stage of the cycle, control limits and details of temperature monitoring points. Records should be kept of the cycle for each precast element with compliance for temperature variances across all monitoring points.

18 REFERENCES

18.1 AUSTRALIAN STANDARDS

1) AS 1012 – *Methods of testing concrete*
2) AS 1141 – *Methods for sampling and testing aggregates*
3) AS 1379 – *Specification and supply of concrete*
4) AS 1478.1 – *Chemical admixtures for concrete*
5) AS 2159 – *Piling – Design and installation*
6) AS/NZS 2425 – *Bar chairs in reinforced concrete*
7) AS 2758.1 – *Part 1: Concrete aggregates*
8) AS 2870 – *Residential slabs and footings*
9) AS/NZS 3582 – *Supplementary cementitious materials* (Parts 1 to 3)
10) AS 3600 – *Concrete Structures*
11) AS 3610.1 – *Formwork for Concrete: Part 1, Specifications*
12) AS 3735 – *Concrete structures retaining liquids*
13) AS 3799 – *Liquid membrane-forming curing compounds for concrete*
14) AS 3850.2 – *Prefabricated concrete elements*
15) AS 3972 – *General purpose and blended cements*
16) AS 4997 – *Guidelines for the design of maritime structures*
17) AS 5100.5 – *Bridge design, Part 5: Concrete*
18) AS HB 79 – *Alkali Aggregate reaction – Guidelines on Minimising the Risk of Damage to Concrete Structures in Australia*

18.2 INTERNATIONAL STANDARDS

1) ACI 117 – *Specification for Tolerances for Concrete Construction and Materials*
2) ACI 305 – *Guide to Hot Weather Concreting*
3) ASTM C 171 – *Standard Specification for Sheet Materials for Curing Concrete*
4) ASTM C 1399 – *Standard Test Method for Obtaining Average Residual-Strength of Fiber-Reinforced Concrete*
5) ASTM C 1556 – *Standard Test Method for Determining the Apparent Chloride Diffusion Coefficient of Cementitious Mixtures by Bulk Diffusion*
6) ASTM C 1609 – *Standard Test Method for Flexural Performance of Fiber-Reinforced Concrete (Using Beam with Third-Point Loading)*
7) ASTM C 1611 – *Standard Test Method for Slump Flow of Self-Consolidating Concrete*
8) EN 14651 – *Test method for metallic fibre concrete. Measuring the flexural tensile strength (limit of proportionality (LOP), residual)*

18.3 GENERAL REFERENCE DOCUMENTS

1) CIRIA C660 '*Early-age Thermal Crack Control in Concrete*' (P B Bamforth)
2) EFFC/DFI '*Best Practice Guide to Tremie Concrete for Deep Foundations*' (EFFC/DFI Task Group)

CCAA OFFICES

NATIONAL OFFICE (NSW)
Level 10
163 -175 O'Riordan Street
Mascot NSW 2020

POSTAL ADDRESS
PO Box 124
Mascot NSW 1460
Telephone: (02) 9667 8300

QUEENSLAND
Level 14, 300 Ann Street,
Brisbane QLD 4000
Telephone: (07) 3227 5200

VICTORIA
Suite 910/1 Queens Road
Melbourne VIC 3004
Telephone: (03) 9825 0200

WESTERN AUSTRALIA
45 Ventnor Avenue
West Perth WA 6005
Telephone: (08) 9389 4452

SOUTH AUSTRALIA
Level 30, Westpac House
91 King William Street
Adelaide SA 5000
Telephone: (02) 9667 8300

TASMANIA
PO Box 1441
Lindisfarne TAS 7015
Telephone: (03) 6491 2529

ONLINE DETAILS
www.ccaa.com.au
Email: info@ccaa.com.au