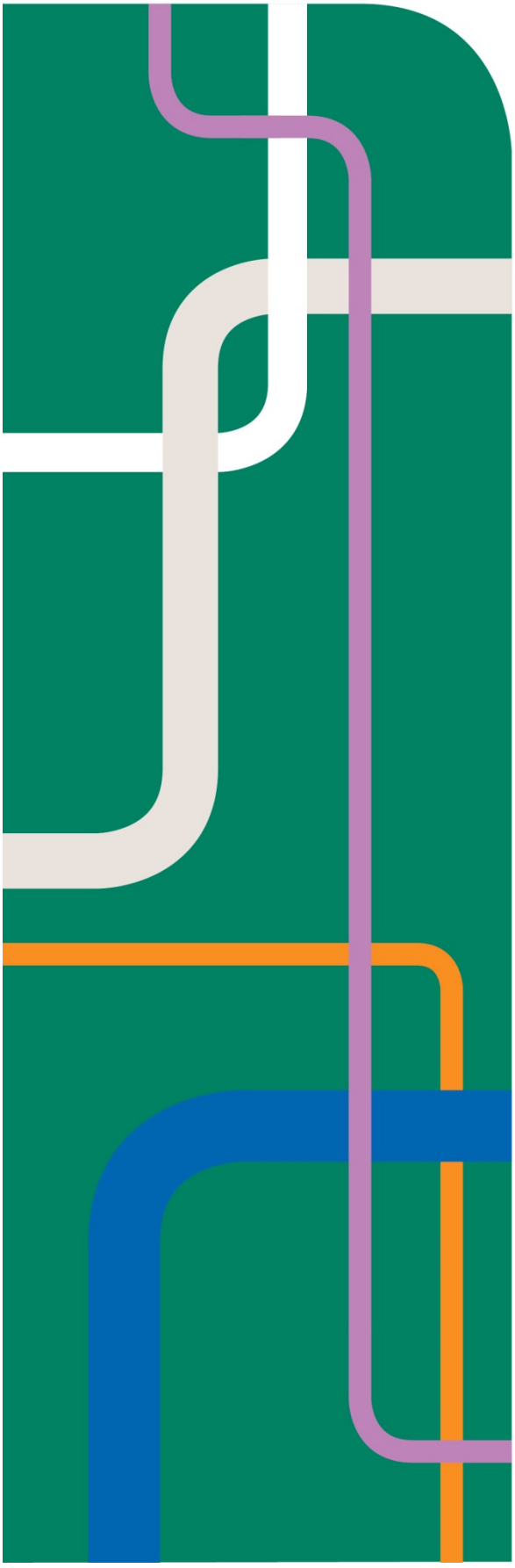
Government of South Australia

SA Water



Engineering Services

Technical Standard
TS 0710

Concrete

Revision: 1.0
Date: 21 November 2016

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Application & Interpretation of this Document

It is the responsibility of the users of this Standard to ensure that the application of information is appropriate and that any designs based on this Standard are fit for SA Water's purposes and comply with all relevant Australian Standards, Acts and regulations.

Users of this Standard accept sole responsibility for interpretation and use of the information contained in this Standard. Users should independently verify the accuracy, fitness for purpose and application of information contained in this Standard.

Only the current revision of this Standard should be used which is available for download from the SA Water website.

Significant/Major Changes Incorporated in This Edition

Nil.

This is the first issue of this Technical Standard.

This Technical Standards supersedes the following SA water Technical Standards:

- TS 1a Supply and Delivery of Lean Mix, No Fines, Grade 20 or 25 Concrete
- TS 1b Supply and Delivery of Grade 32, 40 or 50 Concrete
- TS 3b Fine and Coarse Aggregates for Concrete for Water Retaining Structures and in Aggressive Environments (Excluding Lightweight Aggregate)
- TS 3c Fine and Coarse Calcareous Aggregates (Marble) for Concrete Sewerage Structures (Excluding Lightweight Aggregate)
- TS 68 Reinforced Concrete Construction for Liquid Retaining Structures and/or Aggressive Environments

Document Controls

Revision History

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1.0	21 November 2016	Hany Habib	

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Approvers

Role	Signature and Date
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Role	Name	Revision	Review Date
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1 Introduction

SA Water is responsible for operation and maintenance of an extensive amount of engineering infrastructure.

This standard has been developed to assist in the design, maintenance, construction, and management of this infrastructure.

1.1 Purpose

The purpose of this standard is to detail minimum requirements to ensure that assets covered by the scope of this standard are constructed and maintained to consistent standards and attain the required asset life.

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

1.2 Glossary

The following glossary items are used in this document:

Term	Description
SA Water	South Australian Water Corporation
TG	SA Water Technical Guideline
TS	SA Water Technical Standard

1.3 References

1.3.1 Australian and International

The following table identifies Australian and International standards and other similar documents referenced in this document:

Number	Title
AS 1012.1	Methods of testing concrete - Sampling of concrete
AS 1012.2	Methods of testing concrete - Preparing concrete mixes in the laboratory
AS 1012.3.1	Methods of testing concrete - Determination of properties related to the consistency of concrete - Slump test
AS 1012.3.5	Methods of testing concrete - Determination of properties related to the consistency of concrete - Slump flow, T500 and J-ring test
AS 1012.4.1	Methods of testing concrete - Determination of air content of freshly mixed concrete - Measuring reduction in concrete volume with increased air pressure
AS 1012.4.2	Methods of testing concrete - Determination of air content of freshly mixed concrete - Measuring reduction in air pressure in chamber above concrete
AS 1012.6	Methods of testing concrete - Determination of bleeding of concrete
AS 1012.8.1	Methods of testing concrete - Method for making and curing concrete - Compression and indirect tensile test specimens

Number	Title
AS 1012.8.4	Methods of testing concrete - Method for making and curing concrete - Drying shrinkage specimens prepared in the field or in the laboratory
AS 1012.9	Methods of testing concrete - Compressive strength tests - Concrete, mortar and grout specimens
AS 1012.11	Methods of testing concrete - Determination of the modulus of rupture
AS 1012.13	Methods of testing concrete - Determination of the drying shrinkage of concrete for samples prepared in the field or in the laboratory
AS 1012.14	Methods of testing concrete - Method for securing and testing cores from hardened concrete for compressive strength
AS 1012.20.1	Methods of testing concrete- Determination of chloride and sulfate in hardened concrete and concrete aggregates
AS 1012.21	Methods of testing concrete- Determination of water absorption and apparent volume of permeable voids in hardened concrete
AS 1141.5	Methods for sampling and testing aggregates - Particle density and water absorption of fine aggregate
AS 1141.6.1	Methods for sampling and testing aggregates - Particle density and water absorption of coarse aggregate - Weighing-in-water method
AS 1141.6.2	Methods for sampling and testing of aggregates - Particle density and water absorption of coarse aggregate - Pycnometer method
AS 1141.11.1	Methods for sampling and testing aggregates – Particle size distribution – Sieving method
AS 1141.13	Methods for sampling and testing aggregates - Material finer than 2 micrometre
AS 1141.14	Methods for sampling and testing aggregates - Particle shape, by proportional calliper
AS 1141.15	Methods for sampling and testing aggregates – Flakiness index
AS 1141.22	Methods for sampling and testing aggregates - Wet/dry strength variation
AS 1141.23	Methods for sampling and testing aggregates - Los Angeles value
AS 1141.24	Methods for sampling and testing aggregates - Aggregate soundness - Evaluation by exposure to sodium sulphate solution
AS 1141.25.3	Methods for sampling and testing aggregates - Degradation factor - Fine aggregate
AS 1141.31	Methods for sampling and testing aggregates - Light particles
AS 1141.34	Methods for sampling and testing aggregates - Organic impurities other than sugar
AS 1141.35	Methods for sampling and testing aggregates - Sugar
AS 1141.25.3	Methods for sampling and testing aggregates - Degradation factor - Fine aggregate
AS 1141.60.1	Methods for sampling and testing aggregates – Potential alkali-silica reactivity – Accelerated mortar bar method
AS 1141.60.2	Methods for sampling and testing aggregates – Potential alkali-silica reactivity – Concrete prism method
AS 1141.65	Methods for sampling and testing aggregates – Alkali aggregate reactivity – Qualitative petrological screening for potential alkali-silica reaction
AS 1141.66	Methods for sampling and testing aggregates - Methylene blue adsorption value of fine aggregate and mineral fillers
AS 1289.2.1.1	Methods of testing soils for engineering purposes - Soil moisture content tests -

Number	Title
	Determination of the moisture content of a soil - Oven drying method (standard method)
AS 1289.2.1.2	Methods of testing soils for engineering purposes - Soil moisture content tests - Determination of the moisture content of a soil - Sand bath method (subsidiary method)
AS 1289.2.1.4	Methods of testing soils for engineering purposes - Soil moisture content tests - Determination of the moisture content of a soil - Microwave-oven drying method (subsidiary method)
AS 1289.2.1.5	Methods of testing soils for engineering purposes - Soil moisture content tests - Determination of the moisture content of a soil - Infrared lights method (subsidiary method)
AS 1289.2.1.6	Methods of testing soils for engineering purposes - Soil moisture content tests - Determination of the moisture content of a soil - Hotplate drying method
AS 1289.5.1.1	Methods of testing soils for engineering purposes - Soil compaction and density tests - Determination of the dry density/moisture content relation of a soil using standard compactive effort
AS/NZS 1314	Prestressing anchorages
AS 1379	Specification and supply of concrete
AS 1418.15	Cranes (including hoists and winches) - Concrete placing equipment
AS 1478.1	Chemical admixtures for concrete, mortar and grout - Admixtures for concrete
AS 1478.2	Chemical admixtures for concrete, mortar and grout - Methods of sampling and testing admixtures for concrete, mortar and grout
AS/NZS 1554.3	Structural steel welding - Welding of reinforcing steel
AS/NZS 1554.6	Structural steel welding-Welding stainless steels for structural purposes
AS 1597.1	Precast reinforced concrete box culverts - Small culverts (not exceeding 1200 mm span and 1200 mm height)
AS 1597.2	Precast reinforced concrete box culverts - Large culverts (exceeding 1200 mm span or 1200 mm height and up to and including 4200 mm span and 4200 mm height)
AS 2159	Piling - Design and installation
AS/NZS 2425	Bar chairs in reinforced concrete - Product requirements and test methods
AS 2758.1	Aggregates and rock for engineering purposes – Concrete aggregates
AS/NZS 3582.1	Supplementary cementitious materials – Fly ash
AS 3582.2	Supplementary cementitious materials – Slag – Ground granulated blast-furnace
AS/NZS 3582.3	Supplementary cementitious materials – Amorphous silica
AS 3600	Concrete structures
AS 3610	Formwork for concrete
AS 3610.1	Formwork for concrete - Documentation and surface finish
AS 3735	Concrete structures retaining liquids
AS 3799	Liquid membrane-forming curing compounds for concrete
AS 3850.1	Prefabricated concrete elements - General requirements
AS 3850.2	Prefabricated concrete elements - Building construction
AS 3972	General purpose and blended cements
AS/NZS 4020	Testing of products for use in contact with drinking water

Number	Title
AS/NZS 4058	Precast concrete pipes (pressure and non-pressure)
AS 4198	Precast concrete access chambers for sewerage applications
AS/NZS 4680	Hot-dip galvanized (zinc) coatings on fabricated ferrous articles
AS/NZS 4672.1	Steel prestressing materials - General requirements
AS/NZS 4672.2	Steel prestressing materials - Testing requirements
AS 4997	Guidelines for the design of maritime structures
AS/NZS 4671	Steel reinforcing materials
AS/NZS 4676	Structural design requirements for utility services poles
AS 5100.5	Bridge design - Concrete
AS/NZ ISO 9001	Quality management systems - requirements
BS 1881-204	Testing concrete. Recommendations on the use of electromagnetic covermeters
BS 6744	Stainless steel bars for the reinforcement of and use in concrete. Requirements and test methods
BS 7973-2	Spacers and chairs for steel reinforcement and their specification – Part 2: Fixing and application of spacers and chairs and tying of reinforcement.
BS 8666	Scheduling, dimensioning, bending and cutting of steel reinforcement for concrete. Specification.
BS EN 14721	Test method for metallic fibre concrete. Measuring the fibre content in fresh and hardened concrete
BS EN 14889-1	Fibres for concrete – Part 1: Steel fibres – Definitions, specifications and conformity
BS EN 14889-2	Fibres for concrete – Part 2: Polymer fibres – Definitions, specifications and conformity
EN 206-1	Concrete – Part 1: Specification, performance, production and conformity
ISO 17025	General requirements for the competence of testing and calibration laboratories
ISO 22965-1	Concrete -- Part 1: Methods of specifying and guidance for the specifier
ACI 117	Guide For Tolerance Compatibility In Concrete Construction
ACI 224R-01	Control of Cracking in Concrete Structures
ACI 305-10	Guide to Hot Weather Concreting
ACI 440.6M	Specification For Carbon And Glass Fibre-reinforced Polymer Bar Materials For Concrete Reinforcement
ASTM A380	Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems
ASTM A955M	Standard Specification for Deformed and Plain Stainless-Steel Bars for Concrete Reinforcement
ASTM C1074	Practice for Estimating Concrete Strength by the Maturity Method
ASTM C1018	Standard Test Method for Flexural Toughness and First-Crack Strength of Fibre-Reinforced Concrete (Using Beam With Third-Point Loading) – (This standard has been withdrawn but the method can still be used)
ASTM C1603	Test Method for Measurement of Solids in Water
ASTM C1611	Standard Test Method for Slump Flow of Self-Consolidating Concrete
ASTM C1621	Standard Test Method for Passing Ability of Self-Consolidating Concrete by J-Ring
ASTM C1293	Standard Test Method for Determination of Length Change of Concrete Due to Alkali-

Number	Title
	Silica Reaction
CIA Z5	Shotcreting in Australia
CIA Z7/01	Durability Planning
CIA Z7/04	Good Practice Through Design, Concrete Supply and Construction
CIA Z7/07	Performance Tests to Assess Concrete Durability
CIA Z9	CIA Curing of Concrete
CIA Z12	CIA Pumped Concrete
CIA Z40	Super-workable Concrete
CIRIA C660	Early-age Thermal Crack Control in Concrete
AWWA B100	Granular Filter Material (by American Water Works Association)
FHWA-RD-02-099	Guide for Curing of Portland Cement Concrete Pavements: Final Report
SA HB 79	Alkali Aggregate Reaction – Guidelines on Minimising the Risk of Damage to Concrete Structures in Australia
HB 84	Guide to Concrete Repair and Protection
NT BUILD 443	Concrete, hardened: Accelerated chloride penetration
NT BUILD 492	Concrete, mortar and cement-based repair materials: Chloride migration coefficient from non-steady-state migration experiments
NP:PCH	Precast Concrete Handbook by the National Precast Concrete Association Australia (NPCAA) in conjunction with the Concrete Institute of Australia
ICRI 310.2R	Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, Polymer Overlays, and Concrete Repair
-	National Code of Practice for Precast Tilt-Up and Concrete Elements

1.3.2 SA Water Documents

The following table identifies the SA Water standards and other similar documents referenced in this document:

Number	Title
TS 0002	PVC Waterstop

1.4 Definitions

The following definitions are applicable to this document:

Term	Description
SA Water's Representative	The SA Water representative with delegated authority under a Contract or engagement, including (as applicable): • Superintendent's Representative (e.g. AS 4300 & AS 2124 etc.) • SA Water Project Manager • SA Water nominated contact person
Responsible Discipline Lead	The engineering discipline expert responsible for TS 0710 defined on page 3

Term	Description
	(via SA Water's Representative)

2 Scope

This Technical Standard applies to the construction of concrete structures; it applies to both in-situ works and construction using prefabricated concrete elements. This Technical Standard does not apply to:

- Temporary concrete structures.
- All types of lightweight concrete.
- Special technologies/innovative designs.
- Grout.
- Mortar.
- Recycled concrete.
- Expansive concrete.
- Polymer concrete.

This Technical Standard does not cover health and safety aspects of concrete manufacturing, supply and construction or third party safety requirements.

This Technical Standard shall be read in conjunction with Australian Standards and other Technical Standards as appropriate.

3 Design Life

The design life for the Works shall be instructed by SA Water's Representative and shall include:

1. 50 years: : Building and depots, sheds and warehouses, external tank aprons, hardstands, slabs on ground, ramps, switch board plinths and transformers bundings, access structures and working platforms, stormwater channels…etc.

2. 100 years: Water/wastewater treatment plants and pumping stations, storage tanks, valve chambers, Maintenance holes, pipe chairs, thrust and anchor blocks, bridges and jetty structures…etc.

3. Another period: As stipulated in the project specification.

4 Quality Assurance

The following requirements are in addition to those contained in the Contract.

The Contractor shall plan, establish and maintain a quality system for the project which conforms to this Standard and complies, as a minimum, with all the relevant system elements of AS/NZS ISO 9001 and includes materials certification, method statements, quality records including inspection and test plans (ITPs), hold points, witness points and work instructions.

Quality management systems and quality plans by the Contractor including all Sub-contractors shall be used as an aid to achieving conformance with this Standard, but they shall not relieve the Contractor of the responsibility to comply with the Contract requirements.

A copy of the quality plan shall be submitted to SA Water's Representative for approval prior to commencement of works.

The Contractor shall provide SA Water's Representative at all times with access to the Contractor's quality procedures and records to enable monitoring and quality auditing. This also includes the taking of random samples for proof testing or to carry out or to arrange for destructive or non-destructive testing.

Auditing and proof testing by SA Water's Representative shall in no way relieve the Contractor of any of the obligations under this standard.

5 Concrete

All concrete shall conform to the approved nominated concrete mixes.

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

Concrete is designated as normal class or special class as described in Clauses 5.1 and 5.2 below.

5.1 Normal Class Concrete

Normal Class concrete can be specified for non-critical elements in non-aggressive exposure conditions. Specified concrete requirements are limited in AS 1379 and key items are:

1. Strength grade of 20, 25, 32, 40, 50 MPa.
2. Slump of 20 to 120, nominated in 10 mm intervals.
3. Maximum aggregate size of 10, 14, 20 mm.
4. Air content to maximum 5%.

Normal Class concrete requires a range of concrete properties to be achieved in AS 1379, including drying shrinkage up to 1,000 microstrain (56 day value to AS 1012.13).

Guidance on Normal Class concrete is given in CIA Z7/04.

5.2 Special Class Concrete

Unless otherwise specified and approved, all concrete supplied in accordance with this Standard shall be Special Class concrete as defined in AS 1379.

This Standard describes the additional properties to be specified and criteria to be met for Special Class concretes.

5.3 Lean Concrete

Unless specified otherwise in the project specification or design drawings, lean concrete shall conform to this Standard.

The lean concrete shall have a minimum strength of 10 MPa.

The minimum cementitious material content shall be 220 kg/m^3, the maximum water to cementitious material ratio shall not exceed 0.90 and the maximum size of aggregate shall be 20 mm.

The slump of the lean concrete shall be 100 mm including use of any type of water-reducing admixtures that shall have the prior approval of SA Water's Representative.

5.4 No-Fines Concrete

5.4.1 Scope

This Clause defines the requirements for the supply of all materials and construction of no fines concrete in areas shown on the Drawings.

No fines concrete shall consist of coarse aggregate, uniformly mixed with Portland cement, and water.

5.4.2 Coarse Aggregate

Coarse aggregate shall consist of unweathered, dense, sound, clean, hard, strong, durable pieces of crushed rock free from deleterious coatings and dust and shall comply with all the requirements of AS 2758.1.

The aggregate shall be a nominal 20 mm single sized aggregate.

The flakiness index of the aggregate tested in accordance with AS 1141.15 shall not exceed 35%.

5.4.3 Cement

Cement shall be Portland Cement Type GP complying with AS 3972 and shall be in accordance with Clause 6.1.1 for the requirements that apply for Type GP.

5.4.4 Mix Design Requirements

The no fines concrete mix design shall comply with the following requirements:

1. Minimum cement content 210 kg/m³.
2. Maximum water/binder ratio of 0.5.

The proposed one (1) m³ no fines concrete mix design and all certificates of test (from a NATA accredited authority) to confirm compliance with the Standard requirements shall be submitted by the Contractor to SA Water's Representative for review and approval at least 10 working days prior to use in the Works.

The no fines concrete shall not be used in the Works until the mix design is approved by SA Water's Representative.

5.4.5 Supply and Delivery

No fines concrete shall be manufactured and delivered in accordance with the requirements of AS 1379.

5.4.6 Placement, Compaction and Finish

The no fines concrete shall not be less than the dimensions shown on the Drawings.

The area in which no fines concrete is proposed to be placed shall be inspected and checked immediately prior to commencement of placing. The no fines concrete shall be placed in such manner as to require a minimum of rehandling and shall be so distributed when compacted and finished as required by the Drawings.

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

5.4.7 Curing

No fines concrete shall be cured for at least four days by covering immediately after placing and finishing with polythene sheeting or similar material approved by SA Water's Representative. The use of wet sand or any other material which can enter the voids or curing membrane that cannot cover all the voided surfaces shall not be used for curing purposes.

5.5 Other Types of Concrete

Refer to Clauses 7, 8, 16, 17, 23, 24, 25 and 31.

6 Constituent Materials of Concrete

6.1 Cementitious Materials

Cementitious materials or binder have the same meaning in this Standard.

6.1.1 Cement

The cement shall be General Purpose cement (Type GP), Shrinkage Limited cement (Type SL) or Blended cement (Type GB), in accordance with AS 3972 and this Standard. The Contractor shall provide manufacturer's test certificates showing all cement has been sampled tested and conforms in all respects with AS 3972. Cement more than three months old shall be re-tested for conformance. Cement showing evidence of deterioration or hardening shall not be used.

Cement shall be from one manufacturer and of one brand, type and grind unless approved otherwise by SA Water's Representative. Any variation to the manufacturer, brand, type and grind constitutes a change in material and submission of a new trial mix design is required as per Clause 8.3 of this Standard.

Blended cement Type GB shall consist of a specified minimum quantity of Portland cement in combination with Ground Granulated Blast Furnace Slag, Fly Ash and/or Amorphous Silica and as specified in this Standard. Blending of cement shall be at either the cement manufacturer's facilities or at the concrete batching plant.

High early strength cement (Type HE) can be used only with the written approval of SA Water's Representative and is subject to meeting all other requirements of this Standard.

6.1.2 Fly Ash

Fly ash shall conform to AS/NZS 3582.1 and this Standard.

The use of Grade 2 fly ash is subject to meeting all other requirements of this Standard.

Fly ash shall be from a single source of power station and grade. Variations to the source of the fly ash supply and its grade in the Project shall require submission of a new trial mix design as per Clause 8.3 of this Standard.

6.1.3 Ground Granulated Blast Furnace Slag

Ground granulated blast-furnace slag shall conform to AS 3582.2 and this Standard.

NOTE: Hereafter in this Standard, the approved ground granulated blast-furnace slag is referred to as 'slag'.

Slag shall be from a single source. Variations to the source of the slag supply in the Project shall require submission of a new trial mix design as per Clause 8.3 of this Standard.

6.1.4 Amorphous Silica

Amorphous silica shall conform to AS/NZS 3582.3 and this Standard.

Amorphous silica shall be from a single source. Variations to the source of the amorphous silica supply in the Project shall require submission of a new trial mix design as per Clause 8.3 of this Standard.

6.2 Aggregates

6.2.1 General

All aggregate shall comply with all of the requirements of AS 2758.1 and this Standard. Aggregates shall consist of hard, dense, durable, uncoated rock particles and shall be free from organic matter and injurious amounts of dust, clay lumps, soft or flaky particles, shale, alkali, loam or other deleterious substances.

Calcrete, scoria, non-quarry rock, Adelaide quartzite, volcanic breccia, mudstone, sandstone, shale, highly weathered or altered rocks, argillaceous rocks, arenaceous rocks, lightweight aggregates, aggregate containing any phyllite, and any material with potential to cause deleterious alkali-silicate (ASR) or alkali-carbonate (ACR) reactions shall not be used as aggregate or as a source rock for manufactured fine aggregate.

The Contractor shall nominate the source, type and grading of the fine and coarse aggregates they intend to use. Variations to the source of the aggregates supply and type and/or the grading of the aggregates deviated more than the maximum permissible deviation specified in AS 2758.1 constitute a change in material and submission of a new trial mix design is required as per Clause 8.3 of this Standard.

The aggregates shall consist substantially of particles of satisfactory shape, defined as having a maximum dimension not greater than three times the minimum dimension.

Petrographic testing of aggregates shall be undertaken to provide information on alkali aggregate reactivity (AAR), ASR or ACR risk, by AS 1141.65 or other SA Water Representative approved test method.

Fine and coarse aggregates shall be separately tested for potential alkali aggregate reactivity (AAR) using the Accelerated Mortar Bar Test, AS 1141.60.1 or similar approved method. An alternative test method is the Accelerated Concrete Prism Test, AS 1141.60.2 or similar approved method such as ASTM C1293. Aggregates for use in concrete shall be classified as "non-reactive" when tested using the same cement type as nominated for the Works. Recently completed laboratory test data may be accepted at the discretion of the SA Water Representative.

The risk for AAR in concrete is outlined in SA HB 79 and guidance is given on use of fly ash, slag and silica fume as a mitigation measure for aggregates that would be reactive when using only Portland cement. Use of fly ash, slag and silica fume in this manner is subject to the approval of SA Water Representative. This approach is in accordance with SA HB 79.

6.2.2 Fine Aggregate

The size grading of fine aggregate when tested according to AS 1141.11.1, shall comply with the limits specified in Table B2 of AS 2758.1.

When more than one type of fine aggregate is proposed for use in the mix, the individual aggregate grading shall conform to the limits specified in Table B2 of AS 2758.1.

Where a nominated grading outside the specified limits in Table B2 of AS 2758.1 is proposed, additional information shall be provided to SA Water Representative demonstrating that the concrete produced shall meet all other requirements of this Standard, together with additional evidence of acceptable performance for segregation, bleeding, plastic shrinkage and finishing properties.

The maximum amount of water absorption for fine aggregate shall not exceed 2.5% when tested according to AS 1141.5.

Manufactured fine aggregate from a source that complies with all of the requirements of this Standard will be permitted, provided that the following requirements in either items (a) and (b), or items (b) and (c) are met.

a. The exposure classification of the concrete in accordance with AS 3600 is B1 or less;

b. The required design life of the concrete is not exceeding 50 years;

c. The concrete is used as a sacrificial layer where the face of the concrete structure is exposed to aggressive sewer environment.

Otherwise, a maximum of 25% of manufactured fine aggregate from a source that complies with all of the requirements of this Standard will be permitted. Consideration may also be given to approve the use of up to a maximum of 50% of manufactured fine aggregate by SA Water Representative if objective documented evidence is provided that concrete made with such higher amount of manufactured fine aggregate complies with all other requirements of this Standard both in the fresh and hardened states, including evidence of acceptable performance regarding tendency for segregation, bleeding, plastic shrinkage, satisfactory compaction, finishing and abrasion resistance properties.

Manufactured fine aggregate shall be crushed from rock from which coarse aggregate is produced, conforming to Clause 6.2.3. Production processes shall ensure that the manufactured fine aggregate stockpiles are not contaminated with weathered or highly altered rock or with clay seams or other contaminants. Crushing of multiple source rocks into a single manufactured fine aggregate stockpile shall not be permitted unless it can be demonstrated that such a process is under blend control and produces a consistent product.

For manufactured fine aggregate, the deleterious fines index (DFI) shall not exceed 100 when tested in accordance with AS 1141.66.

Fine aggregates shall be tested at a frequency which is sufficient to ensure that concrete complies with the specified requirements. The frequency shall not be less than that shown in Table 1 below.

Table 1 - Minimum Frequency of Testing for Fine Aggregates

Type of Test	Test Method	Minimum Frequency of Testing[1]
Particle Size	AS 1141.11.1	1. At the start of the project; and 2. 1 per 500 tonnes of aggregate production or part thereof.
Water Absorption	AS 1141.5	Half yearly interval
Material finer than 0.002 mm	AS 1141.13	1. At the start of the project; and 2. 1 per 500 tonnes of aggregate production or part thereof.
Light Particles	AS 1141.31	Monthly interval
Sodium sulfate soundness	AS 1141.24	Half yearly interval
Organic impurities other than sugar	AS 1141.34	Monthly interval
Sugar	AS 1141.35	Monthly interval
Sulfate Content	AS 1012.20.1	At the start of the project
Chloride Content	AS 1012.20.1	At the start of the project
Alkali Aggregate Reactivity	AS 1141.60.1	Yearly interval
Petrographic Examination	AS 1141.65	Yearly interval
Degradation factor[2]	AS 1141.25.3	Quarterly interval
Deleterious fines index[2]	AS 1141.66	Quarterly interval

Notes to Table 1:

[1] Any change in production parameters or change in quarry face shall initiate the commencement of a new test cycle.

[2] Applicable for manufactured fine aggregates only.

6.2.3 Coarse Aggregates

The size grading of coarse aggregate when tested according to AS 1141.11.1, shall comply with the limits specified in Table B1 of AS 2758.1.

The maximum amount of water absorption for coarse aggregates shall not exceed 2.0% when tested according to AS 1141.6.1 or AS 1141.6.2.

In addition to the requirements specified in AS 2758.1, the proportion of misshapen particles in the coarse aggregate retained on the 9.50 mm test sieve shall not exceed 25% when determined in accordance with AS 1141.14 using a 2:1 ratio.

For wearing surfaces of all exposure classifications, surfaces subject to hydraulic abrasion from liquid velocities greater than 4 m/s or concretes with the required design life in excess of 50 years, the durability of the aggregate shall conform to the requirements for exposure classification C specified in AS 2758.1.

Coarse aggregates shall be tested at a frequency which is sufficient to ensure that concrete complies with the specified requirements. The frequency shall not be less than that shown in Table 2 below.

Table 2 - Minimum Frequency of Testing for Coarse Aggregates

Type of Test	Test Method	Minimum Frequency of Testing[1]
Particle Size	AS 1141.11.1	1. At the start of the project; and 2. 1 per 1500 tonnes of aggregate production or part thereof.
Water Absorption	AS 1141.6.1 or AS 1141.6.2	Half yearly interval
Material finer than 2 microns	AS 1141.13	1. At the start of the project; and 2. 1 per 1500 tonnes of aggregate production or part thereof.
Particle Shape	AS 1141.14	Half yearly interval
Flakiness Index	AS 1141.15	Half yearly interval
Los Angeles value	AS 1141.23	Half yearly interval
Sodium sulfate soundness	AS 1141.24	Half yearly interval
Wet strength and wet/dry strength variation	AS 1141.22	Half yearly interval
Sugar	AS 1141.35	Monthly interval
Sulfate Content	AS 1012.20.1	At the start of the project
Chloride Content	AS 1012.20.1	At the start of the project
Alkali Aggregate Reactivity	AS 1141.60.1	Yearly interval
Petrographic Examination	AS 1141.65	Yearly interval

Table 2 Notes:

[1] Any change in production parameters or change in quarry face shall initiate the commencement of a new test cycle.

6.2.4 Additional Requirements for Calcareous Aggregates

Both fine and coarse calcareous aggregates including but not limited to limestone, marble and dolomite may be used in acidic condition where the pH is less than 4.0 if an approved coating or liner is used to isolate the concrete from the acidic condition. Otherwise, the calcareous aggregates shall not be used, unless all of the following criteria are met:

1. Both the fine and coarse calcareous aggregates have a minimum acid solubility of 94% when tested in accordance with AWWA B100; and

2. The calcareous aggregate is used as a sacrificial aggregate and the concrete cover is increased by an amount equal to the loss that would occur over the design life. This additional cover is sacrificial and not considered to make any contribution to the strength of the member.

Where the calcareous aggregates are used as sacrificial aggregate and the surfaces are not subject to hydraulic abrasion from acidic liquid with flow greater than 2 m/s, the maximum Los Angeles Index value of the aggregate may be relaxed but shall not exceed 55% loss.

6.3 Mixing Water

Mixing water shall consist of:

1. Batch water (water weighed or metered through the batching plant);
2. Ice;
3. Water added by truck operator;
4. Wash water retained in the drum for use in the next batch of concrete;
5. Water in the admixtures used; and
6. Free moisture on the aggregates.

The quality of the mixing water shall comply with the requirements of this Standard and AS 1379 and shall have total solids not exceeding 50,000 ppm when tested according to ASTM C1603.

All non-potable water shall be sampled and tested as a minimum at six monthly intervals to demonstrate the compliance with the requirements of this Standard and AS 1379.

6.4 Admixtures

Admixtures shall conform to the requirements of AS 1478.1 and shall be used in accordance with AS 1379, the manufacturer's recommendation and this Standard.

The Contractor may elect to use air-entraining admixtures for the concrete with exposure classification B1 or less. The use of air-entraining admixtures in all other exposure classifications and for freeze thaw resistance shall be subject to approval by SA Water Representative.

Set-accelerating and hydration control admixtures shall not be used unless approved by SA Water Representative.

Admixtures shall have no harmful effect whatsoever upon the quality of the concrete or upon any reinforcement or pre-stressing system or other fixtures embedded therein.

Where two or more admixtures are proposed for incorporation into a concrete mix, their compatibility shall be certified in writing by the manufacturer(s).

Where admixtures are proposed the following information shall be provided to SA Water Representative:

1. Name, type, manufacturer's detail and dosage rate;
2. Purpose/reason for inclusion;
3. Method of use, including storage and method for controlling and measuring dosage; and
4. Conforming test results from the manufacturer.

The Contractor's Premix Supplier may need to use a water-reducing set-retarding admixture to achieve the specified water/cement ratio and workability requirements. Where a water-reducing admixture is used, the Premix Supplier shall show by tests that the use of the admixture, in combination with the other materials to be used in the Works, produces the desired effect without affecting the other qualities required for the concrete, and without endangering the reinforcement.

The water-reducing set-retarding (WRRe) admixture shall comply with the requirements for a Type WRRe admixture specified in Section 2, AS 1478.1. The dosage used in each mix and

section of the works shall be as approved by SA Water's Representative with the mix design at Clause 8.4.

For high-slump concrete in deep pour walls, the Contractor may need to use a mid-range (MWR) or high range (HWR) admixture to increase workability, plus a compatible water-reducing set-retarding admixture, complying with the requirements specified in Section 2, AS 1478.1. The dosage rate shall be as approved by SA Water's Representative with the mix design at Clause 8.4.

The total alkali contribution levels (measured as Na_2O equivalent) of all admixtures used in a mix should not exceed 0.20 kg/m³. Total Na_2O equivalent from admixtures may exceed 0.20 kg/m³ subject to the overall limit of 2.8 kg/m³ Na_2O equivalent for concrete is not exceeded.

The concrete for the floor slab of water tanks only that are typically 150 mm thick and up to 200 mm thick may contain an approved shrinkage-reducing admixture to SA Water's Representative approval, including the dosage rate. Note that the addition of the shrinkage-reducing admixture may reduce the compressive strength compared to a reference concrete without the admixture and the Contractor's Premix Supplier may need to make adjustments to the water/binder ratio to achieve the required strength. Usage shall be in accordance with the admixture manufacturer's recommendations and approval of mix design at Clause 8.4.

Use of integral waterproofing admixtures in the concrete shall only be used with the prior written approval of SA Water's Representative to increase watertight integrity (e.g. in-situ joints in precast walls of water tanks) and to increase resistance to acidic or acid sulfate soils in the absence of a membrane.

6.5 Other Additives

Materials other than those detailed in Clauses 6.1 to 6.4 are considered as additives.

Refer to Clause 31.1 for the use of steel fibres that comply with BS EN 14889-1 CE Marking System 1 and are used for structural purposes.

Refer to Clause 31.2 for the use of polymer fibres EN 14889-2 Class II that comply with CE Marking System 1 and are used for structural purposes.

All other types of steel fibres and polymer fibres shall be classified as additives.

The use of additives shall be used in accordance with AS 1379, the manufacturer's recommendation and this Standard.

The additives shall have no harmful effect whatsoever upon the constituent materials used in the concrete, the quality of the concrete or upon any reinforcement or prestressing system or other fixture embedded therein.

Where additives are proposed for incorporation into a concrete mix, their compatibility with the concrete admixtures shall be certified in writing by the manufacturer(s). Where two or more additives are proposed for incorporation into a concrete mix, their compatibility shall also be certified in writing by the manufacturer(s).

Where additives are proposed the following information shall be provided to SA Water Representative:

1. Name, type, manufacturer's detail and dosage rate;

2. Purpose/reason for inclusion;

3. Method of use, including storage and method for controlling and measuring dosage; and

4. Conforming test results from the manufacturer.

6.6 Soluble Salts

Sulfate and chloride ion contents for the concrete mix shall be reported for the proposed mix designs based on the values in the constituent materials. Sulfate and chloride ion contents shall also be determined by testing of hardened concrete in accordance with AS 1012.20.1.

The sulfate content of concrete expressed as the percentage by mass of acid-soluble SO_3 to the total cementitious material shall not be greater than 5% generally and 4% for steam and heat accelerated cured concrete.

The mass of acid-soluble chloride ion per unit volume of concrete shall not exceed the values given in Table 3.

Table 3 - Maximum Acid-Soluble Chloride Ion Content in Concrete

Exposure classification	Maximum acid-soluble chloride ion content (kg/m^3)
A	0.8
B1	0.6
B2	0.4
C1	0.3
C2	0.3
D & U	To durability assessment

6.7 Storage of Materials

6.7.1 Storage of Cementitious Materials

All cementitious materials including cement, fly ash, slag and/or amorphous silica in solid form shall be delivered and stored in accordance with the requirements of AS 3972, AS 1379 and this Standard. The cementitious materials shall be dry and free from contamination. All transportation units and storages including silos, bins or sheds shall bear a clear indication of the type of binder in them. Different types of cementitious material shall not be mixed in the same transportation units and storages.

In addition, cementitious material in bags shall be stored above ground level in a suitable weatherproof structure of which the interior shall be dry, protected from dampness and well ventilated at all times. Different types of cementitious material in bags shall be clearly distinguished by visible markings and shall be stored in separate stacks. Cementitious material in bags shall be used in the order in which it is delivered. Cementitious material from broken bags shall be rejected.

Cementitious material shall be supplied in the manufacturer's sealed unbroken bags or in bulk and shall be free flowing and free of lumps or signs of moisture absorption. Cementitious material, which has deteriorated, become hardened or lumpy or not conforming to this Standard in any way, shall be rejected.

6.7.2 Storage of Aggregates

All aggregates shall be delivered and stored in accordance with the requirements of AS 1379 and this Standard.

Each type or nominal size of coarse aggregate and fine aggregate shall be kept separated and suitable precautions shall be taken to prevent the aggregates from being contaminated by the ground or by wind-blown dust or other foreign matter. Aggregates shall also be delivered and stored in such a manner that they will prevent entry of surface or groundwater, allow free drainage of rain water and will not segregate.

The storage of aggregates shall be arranged so that drying out and heating in hot weather are prevented in order to avoid fluctuations in water content and reduce temperatures.

6.7.3 Moisture Content of Aggregates

The moisture content of the fine and coarse aggregates shall be determined prior to concrete production for the day and whenever conditions change or fresh aggregates are delivered.

The moisture content of the fine and coarse aggregates shall be determined to constant mass in accordance with AS 1289.2.1.1, AS 1289.2.1.2, AS 1289.2.1.4, AS 1289.2.1.5 or AS 1289.2.1.6. Moisture meters or other equivalent devices may also be used provided they are calibrated, as a minimum, on a monthly basis.

Corresponding corrections shall be made to the mass of all aggregates and the volume of water used in the mix so that the nominated water to cementitious material ratio is achieved.

7 Design of Concrete Mixes

7.1 Requirements for Fresh Concrete

7.1.1 Consistency

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

The consistency of each batch of concrete shall be checked by means of the slump test. Sampling and testing shall be carried out in accordance with AS 1012.1 and AS 1012.3.1, respectively.

Where a slump in excess of 180 mm is proposed, the Contractor shall demonstrate by way of trial pour in accordance with Clause 8.3 that the concrete can be placed, compacted and finished without deleterious effects.

Slump flow shall be specified and tested in accordance with AS 1012.3.5 when a slump greater than 200 mm is required.

Tolerances on slump values shall be in accordance with AS 1379 and for slump flow in accordance with the specified values for consistency greater than 200 mm slump taking account of AS 1012.3.5.

A specified slump of 150 mm or greater (e.g. 180 ± 40 mm) may be considered for wall construction to assist compaction depending on wall height, thickness, slump retention (i.e.

higher slump will retain workability longer, particularly in hot weather concreting) and formwork design to withstand the fresh concrete.

Concrete placed under water shall contain an approved anti-washout admixture.

7.1.2 Slump with Mid-Range and High-Range Water-Reducing Admixture

A concrete mix design with a mid-range (MWR) or high range (HWR) admixture shall have a trial mix (refer Clause 8.3) completed before Works use to determine the concrete properties including total water content and reversion time.

A concrete mix design with a mid-range (MWR) or high range (HWR) admixture added after all other concrete materials have been mixed shall have trial mix slump tests completed before and after the addition of the admixture.

Tolerances on slump values shall be in accordance with Clause 7.1.1.

7.1.3 Drying Shrinkage

Drying shrinkage shall be limited to reduce drying shrinkage cracking.

Drying shrinkage shall be measured for the concrete mix design and acceptance (refer Clause 8) in accordance with AS 1012.13 to 56 days based on the average of three concrete drying shrinkage prisms and shall not exceed the values given in Table 4.

Table 4 – Maximum Shrinkage Strain of Concrete Specimens

Exposure classification	Maximum drying shrinkage (με) at 56 days of drying
A	750
B1	700
B2	650
C1	650
C2	650
D & U	To durability assessment

A shrinkage reducing admixture shall be used in floor slabs of water tanks in accordance with Clause 6.4 to minimise drying shrinkage.

7.1.4 Bleed

Bleed shall be limited in order to control plastic settlement or the formation of bleed channels that might prejudice the concrete durability or appearance. Bleed shall be measured in accordance with AS 1012.6 . Bleed shall not exceed:

1. 3% for slabs;
2. 2% for walls;
3. 1% for piles and diaphragm walls;
4. 2% for other elements.

Concrete bleed has an impact on plastic cracking in combination with the evaporation rate (refer Clause 10.1.4.4).

7.1.5 Air Content

Air content of concrete shall be measured using one of the methods provided in the AS 1012.4.1 or AS 1012.4.2.

The air content of concrete shall not exceed:

1. 3% for higher durability concrete (e.g. concrete in structures for water retaining/excluding, wastewater, dams, desalination, below ground liquid excluding, etc.) not subject to freezing;

2. A specific air content where freeze thaw resistance is required in accordance with AS 3600 Section 4.7 by use of air-entrainment admixture (refer Clause 6.4);

3. 4% for all other content.

7.2 Requirements for Hardened Concrete

7.2.1 Design Requirements

The Contractor shall be responsible for all design requirements for Design and Construct Contracts.

NOTE: The Contractor shall discuss with SA Water Representative prior to undertaking any design that departs from this Standard including all references in Clause 1.3.

7.2.2 Typical Concrete Characteristics and Durability Requirements for Concrete based on Exposure Classifications

The concrete used shall have the typical characteristics given in Table 5 subject to project specific structural and durability requirements and to the approval of SA Water Representative.

The durability requirements for concrete elements based on exposure conditions are related to the design life (refer Clause 3) for the Works as listed below:

1. 50 years in accordance with AS 3600 and AS 3735:
    a. The requirements are for plain, reinforced and prestressed concrete structures and members for 50 years +/- 20% are given in AS 3600 Section 4.1;
    b. AS 3735 durability refers to AS 3600 so the same requirements apply;
    c. AS 3600 requirements can apply without additional durability review for AS 3600 exposure categories A1 and A2;

2. 50 years in accordance with AS 3600/AS 3735 plus additional durability review;
    a. AS 3600 Section 4.1 Notes given below that can justify durability review by the Designer using a Durability Consultant as required;
        - “More stringent requirements would be appropriate for structures with a design life in excess of 50 years (e.g. monumental structures), while some relaxation of the requirements may be acceptable for structures with a design life less than 50 years (e.g., temporary structures).”

- "Durability is a complex topic and compliance with these requirements may not be sufficient to ensure a durable structure."

b. AS 3600/AS 3735 requirements need additional durability review for all AS 3600 exposure categories excluding A1 and A2. The extent of review will vary from minor for exposure category B1 to more detailed for exposure categories B2, C1, C2 and U;

3. 100 years in accordance with AS 5100.5;

   a. For structures designed to AS 3600 and AS 3735 with a design life of 100 years use AS 5100.5 durability since requirements are for plain, reinforced and prestressed concrete structures and members for 100 years. For concrete elements designed in accordance with AS 3735 for 100 years design life, increase the cover of AS 3735 by 10 mm for Class B1/B2 and by 15mm for Class C;

   b. AS 5100.5 requirements can apply without additional durability review for AS 5100.5 exposure categories A and B1 non-aggressive soils. Additional durability review is required for all other exposure categories;

4. 100 years in accordance with AS 5100.5 plus additional durability review;

   a. AS 5100.5 Section 4.1 Notes given below that can justify durability review by the Designer using a Durability Consultant as required;

      - "Some relaxation of the requirements may be acceptable for temporary structures."
      - "Durability is a complex topic and compliance with these requirements may not be sufficient to ensure a durable structure. AS 5100.5 Supp 1 (Commentary to this Standard) contains background to and guidance on the provisions of this Clause."

   b. AS 5100.5 requirements need additional durability review for all AS 5100.5 exposure categories excluding A and B1 non-aggressive soils. The extent of review will vary from minor for exposure category B2 to more detailed for exposure categories C and U.

5. Durability review is required for specific exposure categories of liquid retaining and excluding structures in AS 3735;

6. AS 2159 provides exposure conditions below ground level for 50 and 100 years design life;

7. Greater than 50 years and less than 100 years shall use the above requirements for 100 years together with durability review to determine if any relaxation of the requirements can apply;

8. Greater than 100 years in accordance with AS 5100.5 plus additional durability review by a Durability Consultant;

9. A Concrete Durability Plan specific to the Works that will achieve the intent of this Clause shall be submitted for the approval of SA Water Representative prior to proceeding with the work.

10. All durability review input given above shall be in accordance with CIA Z7/01.

NOTE: Exposure categories are given in AS 3600, AS 4997, AS 5100.5 and AS 2159. The exposure categories are limited and guidance on a broader range of exposure categories are in international Standards such as ISO 22965-1 and EN 206-1.

It is intended that this Clause of this Standard will be revised upon the release of the following documents:

1. *New Australian Standard for Bridge Design Part 5: Concrete (currently in draft DR AS 5100.5);*

2. *CIA Z7/02 Durability Exposure Classes (draft in progress) and CIA Z7/03 Durability Deemed to Comply Requirements (draft in progress).*

Table 5 - Typical Concrete Characteristics

Exposure classification	Minimum f'_c (MPa) at 28 days	Cementitious material content [1] (kg/m^3)		Maximum [2] water-to-cementitious material ratio	Maximum Apparent volume of permeable voids [3]	Chloride ion penetration in marine and saline exposure		Supplementary cementitious material [5]			
						Maximum chloride test coefficients at 20°C ($\times 10^{-12}$ m^2/sec) [4]		Fly ash (% by mass)		GGBFS (% by mass)	
		Minimum	Maximum			NT Build 443 (De)	NT Build 492 (DRMC)	Minimum	Maximum	Minimum	Maximum
A	25	280	320	0.56	-	-		0	30	0	40
B1	32	320	400	0.50	14% at 28 days	-		0	30	0	40
B2	40	360	450	0.45	13% at 28 days	3.5	8.0	20	50	40	70
C1	50	420	500	0.40	12% at 56 days	2.0	4.0	25	50	50	70
C2	50	450	500	0.36	12% at 56 days	2.0	4.0	30	50	60	70
D & U	To the assessment of a Durability Consultant and SA Water Representative approval										

Table 5 Notes:

Note 1: Cement content maximum and minimum values are subject to variations in source of cementitious materials, binder proportions, quality of binder materials, etc. and therefore some variations can occur over time and be applied for specific Works to SA Water's Representative written approval. In addition, the cement content will vary with seasonal temperature variations.

Note 2: The water/cement ratio must not be less than 0.32 for cast-in-place concrete and 0.28 for precast concrete, to ensure cement hydration.

Note 3: % Apparent volume of permeable voids as determined by test method AS 1012.21 with specimen prepared in accordance with AS 1012.8.1.

Note 4: For the Maximum chloride test coefficients, the following terms apply:

- De denotes effective diffusion coefficient from Nordtest NT Build 443.
- DRMC denotes rapid migration coefficient from Nordtest NT Build 492.

- Continuously standard moist-cure after demoulding specimens for the Nordtest NT Build 443 and NT Build 492 tests and test at an age of 56 and 28 days respectively.
- The specified coefficients are based on the minimum concrete covers specified in AS 5100.5:2004 Table 4.10.3 (A).
- The Principal may modify the specified coefficients if the concrete cover is increased.
- The specified coefficients are for a test temperature of 20 ^{o}C. Modify the required coefficients for a given temperature as follows: (De or DRMC)req = 4.15 $e^{-0.0703\,T1}$ where T1 is the specified temperature.

Note 5:

- Minimum and maximum figures do not apply to a triple blend mix;
- GGBFS should be used for members subject to acidic environment;
- The contractor shall address the potential of lower early strength development, curing and stripping times and concrete strength requirements for early lifting;
- Amorphous silica or silica fume shall not be used unless otherwise approved by SA Water Representative; and
- For exposure classifications A and B1, concrete made with blended cement must contain a minimum of 240 kg/m^3 of General Purpose or Shrinkage Limited cement to limit carbonation.

Note 6: For sewage and wastewater structures of item 2 exposures in Table 4.1 of AS 3735, install approved physical barrier (protective coatings or liner) to protect the concrete against acid attacks. The barrier shall cover the entire concrete surface above water level (including cover slab soffit) and extend to a minimum of 500 mm below the low water level. The design life of the physical barrier shall be 100 years. Alternatively, subject to the approval of SA Water Representative, the physical barrier shall be installed such that it can be replaced or repaired without major work. The minimum design life for this alternative approach shall not be less than 25 years.

Note 7: Concrete characteristics for dams, desalination plants, etc. as well as D & U exposures shall be project specific to the assessment of a Durability Consultant and approval of SA Water Representative.

Note 8: Precast concrete shall be according to Table 5. Precaster alternative concrete mix may be considered for any precast concrete elements subject to SA Water Representative review and written approval.

Note 9: Unless otherwise specified on the Drawings, or approved by SA Water Representative, the concrete slump of the nominated mix shall not exceed 180 mm. Where a nominated slump in excess of 180 mm is proposed, demonstrate that the concrete may be placed, compacted and finished without deleterious effects.

Note 10: For consistency of concrete mix refer Clause 7.1.1 and 7.1.2.

Note 11: Drying Shrinkage shall not exceed Clause 7.1.3 requirements.

Note12: Concrete bleed shall not to exceed Clause 7.1.4 requirement.

Note 13: Air content of the concrete shall not exceed Clause 7.1.5 requirement.

Note 14: Maximum crack width shall not exceed Clause 7.2.4 requirement.

NOTE: SA Water encourages and promotes research, development and innovation. SA Water will consider the uptake of new concrete product and technology that have significant potential. The Contractor shall discuss with SA Water Representative prior to using the product and/or technology.

7.2.3 Cover Tolerance Requirements

The tolerance on concrete cover shall be in accordance with AS 3600 for 50 years design life and AS 5100.5 for greater than 50 years up to 100 years design life unless SA Water's Representative requires compliance with the tolerances on minimum cover given in Table 6. Concrete elements designed to AS 3735 shall have tolerance on concrete cover of -0 mm, +10 mm.

Table 6 - Tolerance on Locations of Reinforcement

Element	Tolerance on Minimum Cover (mm)
Beams, columns, walls and suspended slabs	-0, +15
Slabs on grade	-0, +30
Footings cast against ground	-0, +50

7.2.4 Maximum Crack Width Requirement

Unless otherwise designated in the Contract, concrete shall have no cracks at any stage after construction measured at the concrete surface of width greater than the values listed in Table 7.

Table 7 – Maximum Acceptable Crack Width

Exposure classification	Maximum acceptable crack width (mm)
A	0.3
B1	0.2
B2	0.15
C1	0.1
C2	0.1
D & U	To durability assessment

Note: Guidance on the durability of concrete with crack widths is given in CIRIA C660 and will be available in the future from CIA Recommended Practice Z7/06. Both include the acceptable crack width from a particular viewing distance reduces as the prestige of the structure increases. Guidance is also given in ACI 224R-01. The Contractor shall refer to "Campbell-Allen, D., 1979. The Reduction of Cracking in Concrete. University of Sydney in association with Cement and Concrete Association of Australia, Sydney, May."

Concrete early age thermal crack risk assessment is required at Clause 32.

AS 3735 Suppl-2001 provides mean crack widths for design of concrete structures retaining liquids for conditions of early-age thermal, shrinkage and restraint plus limiting steel stress for serviceability.

In addition, where a concrete element is required to be liquid retaining or excluding, concrete shall have no cracks at any stage after construction measured at the concrete surface of width greater than 0.2 mm. All cracks of surface width greater than 0.1 mm and cracks with any visible water leakage in concrete elements to be liquid retaining or excluding shall be recorded by the Contractor in accordance with Clause 18 for assessment and repair to SA Water's Representative requirements.

Note: The liquid retaining or excluding requirements for concrete structures can also apply where a liquid is in contact with the concrete. For example, the suspended roof slab of a water tank or the suspended roof slab of a chlorine building is required to be watertight. In addition, below ground concrete structures may be required to be watertight.

All cracks greater than the crack width specified in Table 7 shall be classified as non-compliant. All cracks shall be inspected and assessment including the need for repair in accordance with Clause 18 and any repairs required shall be in accordance with Clause 21.

7.2.5 Requirements for Concrete and Concrete Structures in Contact with Potable Water

This clause applies to all concrete that is in contact with Potable Water (e.g. concrete water storage tanks, etc.).

All additives, admixtures, release agents, seal coats, paints/linings, repair materials and curing compounds that will remain on the surface of concrete that will be in contact with potable water (including, but not limited to production, treatment, storage and distribution) shall comply with AS/NZS 4020.

The Contractor shall provide evidence in the form of certification by a NATA accredited laboratory to SA Water's Representative.

Variations to the source of the constituent materials of concrete and/or the mix design constitute a change in material and submission of a new certification is required.

In the circumstance where the cost of testing or the time available to get testing completed is not feasible, the Contractor shall apply a AS/NZS 4020 certified coating or liner on the surface of the concrete that comes in contact with potable water.

8 Design and Acceptance of Concrete Mix

8.1 General

The Contractor shall be responsible for the design and production of all concrete so that the specified durability, strength and other requirements of the hardened and fresh concrete are achieved. The concrete used shall be in accordance with AS 1379 and this Standard and can be ready-mixed or batched on site.

Note: The use of ready-mixed concrete or precast concrete shall in no way lessen or remove this responsibility.

Sprayed concrete or shotcrete shall only be used if approved by SA Water Representative.

Under no circumstances shall hand mixed concrete be permitted.

8.2 Proposed Mix Design

The Contractor shall submit details of the mix design for each specified class of concrete to SA Water Representative prior to the commencement of the trial mix. The mix design shall use only the constituent materials that have been shown by testing to meet the requirements of Clause 6 of this Standard.

The proposed mix design submission shall include the following information:

1. Cementitious material, including but not limited to:

a. Brand and type; and

b. Current test results for all cementitious materials demonstrating conformance with Clause 6.1;

2. Aggregates, including but not limited to:

a. Material source and geology;

b. Nominated combined aggregate grading; and

c. Current test results for all aggregates demonstrating conformance with Clause 6.2;

3. Admixtures and additives, including but not limited to:

a. Manufacturer's technical data sheet;

b. Manufacturer's material safety data sheet; and

c. Manufacturer's certification of compatibility;

4. Premix supplier proposed mix design details, including but not limited to:

a. Mix code;

b. Quantity of each constituent material, including all admixtures and additives, based on 1 m^3 and aggregates at saturated surface dry (SSD);

c. Method of controlling alkali-aggregate

d. Target water to cementitious binder ratio;

e. Slump at point of discharge; and

f. For concrete containing high range water reducers: final slump and reversion time.

5. Batching, mixing and transport, including but not limited to:

a. Methods;

b. Level of control and accuracy of batching;

c. Level of control and accuracy of determination of the aggregate moisture content;

d. Minimum mixing time; and

e. Maximum period for completion of discharge; and

f. Compliance of batch plant equipment and transit mixers with AS 1379;

6. Placement of concrete, including but not limited to:

a. Methods for transfer, placement and compaction on site noting specified slump and pour geometries;

b. Concrete delivery rate and number of vibrators onsite;

c. Sequence of casting;

d. Maximum drop height to avoid segregation;

e. Any non-standard site testing requirements such as slump-flow for concretes greater than 200 mm slump; and

f. Particular requirements for sprayed or other special purpose concrete;

7. Hardened concrete properties as per Clause 8.3.2 and for concrete characteristics in Table 5, including but not limited to:

a. Target mean compressive strength;

b. Target mean drying shrinkage; and

c. Target and limiting values for any other specified properties, including but not limited to: Flexural strength, Sulfate and chloride ion contents, apparent volume of permeable voids, chloride diffusion coefficient, and chloride migration coefficient.

The Contractor may submit for consideration the results of tests completed within the previous 12 months from similar mixes produced from the plant and materials proposed for the Project. The SA Water Representative will instruct whether a trial mix shall be undertaken as per Clause 8.3.

The Contractor shall submit the proposed concrete curing method in accordance with Clause 13.1 at the same time of submitting the concrete mix design.

8.3 Trial Mix

8.3.1 General

The Contractor shall make trial mixes for all classes of concrete having a characteristic strength greater than 20 MPa unless directed otherwise by SA Water Representative.

The Contractor may submit for SA Water Representative consideration proposed concrete mix designs with the results of concrete mix tests and materials data for all the requirements in Clauses 8.3.2 and 8.3.3 completed within the previous 12 months from similar mixes produced from the plant (or similar with justification) and similar materials proposed for the Works as an alternative to concrete trial mixes. SA Water Representative shall review the submission and determine if a concrete trial mix is required by the Contractor.

The concrete mixes shall be made using the plant and degree of quality control proposed for the Project. The minimum volume of the trial mix shall be 25% of the rated capacity of the mixer.

Where concrete is not batched and mixed on the site, a time delay equal to an average delivery time on site shall be applied between the mixing of the concrete and the sampling for slump and other samples for the performance requirement tests.

As an alternative to the trial mix approach, the Contractor may conduct the trial mix in accordance with AS 1012.2 using a NATA accredited laboratory. Following the laboratory trial, the Contractor shall conduct a site trial mix with a minimum volume of 25% of the rated capacity of the site mixer to verify the laboratory results of slump, water to cementitious material ratio and 28 days compressive strength.

SA Water's Representative may permit the Contractor to use the remaining trial mix concrete in a non-critical structure.

8.3.2 Trial Mix Test Requirements

Each trial mix shall demonstrate by way of testing that all the performance requirements as specified in Clause 7 are achieved.

Plastic concrete testing shall include:

1. Concrete temperature;

2. Slump;

3. Air content;

4. Mass per unit volume;

5. Bleed; and

6. Reversion time consistency testing to Clause 7.1.1 until an 80 mm slump is reached for concrete containing medium or high range water reducer (AS 1478.1 Type MWR or HWR).

Unless otherwise specified and approved by SA Water's Representative, the measured slump after adding water-reducing admixtures shall be within the allowable range specified in AS 1379 of the target slump.

Not less than twelve (fifteen if 56 day age strengths are required) concrete cylinders and three concrete drying shrinkage prisms shall be cast and cured in accordance with AS 1012.8.1 and AS 1012.8.4, respectively. The following hardened properties shall be tested:

1. Seven (7) days compressive strength based on the average of three concrete cylinders;

2. 28 days compressive strength based on the average of three concrete cylinders;

3. If specified, 56 days compressive strength based on the average of three concrete cylinders;

4. Drying shrinkage after total periods of air drying in accordance with AS 1012.13 of seven (7), 14, 21, 28 and 56 days based on the average of three concrete drying shrinkage prisms;

5. Acid soluble sulfate and chloride ion contents.

6. % AVPV at 28 and 56 days based on the average of two cylinders per age moulded and cured to AS 1012.8.1 and tested in accordance with AS 1012.21.

Additional concrete cylinders (a minimum of three per age) shall be required if strength gain is to be assessed for early stripping or loading.

The following hardened properties shall also be tested for concrete where chloride induced reinforcement corrosion is a potential durability risk during the design life with chlorides from exposure that is marine, inland saline, operational or others:

1. Chloride Diffusion Test NT BUILD 443 based on the average of two concrete cylinders; and

2. Rapid Chloride Migration Test NT Build 492 based on the average of two concrete cylinders.

8.3.3 Trial Mix Report

The Contractor shall submit a Trial Mix Report to obtain approval of the proposed concrete mix design containing the following minimum requirements for inclusion in the Trial Mix Report:

1. Class of concrete;

2. Supplier of concrete (if ready-mixed);

3. Mix design one cubic metre proportions (by weight and water by volume) of all materials comprising the mix including any proposed admixtures (by volume);

4. Name of supplier and Certificates of Compliance with current quality control test results required by this Standard not more than 12 months old for all materials used in the mix (i.e. cementitious binders, aggregates, water, admixtures). Coarse and fine aggregates information on type, source and required test data to be in accordance with Clause 6.2;

5. Concrete mix design and performance test data for any similar recent concrete known and available to be supplied by the Contractor that will assist the concrete trial mix assessment;

6. Trial mix performance to be reported shall include the below:

a. Actual batched quantities of all materials and comparison with the proposed mix design;

b. Moisture condition of all aggregates used in the trial mix;

c. Plastic and hardened concrete properties required by Clause 8.3.2;

d. Concrete containing medium or high range water reducer (AS 1478.1 Type MWR or HWR): Total water added, water/binder ratio, slump, and reversion time;

7. Trial mix concrete testing shall be completed in accordance with relevant Australian Standards unless allowed or specified otherwise in this Standard;

8. Trial mix report shall be in general accordance with AS 1012.2 as a guideline approach.

8.4 Approval of Concrete Mix Design

No concrete shall be placed until approval of the trial mix has been obtained from SA Water's Representative. The details of each proposed mix together with a certificate stating that the nominated trial mix and its constituents conform to this Standard shall be provided before the trial mix is approved.

All trial mix test results shall be provided prior to the mix being approved for use.

The trial mix, the plant and the degree of quality control shall be approved if the trial mix test values achieve the specified performance as detailed in Clause 7.

The test values obtained from the approved trial mix shall become the approved benchmark for assessing the concrete used in the Project. All concrete of the same class used in the Project shall have the same performance or test results, within a tolerance as detailed in AS 1379 or this Standard.

SA Water's Representative may give provisional approval of a mix based on early testing. Notwithstanding any such provisional approval, all the concrete shall meet all performance requirements.

If, during the course of the Project, the degree of quality control is not maintained (as evidenced by a decline in the performance test values and/or by a deterioration in the methods employed in batching and mixing), SA Water's Representative may withdraw the approval of the mix pending establishment of improved quality control, or if necessary, a redesign of the mix.

8.4.1 Variations to Approved Concrete Mix Design

Approved concrete mixes shall not be altered without the approval of SA Water's Representative. The approved mix shall be used until approval is given for an altered mix.

The quantities of the constituents in an approved mix may be varied to improve the quality of the concrete or maintain grade compliance. Variations to the quantities of constituents in the nominated mix shall not exceed the following and shall still conform to the other requirements of this Standard:

1. Cementitious materials: 3% by mass of each constituent;

2. Aggregates: 5% by mass of each constituent; and

3. Admixtures: 5% by volume and/or mass of each admixture.

The varied concrete mix shall conform to the minimum cementitious material content, maximum water to cementitious material ratio and within the specified proportion of cement and supplementary cementitious material as specified in Table 5. The amount of admixture used in the varied concrete mix shall within the manufacturer's recommendations. All such variations shall be

notified in a timely manner to the SA Water Representative, who will instruct any requirement for mix trials to demonstrate continued compliance.

Variation of the approved mix beyond the limits stated above, or changes to the type or source of any constituent, shall require submission of a new trial mix design.

8.4.2 Trial Pours

Trial pours shall be performed on site before making concrete for the actual work when instructed by SA Water Representative.

The mixes to be used in the trial pours shall be those approved in accordance with Clause 8.3.3. The purpose of the trials is to verify that concrete manufactured in accordance with this Standard can be placed, compacted and cured in accordance with this Standard using the plant, equipment and procedures proposed by the Contractor. In addition the quality assurance procedures shall be in effect on these trial pours. The trial pour shall not be incorporated in the actual work unless approved by SA Water Representative.

SA Water Representative will nominate the scope of the trial pours, including preparation of a procedure for determining the performance of the nominated concrete mix(es). The proposed trial shall involve at least two consecutive pours, with the procedure detailing the following information:

1. Transport and placement, including plant and equipment to be used;
2. Dimensions of the proposed pour, to represent a pour for the largest sections to be constructed, but not to be less than a volume to be nominated by SA Water Representative, placed in a pour of approximately equal dimensions (width, length and depth);
3. Temperature control;
4. Temperature monitoring;
5. Curing regime and time between placement of consecutive pours;
6. Crack inspection, recording and monitoring; and
7. Other matters specific to the trial pour (e.g. for sprayed concrete).

The trial pours shall be available for inspection up to fourteen (14) days after placement. If the trial pour fails to meet any requirements of this Standard the mix design and trial pour procedure shall be reviewed and amended as necessary. A new trial pour shall be conducted as directed by the SA Water Representative and the results submitted for approval.

8.5 Concrete Maximum Temperature

The maximum temperature of all precast and cast in situ concrete during the first 28 days shall not exceed the values below in accordance with CIA Z7/04:

1. 70 °C for cement type GP cement; and
2. 80 °C for other approved cement systems incorporating a specified minimum quantity of 40% slag, 20% fly ash or 8% silica fume).

The early-age concrete crack risk shall be assessed in accordance with Clause 32 when the maximum concrete temperature is likely to exceed 70 °C.

The maximum temperature values above are required for all precast and cast in situ concrete to minimise the risk of delayed ettringite formation (DEF) in accordance with CIA Z7/04.

8.6 Concrete Maximum Temperature Differentials

All precast and cast in-situ concrete shall have as a guidance maximum temperature differential across any section limited to values below in accordance with CIA Z7/04 and CIRIA C660:

- Siliceous Gravel: 20 °C
- Granite: 28 °C
- Basalt: 32 °C
- Limestone: 35 °C.

The early-age concrete crack risk resulting from temperature differentials shall be assessed in accordance with Clause 32, which shall take precedence over the above guidance values.

9 Supply and Delivery of Concrete

9.1 General

All concrete supplied shall conform to the approved concrete mix and shall be delivered in accordance with AS 1379 and this Standard. The Contractor is responsible to ensure the concrete is thoroughly and uniformly mixed before discharging the concrete.

The size of each concrete batch shall be determined considering the type and properties of concrete, capacity and performance of mixing equipment, method of transportation, type of construction and quantity of concrete to be placed.

The Contractor's Concrete Supplier shall provide and maintain and operate the batching equipment so as to accurately determine and control the amount of each separate material entering the concrete to the tolerances specified in AS 1379.

Mixing of concrete shall comply with the requirements of AS 1379.

The Contractor's Concrete Supplier shall use truck mixers that comply and have been maintained in accordance with the requirements of AS 1379.

The Contractor's Concrete Supplier shall keep full and detailed batching and delivery records and these will be made available to SA Water's Representative within three (3) working days of any request.

9.2 Concrete Delivery

Concrete shall be transported with minimum delay and in a manner which will prevent segregation, loss of material or premature stiffening.

Concrete which has begun to stiffen shall not be used.

If concrete is delivered using a mixer or agitator, the size of each concrete batch shall not exceed the rated capacity of the agitator drum.

In addition to the information required by AS 1379 the following information shall also be recorded on the delivery docket:

1. Concrete mix unique identification code used by the concrete premix supplier as per the approved mix design;

2. Nominated water to cementitious material ratio;

3. Actual water to cementitious material ratio at discharge;
4. Nominated initial slump;
5. Time at discharge;
6. Total actual water in the batch, including but not limited to:
    a. Moisture contents of both fine and coarse aggregates as required by Clause 6.7.3;
    b. Batch water and any added at the slump stand;
    c. Total amount of water permitted to be added on site that will not exceed the water/binder ratio; and
    d. Water added on site before commencement of discharge, including water used to wash down the mixing blades of the mixer or agitator;
7. Cementitious binder, including but not limited to:
    a. Brand and type;
    b. Total mass of cementitious binder; and
    c. Proportions of components by mass;
8. Chemical admixtures, including but not limited to:
    a. Types; and
    b. Amounts;
9. Any other additives to a batch.

9.3 On-site Transportation

Concrete transportation equipment used on site shall deliver concrete with minimum delay and in a manner which will prevent segregation, loss of material or premature stiffening.

Appropriate measures shall also be taken for protecting the concrete from sunlight and weather.

9.3.1 Concrete Pump

The use of concrete pump shall be in accordance with the requirements of AS 1418.15 and this Standard. Pumping concrete shall be in accordance with CIA Z7/04 and CIA Z12.

The concrete pump location and pipeline route shall be determined so that the pipeline distance and the number of bends are minimised.

The pipeline diameters shall be selected in view of the type and quality of concrete, the maximum size of coarse aggregate, fibre size and content, pumping conditions, ease and safety of pumping.

The type and number of concrete pumps shall be determined based on the pumping load, discharge rate and the rate of placement.

Prior to commencement of placing concrete, the pump and pump line shall be primed with a grout mix and the initial discharge of concrete shall both be pumped to waste until a consistent workable mix is discharged. Aluminium pipes shall not be used for the delivery of concrete.

9.3.2 Concrete Bucket or Kibble

The concrete bucket and kibble shall be fabricated so that:

1. No segregation when concrete is poured in and discharged;
2. Concrete can be discharged at a controlled rate easily when opened; and
3. Concrete does not leak when closed.

The size of the concrete bucket and kibble shall be determined based on the rate of placement.

9.3.3 Chute

The slope of the chute shall prevent segregation of concrete.

Prior to commencement of placing concrete, the chute shall be wetted and the initial concrete that flows down the chute shall be carted to waste until consistent workable mix is discharged.

The use of water in the chute to assist movement of concrete shall not be permitted.

9.3.4 Belt Conveyor

Where belt conveyor is used:

1. Appropriate measures shall also be taken for protecting the concrete from sunlight and weather;
2. Baffle plates and a funnel tube shall be provided at the discharge end of the conveyor to prevent the segregation of concrete; and
3. A device shall be installed at the end of the conveyor to prevent the deposition of concrete on the return belt.

9.4 Period for Completion of Discharge, Placement and Compaction

The time from the addition of the cement to the aggregates to concrete placement and compaction shall not exceed the times in Table 8 without the prior approval of SA Water's Representative:

Table 8 - Allowable Time from Batching to Placing

Concrete temperature at time of discharge (^{o}C)	Maximum elapsed time (minutes)	Concrete Structures
≤32 °C	90 m	All concrete unless approved otherwise by SA Water's Representative
≤35 °C	60 m	Concrete that SA Water's Representative approves concrete placement temperature up to 35 °C and considering the concrete early age crack assessment at Clause 32.

The times given in Table 8 may be varied where it has been demonstrated by trials that the use of set retarding (AS 1478 Type Re or WRRe) admixtures provides adequate retention of consistency for longer periods at the nominated temperature. Guidance on this matter and given in CIA Z7/04.

Nonetheless, concrete shall not be incorporated into the Project Works at any time if its workability is outside the specified limits.

Retempering outside the maximum allowed discharge time using admixtures or water shall not be allowed under any circumstances.

9.5 Retempering with addition of Water or Admixture after Mixing

Water may be added to a mixed batch of concrete prior to the commencement of discharge providing the following conditions are satisfied:

1. Procedure is in accordance with the Contractor's approved Concrete Works Method Statement (refer Clause 32);
2. The workability of the concrete is measured before and after water addition, and the workability after addition shall be compliant with this Standard;
3. Approval is given by SA Water's Representative, the Contractor and the concrete supplier;
4. The additional water is measured and recorded by the Contractor, and witnessed by SA Water's Representative;
5. Immediately after the addition of any water, operate the mixing mechanism at mixing speed until the concrete achieves the required uniformity;
6. The total water does not exceed the allowable additional water content recorded on the delivery docket based on the water binder/ratio not to be exceeded;
7. The water/binder ratio is not exceeded;
8. The period for concrete completion shall be in accordance with Clause 9.4; and
9. The concrete is tested for compressive strength after the addition of water.

A concrete mix design with a mid-range (MWR) or high range (HWR) admixture may have admixture added on site using the above requirements for addition of water (i.e. the normal batching procedure is addition of these admixtures at the batch plant).

10 Concrete Placement and Compaction

10.1 Concrete Placing

10.1.1 General

All concrete shall be placed in accordance with AS 1379 and AS 3600 and AS 5100.5, as appropriate. Guidance on all concrete placement and compaction matters is provided in CIA Z7/04.

The Contractor shall provide the sequence and concrete placing methodology and the precautions taken in adverse weather conditions to SA Water Representative.

Unless otherwise approved by SA Water Representative, concrete shall not be placed in wet trenches or in running water.

10.1.2 Preparation

Where concrete is placed on earth, sand or rock foundations, the earth or sand shall be compacted to at least 95% of Maximum Dry Density as determined by AS 1289.5.1.1, unless otherwise specified in the Contract, and the rock freed of loose material. Where specified in the Contract or shown in the Drawings the foundation shall be covered with a layer of blinding or lean concrete as specified in Clause 5.3.

Where specified in the Contract or shown in the Drawings or where the concrete element is within a covered structure and is constructed on ground surfaces or on foundation bedding, a polythene

sheet separator of thickness not less than 0.2 mm shall be employed between the ground/bedding and the concrete. The separator shall extend not less than 300 mm beyond the concrete work. Care shall be taken to avoid puncturing or tearing the separator. Should puncturing or tearing occur, the damage shall be repaired prior to concreting. Joints in the separator shall be made by overlapping the sheets a minimum of 300 mm or by overlapping and taping. When minimising horizontal base restraint by use of polythene sheeting is not required (e.g. water tank floor slab 150 to 200 mm thick requires base restraint minimised), an alternative to the polythene sheeting is a wax based curing membrane to AS 3799 (refer Section 13) subject to Contractor submission for review and approval by SA Water's Representative.

The Contractor shall refer to Clause 14 for placing concrete against a construction joint.

Immediately before placing concrete, all surfaces against which the concrete is to be placed shall be free from standing water, mud and debris. All reinforcement shall be fixed in accordance with Clause 29. Surfaces of existing concrete against which concrete is to be placed shall be cleaned with air and/or water jets. All surfaces of forms, reinforcement and embedded materials that have become encrusted with dried mortar or grout from concrete previously placed shall be cleansed of all such mortar or grout before the surrounding or adjacent concrete is placed.

Any absorbent surface when in contact with concrete shall be moistened to saturated surface dry condition and any excess free water shall be removed.

10.1.3 Placement

Concrete shall not be placed and shall be rejected if the consistency is outside the acceptable limits as specified in Clause 7.1.1.

The concrete shall be placed in horizontal layers not exceeding 75% of the length of the immersion vibrators being used, except that the first layer of the first lift shall not be more than 350 mm thick and each layer shall be compacted in accordance with the requirements specified in Clause 10.2 before the preceding layer has taken its initial set.

Concrete shall not be placed from a height from which segregation can occur. The concrete placement maximum height without segregation shall be determined by the Contractor for each concrete mix in accordance with CIA Z7/04. Voided concrete resulting from placing concrete at a height that gives segregation and/or inadequate compaction will be non-compliant.

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

Formwork shall not be disturbed or adjusted during the concreting operation, and shall remain undisturbed up to the removal of formwork as specified in Clause 26.4. No strain shall be placed on any projecting reinforcing steel for a period of at least 12 hours following completion of concreting.

If severe segregation is identified during the placement of concrete, the placement shall be stopped and a method for reducing segregation shall be determined and implemented.

Except at planned construction joints, the placement of concrete shall be carried out continuously until the placement is completed.

When a new layer of concrete is placed on a previously placed layer, vibrators shall be inserted into the underlying layer for compaction in accordance with Clause 10.2.

In cases when bleeding water appears at the surface during the placement of concrete, the water shall be removed using appropriate methods, before placing more concrete. Bleed water requiring removal can result in concrete defects (especially at the surface) and the Contractor shall complete a concrete mix review and submit for SA water's Representative review and approval before the same

concrete mix is used in the Works. Where excessive bleed occurs that has caused concrete surface defects and may impact durability the Contractor shall submit a proposal to repair or replace the concrete for consideration by SA Water's Representative.

10.1.4 Adverse Weather Conditions

All fresh concrete shall be protected where required from sunlight, wind and/or rain, until curing is implemented.

Concrete shall be rejected if the temperature of the concrete is less than 10 ^{o}C or more than 32 ^{o}C or 35 ^{o}C in accordance with Clause 9.2.

The Contractor shall be responsible for measuring and recording the concrete temperature and air temperature, relative humidity and wind velocity, at 1 m above the concrete to be placed to determine evaporation conditions before the concrete is placed and to take relevant precaution measures.

The Contractor shall implement precaution measures for concreting in adverse weather conditions including but not limited to cold weather, hot weather, windy, dry or rain conditions. Such precaution measures shall be approved by SA Water Representative.

10.1.4.1 Cold Weather Requirements

If the ambient air temperature is below 5 ^{o}C and freezing conditions are confined to ground frosts during the night the Contractor shall take precaution measures to ensure that concrete is placed and compacted at a concrete temperature of not less than 10 °C and the concrete shall subsequently be cured in accordance with the requirements in Clause 13.

Concrete shall not be placed against any surface bearing frost or ice.

Note: As a guide, depending upon the severity of the conditions, the following precautions may be applied:

1. Formwork to be insulated;
2. Insulating covers to be provided for concrete;
3. Concrete placement temperature not lower than 10 °C;
4. Concrete temperature to be kept not less than 5 °C as measured at the surface until the end of the curing period, which should be at least seven (7) days;
5. Aggregate bins to be covered; and
6. Areas in which concrete is to be placed to be at temperatures above 0 °C, including formwork and reinforcement.

10.1.4.2 Hot Weather Requirements

Placement of concrete shall only be permitted providing;

1. Concrete mix temperature prior to placement shall at no time exceed 32 °C; and either;
2. Ambient shade temperature is less than 38 °C and falling; or
3. Ambient shade temperature is less than 38 °C and rising, but placement can be completed before the ambient temperature exceeds 38 °C.

Maximum delivery temperatures less than 32 °C may be specified for large thickness concrete pours or concrete elements with high restraint where the concrete early age thermal assessment in accordance with Clause 32 of this Standard indicates that lower initial temperatures are necessary. Where specified, such temperatures shall not be exceeded for the pours concerned.

Steel formwork, steel reinforcement and any other metal surfaces that will come in contact with the concrete shall be cooled to below 32 °C before the concrete is placed.

Concrete should be covered with an impervious membrane after screeding in addition to use of evaporation retarders until hardened curing begins and curing compounds may be used but are not as effective as sealing and moist curing methods (refer Clause 13.3). Measures shall be taken to minimise evaporative moisture losses (Refer to Clause 10.1.4.4).

Concrete shall be rejected if the temperature of the concrete at the placing point is more than 32 °C.

Note: As a guide, the following precautions may be applied for good concreting practice in hot weather conditions:

1. Shading aggregate stockpiles and water cooling exposed coarse aggregate in a controlled manner;
2. Adding chilled mixing water or crushed ice to replace mixing water (in part);
3. Formwork and reinforcement to be continuously sprayed with cold water in advance of the concreting, with all free water removed from the formwork;
4. Concrete to be mixed, transported, placed and compacted as rapidly as practicable;
5. Placing the concrete at a time of day or night when the air temperature is lower than the maximum;
6. Internal cooling using cooling pipes within the concrete;
7. Suitable barriers to be provided to protect freshly placed concrete from the evaporative influence of wind; and
8. Excessive temperature rises to be reduced by shading the work areas and the concrete from direct sunlight and/or covering with a reflective sheet during curing.

10.1.4.3 Wet Weather Requirements

The Contractor shall take measures to protect the freshly placed concrete from rain.

Concrete affected by rain will be rejected.

10.1.4.4 Evaporation or Drying Requirements

The Contractor shall take additional precautions (refer to Clause 10.1.4) to minimise evaporative moisture losses that can create plastic cracking in the concrete exposed surface when the evaporation rate exceeds 0.5 kg/m^2/hour as determined using the formula and web calculator given in FHWA-RD-02-099 that is based on the monograph in ACI 305-10. The Contractor can obtain guidance on concrete plastic cracking and evaporation rates in CIA Z7/04. When evaporation exceeds the concrete bleed rate water is drawn out from the concrete surface so concrete bleed shall be considered as detailed in CIA Z7/04.

The evaporation shall be evaluated prior to placing concrete and during the curing period.

10.1.5 Unscheduled Interruptions to Concrete Placing

Fresh concrete shall not be placed against concrete which has taken its initial set. Initial set is defined for this purpose only as the concrete surface not being able to be easily penetrated by a 12 mm bar. If concrete placing is interrupted and the concrete has taken its initial set, the Contractor shall immediately inform SA Water Representative and take the necessary action to form a construction joint as per Clause 14 at the place of stoppage in the manner that shall least impair the durability, appearance and proper functioning of the concrete. Otherwise, the concrete is liable for rejection.

Note: As a general guidance, if an interruption greater than 45 minutes occurs, a construction joint approved by SA Water Representative shall be placed for in-situ cast concrete.

For precast concrete, the interruption greater than 45 minutes shall be identified as a non-conformance and the unit shall be rejected.

The Contractor shall eliminate as far as possible feather edges and adversely sloping top surfaces and shall thoroughly compact the concrete already placed in accordance with Clause 10.2. All work on the concrete shall be completed while it is still plastic and it shall not thereafter be disturbed until it is hard enough to resist damage.

Sufficient equipment and materials to comply with this requirement shall be readily available at all times during concrete placing.

Before concreting is resumed after such an interruption the Contractor shall cut out and remove all damaged or uncompacted concrete, feather edges or any other undesirable features and shall leave a clean sound surface against which the fresh concrete may be placed.

If it becomes possible to resume concrete placing without contravening this Standard and SA Water Representative approves such resumption, the new concrete shall be thoroughly worked in and compacted against the existing concrete so as to eliminate any construction joints.

10.1.6 Dimensions of Concrete Placing

The positioning of construction joints if not shown on the Drawings shall be subject to approval of SA Water Representative. The Contractor shall not change the position of construction joints without the prior written approval of the Designer and SA Water's Representative.

The Contractor shall submit details of the concrete placing sequence and plan in the Works method statement (refer Clause 32) to SA Water Representative.

Concrete shall be placed to the full planned height of all pours shown on the Drawings and to the requirements of this Standard including concrete consistency (refer Clause 7.1.1), placement (refer Clause 10.1.3) adverse weather conditions (refer Clause 10.1.4), unscheduled interruptions (refer Clause 10.1.5) and early age thermal crack risk assessment (refer Clause 32).

10.1.7 Concrete Placing Sequence

In order to prevent cracking due to restraint of earlier lifts, the Contractor shall arrange that as far as possible the intervals between placing successive lifts of concrete in one section of the project are of equal duration.

Note: As a guide, this duration shall normally be not less than three or more than seven (7) days under similar temperate weather conditions unless justified by a concrete early age thermal crack risk assessment (refer Clause 32) approved by SA Water Representative.

When the Drawings call for contraction gaps in concrete, these shall be of the widths, details and in the locations shown on the Drawings and they shall not be filled until the full time interval shown on

the Drawings has elapsed. Concrete placement in contraction gaps typically will be subject to high restraint where a concrete early age thermal crack risk assessment (refer Clause 32) is required.

10.1.8 Underwater Concrete Placement

The Contractor shall submit the methodology for underwater concreting prior to concreting for the review of SA Water Representative. Concrete shall not be placed until the proposed methodology has been approved by SA Water Representative.

Note: As a guide, the following techniques may be employed:

1. Pump;
2. Tremie;
3. Slipform;
4. Dewatering of formwork.

The Contractor shall not place concrete in water having a temperature below 5^{o}C.

10.1.9 Use of Rock Spalls

Spalls of solid rock may be used in mass concrete construction where approved by SA Water Representative.

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

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

10.1.10 Traceability of Concrete

All concrete batches placed shall be recorded and traceable from the batch plant to its general location in the concrete element by the serial number on the delivery docket.

10.2 Compaction of Concrete

Compaction of concrete by means of mechanical vibration shall commence immediately after the concrete is placed. Compaction shall either be achieved by the use of internal vibrators or external form vibrators. The amount and type of vibration used shall be in accordance with CIA Z7/04 and approved by SA Water Representative.

Compaction by hand tamping shall not be used without the approval of SA Water Representative.

Vibration shall be applied to the full depth of each layer and extended into the top 100 mm of the underlying layer. Vibration shall continue at each point until air bubbles cease to emerge from the concrete, then withdrawn slowly. Concrete shall not be vibrated to the point where segregation of the ingredients occurs.

Vibration shall not be applied either directly or through the reinforcement to any concrete which has taken its initial set.

Where internal vibrators are used, they shall be inserted vertically at successive locations at spacing not exceeding the manufacturer's stated zone of influence, and shall not be allowed to rest on the steel reinforcement.

Where intense compaction is specified, the formwork shall be made of rigid metal complying with Clause 26 and the use of external form vibrators is mandatory. Internal vibrators shall be used in conjunction with external form vibrators.

Note: For good concreting practice, the Contractor shall provide at least two vibrators in good working order on standby on site during the concrete placement.

10.3 Screeding

Immediately after placing and compaction, exposed surfaces shall be screeded off to the specified levels and profiles.

After screeding, the Contractor shall protect the surface and comply with the requirements of Clause 13.2 so that no drying out of the surface occurs. Bleed water shall be dealt with in accordance with Clause 10.1.3. Water for curing shall not be introduced on the concrete surface until it has hardened and shall be in accordance with Clause 13.3.

Cracks should not appear on the concrete surface during the screeding or finishing when curing is completed in accordance with Clause 13. However, any cracks that form during screeding and finishing shall be closed up by re-vibrating the concrete while the concrete is still in a plastic state. The Contractor shall submit details of any cracks that form during screeding and finishing to SA Water's Representative within two (2) days of finishing the concrete and crack inspection on these areas shall be completed in accordance with Clause 18.

11 Finishing of Unformed Concrete Surfaces

11.1 General

All unformed surfaces shall be finished true to lines and levels within the tolerances specified in the Drawings, AS 3600 and AS 5100.5, as appropriate.

Finishing of exposed concrete surfaces shall be carried out after the concrete has become sufficiently hard to support the finishing operation. Working of the unformed surfaces shall be the minimum necessary to produce the desired finish.

The edges of the unformed surfaces shall be neatly rounded with an approved jointing tool, having a minimum radius of 5 mm, to a finish conforming to the requirements of this Standard.

Unless specified otherwise, toppings shall not be used.

The finished surfaces graded for drainage shall not retain pools of surface water.

The classes of finish for unformed surfaces shall be as specified or as shown on the Drawings.

The designated classes for unformed surfaces are U1, U2, U3, U4 and U5 as defined in Clauses 11.2 to 11.6.

Curing shall commence immediately in accordance with Clause 13 following the progressive completion at any location of final finishing operations.

For the purpose of this Clause, abrupt irregularities is defined as vertical offsets and be assessed by direct measurement. Gradual irregularities shall be measured from a straight template 3 m long.

11.2 Class U1

Class U1 finish is a hard and smooth steel trowelled finish produced by the successive trowelling of a Class U3 finish. Powered steel trowels, vibrating screed or plate finish may be used in lieu of hand trowels where appropriate.

A Class U1 finish shall be used where specified and on uncovered slabs in control rooms, switchboard rooms, chlorination stations and where appearance and cleanliness are of paramount importance and where added resistance to wear and resistance to erosion and cavitation under the action of water at high flow velocities are required.

For Class U1 finish, gradual irregularities shall be less than 5 mm and shall not contain any abrupt irregularities.

11.3 Class U2

Class U2 finish is a 'broomed' steel trowelled finish used on surfaces where specified and on all walkways and slabs that will be walked on regularly during subsequent operation and will be periodically wetted by rain and/or wash-down water. Such surfaces include walkways, external cover slabs on tanks at water filtration works, and wet well floors in water and sewage pumping stations.

The surface shall be first worked to a Class U3 finish. It shall then be broom finished at an appropriate stage when the concrete has hardened to a state where a broom finish can be applied without 'tearing' the surface and one which matches the finish of the reference sample slab (Refer to Clause 11.7).

Brooming shall be in one direction only and it shall be carried out using a medium stiff long handled broom and by applying the necessary pressure to produce the desired non-slip finish.

The average texture depth shall be not less than 0.8 mm.

11.4 Class U3

Class U3 finish is a steel trowelled finish and shall apply only to surfaces specified for this finish. It includes all flat traffic surfaces, all surfaces which are periodically wetted but not used as walkways, such as the tops of tank walls, valve chambers, foundations, stair wells, exposed floors of water retaining structures, and all expansion and contraction joint seatings.

The preliminary operations as specified for Class U4 finish shall be carried out and any necessary cutting with edging or jointing tools and any fill shall be done during floating.

Steel trowelling shall begin immediately after floating. It shall be performed with a firm pressure that will flatten and smooth the sandy texture of the previously floated surface, and shall produce a dense, uniform surface free from blemishes and trowel marks.

11.5 Class U4

Class U4 finish is a wood float finish and shall apply only to surfaces specified to receive this finish. This finish shall not apply to water retaining surfaces. Class U4 finish is also used as the second stage of finishes U3, U2 and U1.

The surface shall be first levelled and screeded as for Class U5 finish. Floating shall only begin when the screeded surface has stiffened sufficiently and only after all bleed water has evaporated or has been removed. For finishing larger floor areas or to eliminate any ridges and fill in any depressions left by the straight edge, floating operations by the use of bull floating or darbying may be employed.

A Class U4 finish shall be a surface uniform in texture and free from screed marks. A Class U4 finish shall not have any abrupt and/or gradual irregularities of more than 5 mm.

11.6 Class U5

Class U5 finish applies to surfaces where roughness is not objectionable such as those upon or against which fill material or concrete will be placed and surfaces that will otherwise be permanently concealed. It is also the first stage of all other finishes.

The finishing operations shall consist of levelling and screeding the concrete to produce an even uniform surface. Surplus concrete shall be removed immediately after compaction by striking it off with a sawing motion using a straight edge or screed across wood or metal strips which have been set as guide. Special screeds shall be used for curved surfaces.

A Class U5 finish shall not have any abrupt and/or gradual irregularities of more than 10 mm.

11.7 Reference Sample Slabs

At the request of SA Water's Representative, the Contractor shall cast on site a sample slab of approximately 1.0 x 0.5 metres as a reference for any one or more of the specified surface finishes.

The surface finish of the approved sample slabs will be used by SA Water's Representative as a reference for acceptance of finished work.

12 Formed Concrete Surfaces

The classes of finish for formed concrete surfaces shall be as specified or as shown on the Drawings.

Formed concrete surfaces shall be defined in accordance with AS 3610.1.

13 Concrete Curing and Protection

13.1 General

All finished concrete surfaces shall be protected from damage from any cause including mortar splashes and stains, timber stains, rust stains, chemical attack, additives, oils, drainage water, protective coatings, foreign matter and the like.

The curing of unformed surfaces of concrete shall commence as soon as the concrete is placed in accordance with CIA Z7/04.

The Contractor shall submit full details of the proposed methodology of curing, including but not limited to materials and period of curing, as part of the proposed concrete mix design submission to SA Water Representative for approval.

As far as is practicable concrete shall not be exposed to aggressive environments, including but not limited to sea water or liquids with pH < 5, until the end of the curing period.

The concrete shall be maintained at a temperature above 5 °C.

13.2 Curing after Placement

The concrete shall be kept moist from time of placement until surface finishing is completed when hardened curing begins by use of spraying an evaporation retardant to prevent plastic shrinkage cracking and/or crusting. Re-apply the evaporation retardant as weather conditions justify.

13.3 Curing after Hardened

Hardened concrete curing of exposed concrete surfaces commences as soon as surface finishing operations are completed when the concrete has hardened sufficiently to prevent damage. The concrete surface shall be kept continuously moist and the whole surface protected from the effects of wind and sun. Acceptable curing methods include:

1. Maintain water saturation of concrete by pond or continuously sprinkle the surface with water. Intermittent curing, such as spraying with water once a day, is not acceptable;

2. Covering with sealed plastic film to prevent moisture evaporation from the concrete surface by covering completely with polythene sheeting or equivalent covering material securely held in position. The covering shall be in full contact with the concrete surface. The edges of the sheeting shall be taped or shall be overlapped by at least 200 mm and the whole shall be securely held in position. Any damage to or displacement of the sheeting during construction operations shall immediately be made good. An additional measure for consideration is the top concrete surface shall be kept continuously moist by the use of an absorbent cover being saturated with water and then immediately being covered by the polythene sheet;

3. Apply an approved liquid curing compound to exposed concrete surfaces where approved by the Superintendent;

4. Covering with wet adsorptive material (e.g. hessian, geotextile, canvas, etc.) and wrapping this with sealed plastic;

5. Retain formwork in place.

13.4 Liquid Membrane Forming Curing Compound

General and specific characteristics of curing compounds and testing thereof shall comply with the requirements of AS 3799.

The Contractor shall provide the following curing compound information to SA Water Representative with all curing submission in accordance with Clause 13.1:

1. Name, type, manufacturer's detail and dosage rate;

1. Method of use, including storage and method for controlling and measuring dosage; and

2. A current Certificate of Compliance from the manufacturer; and

3. For each batch delivered, a Certificate of Uniformity from the manufacturer.

Only wax-based (AS 3799, Class A), resin based (AS 3799, Class B), and water-borne (AS 3799, Class Z) curing compounds that comply with the requirements of AS 3799 may be used.

All curing compounds applied to concrete that will come in contact with drinking water shall be approved for use in potable/drinking water in accordance with AS/NZS 4020.

A pressurised sprayer to give uniform cover shall apply the curing compound. The sprayer shall incorporate a device for continuous agitation and mixing of the compound in its container during spraying. The curing compound shall be applied using a fine spray at the rate stated on the Certificate of Compliance.

Curing compounds shall be used in accordance with the manufacturer's recommendation and CIA Z9.

The curing compound shall be applied to unformed surfaces immediately after completion of all finishing operations, and to formed surfaces within 30 minutes of the removal of formwork from the section.

Any required repair of concrete surfaces not completed prior to application of the curing membrane shall only be performed after completion of the curing period and (at least local) removal of the curing membrane. Each repair, after being applied, shall be moistened and coated with curing compound in accordance with the foregoing requirements.

Curing compound shall not be applied to construction joints unless the joint is to have curing compound removal by roughened or blast cleaning at a later stage prior to concreting

Curing compound shall not have a deleterious effect on the concrete or strain the surface of the concrete.

Any curing compound shall be compatible with both the concrete mix and the applied finishes and shall take account of all possible finishes (e.g. protective coatings, waterproofing or surface system) to be applied to the concrete, and consider concrete surface preparation for such finishes. If the curing membrane has an impact on the concrete surface preparation (e.g. requiring blast cleaning removal) alternative curing methods shall be considered.

Curing compounds shall not be used on surfaces against which fresh concrete is required to bond.

The curing membrane shall be maintained intact after its initial application, for the required curing period. Any damage to the curing membrane shall be made good by re-spraying of the affected areas without delay.

Traffic and other operations by the Contractor shall be such as to avoid damage to coatings of curing compound for the whole period of curing. Where it is impracticable because of construction operations to avoid traffic over surfaces coated with curing compound, the concrete surface shall be protected (e.g. by a covering of sand not less than 25 mm in thickness, polythene sheeting plus plywood formwork or by other effective means. The protective covering shall not be placed until the curing compound is completely dry. The Contractor shall remove all protective covering after completion of the curing period. Any curing compound that is damaged or that peels from concrete surfaces shall be repaired without delay.

13.5 Retention of Formwork

Where formwork is left in place for curing purposes, any exposed surfaces of the concrete shall be cured by other means in accordance with Clause 13. The formwork shall also be sealed against evaporative moisture losses for the duration of curing.

Where part of or all the formwork is to be stripped before the required curing period is completed, curing of the formed surface shall commence within 30 minutes of stripping and continue for the remainder of the curing period.

13.6 Accelerated Heat Curing

Where accelerated heat curing is proposed, the Contractor shall submit the method of steam or temperature control and proposed curing cycle, duration of heat curing to SA Water Representative with all curing submission in accordance with Clause 13.1.

13.7 Curing Duration

Curing shall be undertaken to satisfy short-term requirements to prevent plastic cracking and long-term requirements of ensuring continued cement hydration. Curing shall be continued until the requirements of Options 1, 2 or 3 described below are met:

1. Option 1: 7 days minimum curing for GP cement;
2. Option 2: 14 days minimum curing for GB or LH cement;
3. Option 3: Until the concrete in the cover zone achieves 60% of its characteristic strength that shall be determined by cover zone maturity monitoring in accordance with ASTM C1074 or strength testing of additional cylinders cast by the premix concrete supplier and cured in a similar manner to the cover zone concrete it represents.

No traffic shall be allowed to pass over and no materials shall be deposited on any concrete during its curing period without taking precautions to prevent damage to the concrete.

14 Joints

14.1 General

All control and construction joints shall be completed straight and plumb. All transverse joints shall be normal to longitudinal joints.

The use of waterstops for water retaining or excluding structures shall comply with TS 2 (PVC waterstop) and Clause 14.4.

14.2 Construction Joints

Construction joints shall be in accordance with AS 3735, AS 3600 and AS 5100.5, as appropriate, except where specified otherwise in this standard.

The number of construction joints shall be kept to a minimum.

The Contractor shall propose construction joint locations and shall submit their construction joint proposals to SA Water Representative for approval.

Construction joints shall, unless otherwise detailed or agreed, be truly horizontal or vertical and made with a small formed chamfer or other approved means of ensuring that a straight, clean line appears at the joint on completion.

Concrete against which new concrete is to be placed shall be intentionally roughened by removing all laitance and sufficient mortar to expose the coarse aggregate to a depth of 3 mm. The roughened surface shall be cleaned of foreign matter, laitance and loose or porous material and other foreign material likely to affect bonding of new to old concrete. The surface shall be in a saturated surface dry condition immediately before placing of new concrete.

Green cutting or the use of water and/or air jetting prior to final set of concrete to roughen the construction joint surface may be permitted if the Contractor can provide proof of competency with the use of this method in accordance with the requirements of this Standard and to the satisfaction of SA Water Representative.

Alternatively, SA Water Representative may allow the use of an approved surface retarder. The surface retarder shall be used in accordance with the Manufacturer's written instructions. The Contractor shall provide the following information to SA Water Representative:

1. Name, type, manufacturer's detail and dosage rate;
2. Method of use, including storage and method for controlling and measuring dosage; and
3. Conforming test results from the manufacturer.

14.3 Control Joints

All control joints shall be provided as located and detailed on the Drawings or in the Contract.

14.4 Concrete Joints for Water Retaining and Excluding Structures

14.4.1 General Requirements

The Contractor shall develop a Method Statement for all construction joint detail installations, including proposed materials to be used, and submit for SA Water's Representative approval at least 28 days prior to any construction joint works.

All waterproofing materials that come in contact with water intended for human consumption shall be approved for use in drinking water in accordance with AS/NZS 4020.

In the event of an unscheduled delay in a concreting operation, any proposal by the Contractor to introduce an unplanned construction joint shall be subject to approval by SA Water's Representative. The Superintendent may direct removal of the concrete and replacement with fresh concrete at his discretion.

Waterstops, sealants and coatings shall be subject to approval for use by SA Water's Representative, including durability review to achieve the design life.

Construction and expansion joint surfaces shall receive special attention when placing concrete to ensure they have sound concrete with no voids.

The approach for concrete joints shall provide:

1. Multiple barriers in order to provide levels of redundancy and backup;
2. High workability concrete with slump greater than 150 mm for wall joints may be an acceptable barrier subject to the SA Water Representative's review and approval;
3. Access for joint maintenance as operational constraints allow (e.g. sealant in joint groove can be replaced but waterstops within the concrete are not intended to be replaced);
4. Ability to return and drill the concrete to allow grout injection of any leaks with polyurethane or other approved methods;
5. Ability to return and treat leaks by injecting re-injectable tubing where provided.

14.4.2 Waterstop Proven Durability and Requirements

Surface sealant materials proposed to be used by the Contractor shall have written confirmation from the manufacturer that they have a minimum 15-year service life in contact with chlorinated and/or chloraminated potable water with any qualifications to the approval of SA Water's Representative.

Plastic waterstops proposed to be used by the Contractor shall have written confirmation from the manufacturer of the minimum service life when cast into concrete that shall achieve the Works design life.

The Contractor shall provide evidence from the sealant material manufacturer of the long term use of the products elsewhere, samples of the sealant materials and the names and experience of the applicators to the SA Water Representative for approval at least two weeks prior to installation.

Water-stops at water-tight joints shall include the following as nominated on the drawings:

1. Rear guard and centre-bulb water-stops installed in the concrete;

2. Hydrophilic seals installed within the concrete, with minimum concrete cover required by the hydrophilic seal manufacturer. Concrete is required to be acceptably compacted since voided concrete above the hydrophilic seal will allow water penetration around the hydrophilic seal. Use of hydrophilic seals in water retaining or excluding structures requirements assessment in accordance with CIA Z7/04. Unless otherwise approved by SA Water Representative, swellable hydrophilic seals shall not be used as the primary waterstop in water retaining structures;

3. Gun applied polyurethane sealant in a groove on the concrete surface.

All joint sealing systems shall be installed in accordance with the manufacturer's recommendations.

The Contractor shall provide the Superintendent with written confirmation that the joint installation has been completed in accordance with the method of installation recommended by the joint material manufacturer.

15 Concrete Temperature and Strain Monitoring

The Contractor shall propose methods of assessment of the in-situ concrete temperature rise, monitoring of pour temperatures and strain which shall be subject to approval by SA Water's Representative.

A thermal block or hot box (refer Clause 15.1) shall be cast and monitored for concrete that requires concrete early age thermal crack assessment (refer Clause 32) and data is not available for the same or similar concrete as determined by SA Water's Representative.

Site monitoring of temperature and strain shall be conducted on initial concrete pours to Clause 15.2 for each concrete mix type and the results interpolated for future similar constructed components. Additional site monitoring shall be as directed by SA Water's Representative where the test data cannot be interpolated.

15.1 Thermal Block

The thermal test block shall be completed in accordance with CIA Z7/07 to obtain semi-adiabatic temperature for the concrete that shall be predicted to adiabatic temperature using guidance from CIA Z7/07.

15.2 Site Monitoring

Thermocouples and vibrating wire strain gauges shall be positioned at a range of positions to determine the concrete peak temperature, differential temperature and strain across the concrete section (in accordance with CIA Z7/07) of liquid retaining/excluding and other critical elements (e.g. minimum of one in situ element first constructed). Locations of temperature and strain monitoring points shall be submitted by the Contractor for approval by SA Water's Representative and Durability Consultant that completes the concrete early age thermal crack assessment (refer Clause 32).

16 Precast Concrete Units

16.1 General

This Clause provides the special requirements for precast concrete units construction.

The Contractor is responsible for the design, manufacture, storage, handling, delivery and erection of precast concrete unit. The precast concrete supplier shall implement and maintain a quality management system in accordance with AS/NZ ISO 9001.

The Contractor shall produce all shop drawings for the precast concrete unit and the shop drawings shall be submitted to SA Water Representative for approval. The Contractor shop drawings shall indicate the position of the precast elements in the structure, all reinforcements, prestressing, ducts, embedded items etc. These shop drawings shall be submitted to SA Water's Representative for approval a minimum of 14 working days before commencing production of the precast elements. Allow a minimum of 14 working days for review. Approval of the shop drawings does not relinquish the Contractor from any responsibility of constructing the structure in accordance with the design.

The Contractor shall also submit, for review by SA Water Representative, details of the lifting calculation and proposed handling and supporting methodology prior to lifting and supporting the units. The calculation shall be certified by a competent and experienced Structural Engineer.

The Contractor shall design, manufacture, store, handle, deliver and erect precast concrete units in accordance with:

1. All requirements contained within this Standard;
2. All requirements, recommendations and guidance in the following Australian Standards, as appropriate:
    a. AS 1597.1;
    b. AS 1597.2;
    c. AS 2159;
    d. AS 3850.1;
    e. AS 3850.2;
    f. AS/NZS 4058;
    g. AS 4198;
    h. AS/NZS 4676; and
    i. AS 5100.5;
3. All requirements, recommendations and guidance in National Code of Practice for Precast, Tilt-Up and Concrete Elements in Building Construction;
4. Manufacture and acceptance of precast concrete elements shall be in accordance with this Standard, the Drawings, and the Precast Concrete Handbook (NP:PCH-2009) by the National Precast Concrete Association Australia (NPCAA) in conjunction with the Concrete Institute of Australia.

In the case of a discrepancy among the above documents, this Standard shall govern. The order of precedence is then followed by the relevant Australian Standard; National Code of Practice for Precast, Tilt-Up and Concrete Elements in Building Construction and Precast Concrete Handbook. The Contractor shall also notify SA Water Representative of these discrepancies immediately.

Where the requirements, guidance and recommendations contained among the above documents are not defined, the Contractor shall seek clarification from SA Water Representative.

Maximum temperature of concrete during accelerated curing of precast manufacture shall not exceed 70 °C to minimise the risk of delayed ettringite formation (DEF), except where at least 20% fly ash, or 40% slag or 8% silica fume by mass of binder is incorporated, in which case the maximum temperature shall not exceed 80 °C.

The precast elements shall be stored, handled and placed strictly in accordance with the precaster's recommendations.

If holes or lifting lugs are used in the precast elements for handling purposes, the holes or lug recesses shall be filled with a SA Water's Representative approved proprietary shrinkage compensating grout after installation. An additional surface coating approved by SA Water's Representative shall be applied over lifting lug points where the concrete cover to the lug does not meet the specified cover.

Precast concrete units shall be liable for rejection if the requirements, guidance and recommendations contained in the above documents are not followed.

Any units damaged or distorted in excess of the specified tolerances prior to or during erection shall be replaced at the Contractor's expense.

16.2 Traceability of Precast Concrete Units

All manufactured precast concrete units shall be traced from the completion of manufacture to their final location by a unique identification number.

The identification number, date of casting, the manufacturer's name or registered mark and the maximum mass shall be marked on every precast unit.

Temporary identification shall be made on the surface of the unit where it can be easily identified. Final marking shall be made by indelible marking material, using letters approximately 40 mm high.

17 Sprayed Concrete

17.1 General

This Clause provides the special requirements for application of wet process sprayed concrete (i.e. shotcrete) and dry process sprayed concrete (i.e. gunite). This Standard does not cover the use of proprietary spray applied cementitious materials.

Only shotcrete shall be used for structural applications including but not limited to retaining walls, soil nail walls, tunnel linings, supporting in situ excavated material, surface improvement and short-term support.

Shotcrete and gunite may be used for concrete repair works and for the construction of overlays for cathodic protection (CP) of concrete structures.

Information detailed in CIA Z5, particularly on mix design and materials used in sprayed concrete can be used to supplement this Standard as deemed suitable by the designer. CIA Z5 also contains details on suitable methods of sprayed concrete application of and these processes can be specified by reference to CIA Z5. The test methods given in this Standard are similar to those in CIA Z5 and it is recommended designers consider the recommendations on tests and test frequency given in CIA Z5 when finalising a project specification.

Sprayed concrete shall neither be applied in liquid nor applied in aggressive environment including but not limited to sea water and liquids with pH < 5.

In addition to the requirements specified in Clause 9.1, any accelerators and other admixtures that are added to concrete at the nozzle or at the delivery hose shall be dispensed by calibrated mechanical means at dosage rates not exceeding the maximum recommended by the manufacturer. All chemical admixtures added to wet process pre-mixed concrete at the nozzle or at the delivery hose shall be included as part of the concrete mix design reviewed in accordance with the requirements of Clause 8.2.

Refer to Clauses 31.1 and 31.2 for the use of steel and synthetic fibres.

17.2 Competency of Personnel Involved in Sprayed Concrete

Personnel undertaking the sprayed concrete works including the nozzle operator, supervisor and finisher, shall have a minimum of 5 years' experience in sprayed concrete application and a demonstrated competency for substrate preparation, sprayed concrete placement techniques and inspection, sprayed concrete material quality, equipment operation, encapsulation of steel reinforcement, finishing and curing.

The nozzle operator shall have a demonstrated competence and ability to produce sprayed concrete complying with this Standard and have prequalification to the sprayed concrete procedure requirements as stated in Clause 17.3.

The sprayed concrete supervisor shall be trained and qualified on all aspects of sprayed concrete application techniques and shall be present at each stage of the works. Installation personnel shall be trained and skilled in the application procedures to be used.

Documented evidence shall be available to demonstrate experience, qualification, skills and training of personnel.

17.3 Prequalification of Spraying Procedure

17.3.1 General

The Contractor shall submit details of the proposed sprayed concrete operations, including the proposed type of sprayed concrete, mix design, substrate preparation, method of application, equipment and nozzle operators for review by SA Water Representative prior to commencement of the sprayed concrete operation.

The Contractor shall produce evidence of the nozzle operator's previous experience in the application of sprayed concrete. The nozzle operators shall have demonstrated competence and ability to produce sprayed concrete complying with this Standard.

17.3.2 Preparation of Test Panels

Two test panels 750 mm x 750 mm and the greater of the specified thickness or 150 mm shall be constructed by the Contractor for each nominated nozzle operator prior to commencing full scale spray concrete operation, for the purpose of checking the suitability of the proposed mix design, materials, plant and equipment, the method of working and the competence of the operator intended for the Project.

The test panels shall be representative of the spraying operation(s) to be adopted, the in situ material(s), the location and the actual orientation (i.e. vertical, overhead etc.) of the sprayed concrete.

Spraying of concrete into the test panels when placed horizontally on the ground shall not be allowed.

Additional panels will be required if the Contractor should change the mix design, plant and equipment or operator. The test panels shall be stored and cured under similar conditions to the sprayed concrete placed in situ and in accordance with the requirements of this Standard.

Where reinforcement in the form of steel fabric or steel reinforcement, or titanium anode mesh for cathodic protection, is to be used the same reinforcement detailing and number of layers or mesh shall be provided in the test panel.

17.3.3 Sampling and Testing of Panels

The Contractor shall cut sample of cores from each test panel, in accordance with AS 1012.14, at right angles to the plane of the panel approximately 48 hours after the panel has been sprayed. Cores shall not be taken within 125 mm of the edges of the panel.

The Contractor shall ensure that 2 cores per test panel are cut from concrete adjacent to or through steel reinforcement for the purpose of visual assessment of the quality of the sprayed concrete adjacent to steel reinforcement

17.3.4 Prequalification

Sprayed concrete shall not be placed until SA Water Representative has reviewed all prequalification procedures, the results of testing, and visual inspection of both the cores sampled and the test panels in accordance with the requirements of Clause 17.3.3. Concrete shall not be sprayed until the mix design has been reviewed by SA Water Representative.

Where it is shown that the same materials, mix designs, equipment, procedures and personnel have given satisfactory results in similar works, SA Water Representative may accept the construction of test panels concurrently with the first sprayed concrete placed in the Works.

The prequalified sprayed concrete procedure shall be adhered to throughout the sprayed concrete operation. Sprayed concrete shall only be carried out by the same nozzle operator who performed the prequalified procedure and produced the conforming test panels.

The prequalified nozzle operator and prequalified sprayed concrete procedure may only be changed after further prequalification and with the approval of SA Water Representative.

17.4 Application of Sprayed Concrete

17.4.1 Equipment

The equipment used shall have adequate capacity and be capable of delivering the concrete constituents to the nozzle at a uniform rate such that the sprayed concrete leaves the nozzle in a continuous uninterrupted stream and at a velocity of discharge which will maximise compaction, minimise rebound and overspray and prevent sagging of the applied concrete.

Equipment shall be capable of allowing the nozzle to be maintained perpendicular. For hand spraying operation, the equipment shall be at a distance of less than 1 m from the receiving surface, and except where necessary at the required angle which will produce a dense in situ concrete with maximum adherence of material onto the prepared substrate.

For machine spraying operation, the equipment shall be at a distance of less than 2 m or as recommended by the manufacturer from the receiving surface.

Delivery hoses shall have an internal diameter for unimpeded flow of material without blockages, balling of fibre or segregation of aggregate and/or fibre.

Chemical admixture dispensing equipment shall be subject to regular maintenance and calibrated at three monthly intervals.

17.4.2 Surface Preparation

17.4.2.1 Surface of In Situ Material

Excavation to the required line and grade shall be carried out in accordance with the project drawings and earthworks specification.

The integrity of the surface of the in situ or excavated in situ material shall be maintained free of excessive wetting or drying prior to the application of the sprayed concrete.

Action shall be taken to control groundwater by the installation of drains to prevent contact with the newly sprayed concrete surface or the development of hydrostatic pressures behind the sprayed concrete, effective for the design life.

Loose and unsound material which may affect adhesion of the sprayed concrete to the in situ surface shall be removed and the surface shall be cleaned before applying sprayed concrete. The surface shall be damp but without free water and prepared so that no abrupt changes in the thickness of the sprayed concrete occur.

17.4.2.2 Concrete Surfaces

Loose and unsound material shall be removed from the existing concrete surface. The concrete surface shall be thoroughly cleaned down to remove any traces of dirt, grease, oil, remnants of curing compounds and organic contaminants (i.e. moss, algae, etc.), or other substances that could interfere with the bond of the newly placed sprayed concrete. Where sprayed concrete is to be placed against a smooth concrete surface, the surface shall be roughened as a minimum to an exposed aggregate finish (not less than CSP7 per ICRI 310.2R-2013) by suitable means. The concrete substrate shall be adequately pre-wetted prior to the application of the sprayed concrete. The surface shall be prepared such that no abrupt changes in thickness of the sprayed concrete occur.

For concrete repair and CP overlay works completed with proprietary spray applied cementitious mortars the concrete substrate shall be prepared in accordance with the requirements of the overlay manufacturer.

17.4.2.3 Steelwork and Reinforcement

Steelwork and reinforcement bars shall be free of loose or thick rust, oil, grease, paint, mud or any other harmful coating in accordance with Clauses 29.1.7, 29.2.7 or 29.4.7 as appropriate prior to the application of sprayed concrete.

Reinforcement shall be firmly fixed to provide the cover, clearances and laps described in the drawings.

17.4.3 Application

Sprayed concrete shall not be placed until the evidence that the substrate preparation, reinforcement, and embedments have been reviewed by SA Water Representative.

Sprayed concrete shall be applied as soon as is practical following the preparation of the substrate as specified in Clause 17.4.2.

The finished sprayed concrete shall be dense and homogeneous for its full thickness, without segregation of aggregate or fibres, and without collapsing, excessive rebound or other visible imperfections.

Each layer of the sprayed concrete shall be built up by making several passes over the working area. During starting and stopping of the spraying operation or whenever flow becomes intermittent or irregular for any cause the nozzle operator shall direct the nozzle away from the work until it again becomes constant.

Where a layer of sprayed concrete is to be covered by succeeding layers, it shall be allowed to set prior to application of the succeeding layer. The surface shall be checked for soundness, segregated, loose or otherwise uncompacted sprayed concrete. Defective concrete shall be removed, repaired as specified, cleaned, and wetted using a blast of air and water.

For vertical and near vertical surfaces application shall commence at the bottom. For overhead surfaces sprayed concrete shall be applied from the shoulder to the crown.

Layer thickness shall be limited to a maximum of 150 mm to ensure that the material does not sag or delaminate.

The spray nozzle shall be held at such a distance and angle to ensure placement of concrete behind and around steel reinforcement before any concrete is allowed to accumulate on its front face. Sprayed concrete shall not be placed through more than one layer of steel fabric, reinforcement or titanium anode mesh in one application.

Any areas where rebound cannot escape or be blown free shall be filled with sound concrete. All overspray or rebound shall be removed, prior to the placement of sprayed concrete onto adjacent surfaces.

Where the spraying process is adversely affected by wind or other adverse effects during application, spraying shall be discontinued unless special precautions can be implemented to ensure compliance with the requirements of this clause.

Sprayed concrete shall only be applied in accordance with the requirements of Clauses 10.1 and 13

17.4.4 Finishing

Unless otherwise specified in the Contract, the surface finish of sprayed applied structural concrete retaining walls, soil nail walls, tunnel linings and other structural components forming part of permanent Works shall be steel floated and satisfy the requirements of Clause 11.3 for Class U2 surface finish.

Unless otherwise specified in the Contract, other sprayed concrete surfaces shall be left as sprayed. All surface finishes shall be uniform in texture and free from any blowholes or surface imperfections.

17.4.5 Tolerances on Surface of Sprayed Concrete

Tolerances for sprayed applied structural concrete shall satisfy the requirements of Clause 21.3.

Where sprayed concrete is to be placed to a specified shape it shall be within ± 25 mm of that shape and contain no depression greater than 15 mm below a 2 metre straight edge. For sprayed concrete on natural surfaces or surfaces with undefined shape the thickness shall be within 0 mm + 15 mm of the nominal thickness.

The Contractor shall utilise probes during application of sprayed concrete to enable the monitoring of the required thickness.

The Contractor may propose alternative methods for the monitoring of sprayed concrete thickness during application, for the approval of SA Water Representative.

17.4.6 Joints

The positions and types of joints shall be as shown on the drawings or specified in the Contract.

The use of internal waterstops is not permitted.

Unless otherwise specified in the Contract, the construction joint shall be of one of the approaches shown in Figure 9.12 and 9.13 of the Concrete Institute of Australia's Recommended Practice Z5 - Shotcreting in Australia, Second Edition, prepared by Australian Shotcrete Society, except the use of unformed joint.

17.4.7 Inspection and Soundness of Finished Sprayed Concrete

The Contractor shall undertake a visual inspection and a soundness inspection of the finished sprayed concrete at the age of at least 28 days. Visual inspection shall be for defects such as lack of compaction, dry patches, voids or sand pockets. Soundness inspection shall be by tapping with a small (0.8 kg) hand-held hammer to locate 'drummy' or 'hollow' response areas that might indicate a possible lack of bond, delamination or other defect. The Contractor shall remove and rectify such defects.

17.4.8 Repair of Defective Areas

Areas of the finished work that exhibit a lack of compaction or bonding, dry patches, voids and sand pockets, or have slumped or sagged, shall be removed and repaired with a single component, shrinkage compensating proprietary cementitious material in accordance with the requirements of Clause 21 to achieve the specified level of durability. The exposed surface of the repaired defective area shall be similar in texture and colour to the surrounding sprayed concrete.

18 Crack Inspection and Assessment

A site crack inspection shall be completed on all concrete surfaces in accordance with the procedures contained in CIA Z7/07 by the Contractor in the presence of SA Water's Representative:

1. At the completion of the curing period and when the concrete has cooled to ambient conditions (approximately 7 days after cast). This will identify any unexpected cracking and allow adjustments as needed for future concrete pours;

2. Immediately after all construction activities are completed (prior to backfilling of soil if required for below ground level structures) and allowing sufficient time prior to operational use to document crack positions and measure the surface width of any cracks that have formed and complete any repairs that are justified;

3. 12 months after completion of the Project or prior to the end of the defects liability period, whichever is earlier;

4. In addition for liquid retaining structures, detailed inspection on the last day of testing for liquid tightness in accordance with AS 3735 Section 7 to identify any visible water leakage or darker coloured concrete that indicates water penetration through cracks, plus other construction joints, surface voids or other requirements of this Standard.

All inspections shall determine the presence of any cracks with width greater than that specified in Clause 7.2.4.

Where crack width greater than that of specified in Clause 7.2.4, they shall be identified as a non-conformance. In addition, the Contractor shall:

1. Measure length and width of cracks in accordance with CIA Z7/07;

2. Mark cracks on plan and elevation drawings and issue as “As Built Concrete Cracks” drawings in accordance with a format acceptable to SA Water’s Representative and issue the data in an MS Excel spreadsheet;

3. Undertake an assessment to evaluate the influence of the non-conforming cracks (more details below);

4. Establish the cause(s) of the cracks, crack width, the moisture condition of the crack and whether a crack is active or inactive including concrete early age thermal crack assessment in accordance with Clause 32;

5. SA Water’s Representative may require representative 50 mm diameter core samples to be taken through representative cracks to the interior reinforcement depth to assist in evaluation of future durability and crack repairs required; and

6. Submit a crack repair methodology for SA Water Representative review, prior to any repair works being undertaken in accordance with Clause 21.

The assessment of the cracked concrete structure and the proposed crack repair methodology shall be undertaken by a Durability Consultant or an experienced concrete technical specialist with a minimum of 5 years practical experience in the diagnostic assessment and investigation of concrete structures. The crack repair methodology shall include details of the crack filling material properties, location, surface preparation and method of application, likely post-repaired crack behaviour, and effect on the requirements specified in this Standard, the structural adequacy impact and durability impact to achieve the required design life without increased maintenance by comparison to uncracked concrete.

Note: Guidance on the durability of concrete with crack widths is given in CIRIA C660 and will be available in the future from CIA Recommended Practice Z7/06.

19 Site Concrete Cover Measurements

A site cover inspection shall be completed after construction on a representative number of exterior and interior areas using a cover meter with capabilities complying with BS 1881-204. Inspection shall be conducted in the presence of the SA Water representative. Where more than 5% for normal compaction and quality control, and 1% for intense compaction and high level of quality control, of cover measurements are less than specified, the Contractor shall commission a durability review by a Durability Consultant and rectify the problem in accordance with the recommendations of the Durability Consultant, and to the acceptance of SA Water’s Representative. Guidance is given in CIA Z7/04.

20 Wall Concrete Compaction for Liquid Retaining Structures

Concrete compaction at the base of walls has the greatest risk of inadequate compaction and shall be inspected and tested after completion as below.

1. Visual inspection to determine any surface voids or bleed channels. Photographs shall be taken to record all visible defects;

2. Mechanical hammer tapping (very hard with a 1 kg hammer) of the concrete surface to determine any skim concrete matrix over voided interior concrete. Photographs shall be taken to record all visible defects identified by any surface skim removal;

3. Concrete core sampling shall be carried out on concrete in the trial wall casting, where a trial is carried out, or on the first wall cast of each construction type, and if concrete void defects are indicated by visual inspection or mechanical hammer tapping investigations, where instructed by SA water's Representative. A minimum of two cores shall be taken from the wall element to be tested:

    a. Core samples shall be 50 mm diameter. The core locations shall be determined by visual inspection and mechanical hammer tapping findings and shall be in areas of worst defects, if any. The cores shall be located to avoid reinforcement bars by use of cover meter rebar detection;

    b. Cores shall be from the exterior surface of the wall unless the defects are clearly on the inner face. The cores shall go to mid depth of the wall only;

    c. Photographs shall be taken to record all core positions (i.e. surface before coring), cores extracted, and all core holes showing in-situ concrete;

4. All core sampling shall be undertaken by the Contractor.

21 Concrete Repair

21.1 General

This Clause applies only to repair of minor and non-structural concrete defects including cracks, voids, honeycombing, blowholes, air pockets, bleed voids, concrete where formwork removal creates spalls or the concrete surface not conforming to the surface finish class as specified in Clause 11.

The Contractor shall make good any concrete defects and remove any protrusions or excess concrete to the specified finish requirements as required by this Standard in accordance with the procedures contained in HB 84.

The Contractor shall provide a detailed Repair Method Statement for conduct of each repair including technical data sheets of proprietary materials to be used, bonding agents, coatings, extent of saw cutting and breakout, surface preparation, placement method, curing, quality control and a summary of the Repair Contractor's relevant experience, submitted to SA Water's Representative at least seven (7) working days prior to commencement of repair work. Repairs shall not proceed until the Contractor's Repair Method Statement has been approved by SA Water Representative. SA Water Representative may request submission of independent test data to confirm performance parameters stated on product data sheet.

21.2 Concrete Repair Materials and Procedures

Contractor repair of concrete defects (refer Clause 21.1) shall be to the approval of SA Water's Representative, and to achieve a colour match with adjoining external surface concrete when repair work has set.

Repair of concrete shall be performed by acceptably skilled workers approved by SA Water's Representative. The Contractor shall keep SA Water's Representative advised as to when repair of concrete will be performed.

Unless inspection is waived by SA Water Representative in each specific case, repair of concrete shall be performed only in the presence of SA Water Representative.

The repaired concrete surfaces shall be to the requirements of this Standard.

According to the nature of the defect to be repaired, repairs shall be by one of the following methods:

1. Pre-bagged proprietary cementitious repair mortar for concrete defects typically of depth 0 mm to 70 mm;
2. Proprietary cementitious micro-concrete for concrete defects typically of depth 50 mm to 200 mm;
3. Concrete as specified in the works for excessive voids or concrete replacement;
4. Epoxy resin based repair mortar for concrete defects after full evaluation of potential incompatibility with concrete due to differential movement (e.g. thermal and moisture gradients) plus bond adhesion within epoxy open time;
5. Polyurethane resin or similar flexible materials injection of cracks for durability repair;
6. Low viscosity epoxy resin injection of cracks for structural repair;
7. Protective coatings or finishes for inadequate cover; and
8. Others to be approved by SA Water's Representative.

All proprietary repair materials shall be used strictly in accordance with the manufacturer's instructions.

Protection and curing of cementitious repair materials shall be carried out in accordance with the requirements of the product manufacturer's instructions, minimum seven (7) days curing in accordance with Clause 13.3 and as approved by SA Water's Representative.

Where directed by SA Water's Representative, areas of concrete to be repaired shall be "Trial Repairs" to prove acceptable materials and methods as stated in the Contractor's Repair Method Statement prior to proceeding with full scale repair works. The trial area shall be a minimum of 0.5 m^2 or as directed by SA Water's Representative and the entire trial repair process shall be observed by SA Water's Representative.

21.3 Repaired Concrete Tolerances

The tolerance on edges and surfaces in plan and level shall be ± 3 mm.

Maximum allowance for irregularities when measured with a 2.0 metre straightedge shall be 3 mm. In addition, evenness shall not deviate by more than 1 mm when checked with a 300 mm straightedge.

21.4 Repaired Concrete Quality Control

The Contractor shall complete a visual inspection and delamination survey (refer to CIA Z7/07) to identify any defects of all concrete repair areas at seven (7) days after the repairs are completed and immediately prior to the application of any coating. The delamination survey shall be conducted using a small hammer along the whole surface area of the concrete patch repairs and delaminated areas shall be characterised by a 'drummy' or hollow sound. Testing for delamination areas shall be conducted in the presence of SA Water's Representative unless prior approved otherwise. Bond adhesion strength testing of the repair to the substrate concrete shall be completed at the discretion of SA water's Representative.

There shall be no defects in the concrete as listed at Clause 21.1, including no cracks at the interface of the concrete repair with the existing concrete.

All defects identified by the Contractor shall be recorded and submitted to SA Water's Representative within three (3) days of completing the site inspection.

All defective repairs including delaminated patch repairs shall be removed and repaired in accordance with the requirements of Clauses 21.1 and 21.2 to the satisfaction of SA Water's Representative.

The Contractor shall record and document all repair completed including repair method statement, location of repairs, depth and extent, materials used plus technical data sheets, quality control tests conducted and representative photos to the satisfaction of SA Water's Representative.

22 Concrete Quality Control

22.1 General

The Contractor shall be responsible for all testing, as specified, to prove compliance with the requirements of this Standard. This includes any inspections, checks, calibrations or self-audits as required by this Standard.

Irrespective of the testing carried out by the Contractor, SA Water's Representative reserves the right to carry out independent inspections and audit testing. These costs shall be borne by the Principal, except in the case of failure and subsequent re-tests to validate conformity; they shall be at the Contractor's expense.

SA Water's Representative may direct the Contractor to carry out additional testing (increase in the frequency of testing) to that specified. The cost of additional testing will be at the Principal's expense, but where failure to comply with the specified requirements has been identified, they shall be borne by the Contractor. The cost of re-testing of work which has failed and been subsequently rectified as a result of additional testing shall be borne by the Contractor.

22.2 Concrete Quality Criteria

All concrete to be incorporated in the Works shall be manufactured in accordance with AS 1379 except as otherwise stated in this Standard. Concrete materials shall be proportioned so that, when transported, placed, compacted and cured in accordance with AS 3600 for a design life up to 50 years and AS 5100.5 for a design life greater than 50 years up to 100 years, the hardened concrete will comply with the strength grades given in this Standard, as shown on the Drawings and as defined in AS 1379.

All construction materials that will come in contact with drinking water when the concrete is in operation use shall be approved for use in drinking water in accordance with AS/NZS 4020.

22.3 Batch Certificates

All concrete supplied shall, at arrival on site, be provided with batch plant certificates for the respective batches. Batch certificates shall contain all information about the concrete supplied as required by AS 1379 and in addition the requirements of Clause 9.2.

22.4 Requirements for Testing Facilities and Personnel

All testing facilities and field testing personnel shall hold current accreditation to ISO 17025 from the National Association of Testing Authorities, Australia (NATA) for the relevant test methods, unless specifically exempted by SA Water's Representative.

The Contractor shall supply a copy of all test results to SA Water's Representative no later than two (2) working days after testing has been completed for compression strength and no later than five (5) working days after testing for all other tests.

22.5 Testing Frequency

Inspection and Test Plans (ITPs) shall nominate the proposed testing frequency to verify conformity of the item and it shall not be less than requirements in this Standard. Where a minimum frequency is not specified a minimum frequency shall be nominated for approval by SA Water's Representative.

Variations to reduce the frequency of testing shall be at the discretion of SA Water's Representative. Where the Contractor has implemented a system of statistical process control and can demonstrate that a lower frequency can assure the quality of the product, SA Water's Representative may agree to a lower frequency.

22.6 Sampling and Testing

Fresh concrete shall be sampled and tested in accordance with AS 1379 and AS 3600 Section 17.1.6, for project assessment testing.

Test specimens shall be tested in accordance with requirements in this Standard.

22.7 Non-compliances

The Contractor shall record and immediately report all non-compliances with this Standard, including all referenced tests within the Standard from the list at Clause 1.3, to SA Water's Representative. The record shall indicate the nature of the non-compliance, the corrective action taken and the location(s) within the Works potentially or actually affected by the non-compliance.

The following steps shall be taken by the Contractor to the approval of SA Water's Representative.

1. Identify the extent and cause of the non-compliance;
2. Take measures to prevent re-occurrence, including suspending works;
3. Propose investigations to determine the quality of the concrete and other materials in the works;
4. Propose repair actions to reinstate the appearance, strength and durability of the affected Works, with durability review in particular for watertightness of liquid retaining or excluding elements; and
5. The Contractor shall engage a Durability Consultant (refer CIA Z7/01) for any matters that reduce durability including to achieve the required design life without additional inspection and maintenance.

SA Water's Representative shall review all non-compliances and determine rejection of concrete in accordance with Clause 22.8 or concrete repair in accordance with Clause 21.

22.8 Rejection of Concrete

Concrete supplied to site but deemed by SA Water's Representative to not comply with the acceptance criteria will be rejected by SA Water's Representative. Hardened concrete that exhibits any of the defects listed in Section 17.1.7 of AS 3600 shall be rejected.

Hardened concrete which exhibits a 7-day compressive strength below 60% using GP cement or 50% using GB or LH cement of the 28 day characteristic strength for that grade of concrete shall be considered as a sufficient basis for rejection. This shall constitute sufficient grounds for SA Water's Representative to instruct the Contractor to withhold further work on those components which:

1. Constitute major structural members; or

2. Are supported or connected to the components with the concrete of suspect quality.

Until the 28-day characteristic strength of the concrete is obtained and the concrete accepted or rejected accordingly. The Contractor shall not be entitled to any claim for compensation or Contract extension of time consequential to the issuance of SA Water's Representative instruction to withhold such work irrespective of the 28-day strength of the suspect concrete.

Any concrete rejected because of non-compliance with the requirements of this Standard shall be replaced at the cost of the Contractor. The cost of removal and replacing other components or works deemed necessary because of their connection to the rejected concrete shall be borne by the Contractor. SA Water's Representative will not consider any claim arising from the rejection of non-complying concrete supply or installation.

23 Super Workable Concrete

23.1 General

Unless specified otherwise in this Clause, super workable concrete shall conform to this Standard. Super workable concrete shall only be used in very heavily reinforced elements, in inaccessible areas and where very rapid concrete placing is desired. The use of super workable concrete shall be approved by SA Water Representative. Guidance is available form CIA Z40.

Where super workable concrete is proposed, a trial mix is mandatory and shall be undertaken in accordance with the requirements specified in Clause 8. The super workable concrete supplier shall implement and maintain a quality management system in accordance with AS/NZ ISO 9001 for the concrete batching and production process.

The super workable concrete mixing method shall be determined based on the existing records or by conducting tests.

The requirements for slump flow, difference between slump flow and J-ring flow, time for the concrete to reach 500 mm diameter (T500) and Visual Stability Index shall be applied in lieu of the slump requirements.

23.2 Requirements for Fresh Super Workable Concrete

Table 9 - Minimum Acceptable Criteria for Fresh Super Workable Concrete

Property	Test Method	Acceptable Criteria
Slump Flow	AS 1012.3.5	550 mm to 800 mm Spread
Difference between Slump Flow and J-Ring Flow	AS 1012.3.5	≤ 50 mm

Property	Test Method	Acceptable Criteria
Time for the concrete to reach 500 mm diameter	AS 1012.3.5	≤ 5 seconds
Visual Stability Index	ASTM C1611	≤ 1

23.3 Sampling and Testing

Sampling and testing for super workable concrete shall be in accordance with the requirements of concrete in this Standard except that the slump flow, difference between slump flow and J-ring flow, time for the concrete to reach 500 mm diameter (T500) and Visual Stability Index shall be sampled and tested at the same frequency as the slump test for other type of concrete.

When making test cylinders for super workable concrete the test sample shall be placed into the cylinder moulds from a height not exceeding 100 mm from the top of the mould. The placing of the concrete into the moulds shall be done in one continuous motion. With the exception of light tapping of the sides of cylinder moulds with a plastic mallet, rodding or vibration shall not be applied to test cylinders made up of super workable concrete.

23.4 Self-Compacting Concrete (SCC)

In addition to the requirements specified in Clause 23.1 to 23.3, compaction as per Clause 10.2 shall not apply with SCC to be self-consolidating without compaction. Until the concrete is hardened, self-compacting concrete shall not be subjected to any physical disturbance after placement.

24 Ultra-High Performance Concrete

For the purpose of this Standard, ultra-high performance concrete is a high strength, ductile concrete with compressive strength in excess of 100 MPa when tested according to AS 1012.9, modulus of rupture in excess of 18 MPa when tested according to AS 1012.11 and fracture energy in excess of 10 N/mm when tested according to ASTM C1018.

Unless specified otherwise in this Clause, ultra-high performance concrete shall conform to this Standard. The use of ultra-high performance concrete shall be approved by SA Water Representative.

The Contractor shall provide a project execution plan and methodology for using ultra high performance concrete, based on the full understanding of material characteristics during placement and after hardening. The ultra-high performance concrete supplier shall implement and maintain a quality management system in accordance with AS/NZS ISO 9001 for the concrete batching and production process.

Trial mix is mandatory and shall be undertaken in accordance with the requirements specified in Clause 8. The fresh and hardened concrete requirements shall be based on appropriate indices contained within this Standard according to the type of ultra-high performance concrete, construction conditions and construction methods and shall be demonstrated by way of testing.

25 Alkali Activated Concrete

For the purpose of this Standard, alkali activated concrete is concrete made of essentially any binder system derived by the reaction of an alkali metal source, either solid or dissolved, with a solid silicate or aluminosilicate-rich powder.

Unless specified otherwise in this Clause, alkali activated concrete shall conform to this Standard and all technical requirements of this Standard shall be met. Alkali activated concrete shall also comply

with AS 1379. While alkali activated concrete may not contain cement, in this Standard, the term "Concrete" in AS 1379 shall be interpreted to include alkali activated concrete.

The use of alkali activated concrete shall be subject to approval by SA Water Representative.

The Contractor shall provide a project execution plan and methodology for using alkali activated concrete, based on the full understanding of material characteristics during placement and after hardening. The alkali activated concrete supplier shall implement and maintain a quality management system in accordance with AS/NZS ISO 9001 for the concrete batching and production process.

Trial mix is mandatory and shall be undertaken in accordance with the requirements specified in Clause 8.3. The fresh and hardened concrete requirements shall be based on appropriate indices contained within this Standard according to the type of ultra-high performance concrete, construction conditions and construction methods and shall be demonstrated by way of testing.

Where alkali activated concrete is proposed, the alkali-activated concrete supplier shall implement and maintain a quality management system in accordance with AS/NZS ISO 9001 for the concrete batching and production process.

26 Formwork and Falsework

26.1 General

Formwork and falsework including all temporary supporting members, shall conform to Safe Work Australia Formwork and falsework guidance material, the relevant Australian Standards including but not limited to AS 3610 and AS 3610.1, and this Standard.

Formwork and falsework shall be designed considering the type, scale and importance of the structure and the conditions of construction and environment.

Formwork and falsework shall be designed, inspected and certified by competent and experienced engineer(s) such that the erection of formwork and falsework satisfy the performance requirements.

Errors in line or level of the formwork, or positioning and/or quantity of steel reinforcement shall be corrected prior to placing concrete. The Contractor will be responsible for any defects to the formwork, reinforcement, embedded components, or the formed concrete surface, which may become apparent during or after casting the concrete.

Unless it is waived by SA Water Representative in each specific case, the relevant Certificate of Compliance for formwork and falsework shall be submitted to SA Water's Representative. The application of any load shall not proceed until the Certificate of Compliance of the constructed formwork has been reviewed by SA Water's Representative.

Formwork drawings and design computations, if required by SA Water Representative, shall also be prepared by the Contractor and submitted for examination.

Blockouts, inserts, ducts, embedded items, etc. shall be located and fixed so that the construction tolerances specified are compliant.

26.2 Formwork Construction

Formwork shall be watertight, braced and tied together to confine freshly placed concrete and maintain position and shape during construction. Formwork shall be constructed in such a way that it can be removed without damage to the concrete.

Where formwork is intended for re-use, the deterioration of the materials following their use and handling shall be assessed. Forms which become unsatisfactory shall not be used.

Unless specified otherwise in the Contract, all corners of cast-in-place or precast concrete shall have 20 mm x 20 mm chamfers or fillets. Chamfers and fillets shall be formed and cast integrally with the concrete member. Cutting or grinding of chamfers shall not be allowed.

The interior surface of formwork shall be thoroughly cleaned out and treated with release agent or lubricant to prevent adhesion of the exposed concrete surface, in accordance with the manufacturer's instructions. The release agent or lubricant shall be of the non-staining type and shall not discolour the surface of the concrete. The release agent or lubricant shall be applied uniformly in a thin film and any surplus removed prior to the concrete placement. Reinforcement and other embedments shall not be soiled by the release agent or lubricant. In accordance with Clause 7.2.5 the release agent shall be compliant with AS/NZS 4020 if residual amounts come in contact with potable water.

All forms shall be cleaned and free from sand, shavings, tie wire ends and other debris. Surplus water shall be drained. If necessary, temporary openings shall be provided at appropriate positions in the form to facilitate cleaning, inspection and placing concrete. Any temporary openings shall be closed in proper manner prior to placing concrete.

26.3 Form Ties

Form ties shall consist of bolts, rods or other fastening systems that will ensure that forms or falsework are rigidly fixed.

Form ties for use in water retaining and water excluding structures shall be approved proprietary products specifically designed and manufactured to be watertight. Only approved watertight form tie products by manufacturers PCH, Peri, Max Frank or equivalent approved shall be used.

Form ties that after removal leave a hole extending throughout the thickness of a concrete section will not be permitted.

Any embedded form ties shall remain embedded and shall terminate not less than the minimum cover specified in the Contract or this Standard.

Holes or gaps left from form ties shall be repaired in accordance with Clause 21 and the tie manufacturer's instructions.

Top form ties shall not be located within 150 mm of the top of the pour.

26.4 Removal of Formwork

Formwork and falsework shall be removed in such a manner and sequence that the concrete element is not subjected to impact, excessive load or eccentric load and no damage to the concrete surface occurs.

Minimum formwork stripping times shall be in accordance with the minimum formwork stripping times set out in Table 5.4.1 of AS 3610 and guidance given in CIA Z7/04.

Formwork and falsework shall not be removed until the concrete has achieved sufficient strength to carry its own weight and any loads superimposed during the course of further construction.

The Contractor shall determine the timing and sequence of the removal taking the strength of concrete, the structure type and importance, member types and dimensions, loads imposed on all members, temperature, weather and ventilation into appropriate consideration. Formwork for successive wall lifts shall not be supported by previously placed concrete until that concrete has

achieved a minimum characteristic strength of 15 MPa. Horizontal forms (for suspended slabs and beams) shall not be removed until a compressive strength of 25 MPa has been achieved. The Contractor may submit Structural Engineer certified calculations for lower strength formwork support or removal for review and approval by SA Water's Representative.

In cases when the structure is subjected to loads immediately after the removal of formwork and falsework, the concrete strength, the structure type and the characteristic and value of imposed loads shall be carefully considered in order to avoid harmful cracks and other damage to the structure.

To reduce the likelihood of cracking due to thermal shock, formwork shall not be stripped in the coldest part of the day. The period of time before stripping should be increased if the average temperature over the curing period is less than 5 °C. AS 3600 provides guidance on the increased duration in this period depending on the ambient temperature.

Notwithstanding the minimum stripping times in Table 5.4.1 of AS 3610, formwork shall only be removed where it can be demonstrated that doing so will not initiate early age concrete cracks by premature removal of plywood formwork, if plywood formwork is used.

Curing shall be immediately applied to the exposed concrete surface if the formwork is removed within the curing period (refer Clause 13.7).

26.5 Proprietary Formwork and Falsework System

Where proprietary formwork products are approved by SA Water Representative, the Contractor shall install such formwork in accordance with the manufacturer's specification and recommendation.

27 Insert and Support

Inserts and supports shall be in accordance with AS 3600 or AS 5100.5 as appropriate, as specified in this Standard and to the satisfaction of SA Water Representative.

Inserts and supports shall be accurately cast into the concrete by the Contractor, within 4 mm of their indicated position unless shown otherwise on the Drawings. The provision of holes or pockets and the subsequent grouting of inserts and supports will not be allowed unless approved in writing by SA Water Representative.

Tapped holes and other recesses shall be sealed and the sealing material later removed. After stripping of formwork, all concrete and other materials shall be cleaned from the surfaces of inserts and supports.

27.1 Embedment of Inserts

The Contractor shall install, fix and cast in all pipes, pipe sleeves, bolts, conduits, frames, castings, steel beams and other items, which are required to be wholly or partially embedded in the concrete, as shown on the Drawings.

Before casting of inserts and openings, the Contractor shall check their positioning, alignment and elevation to ensure they are accurately placed and adequately supported in suitable templates, frames and forms. Any misplacement or deviation from the specified tolerance shall be corrected by the Contractor at the Contractor's expense to the satisfaction of SA Water's Representative.

Metal embedment items shall be fixed in place by tying with tie wire made of the same metal and same grade, or by anchoring to the forms using fixings made of the same metal and same grade.

The Contractor shall ensure proper placement and adequate compaction of the concrete are achieved around the inserts and openings as specified in Clause 10.2.

27.2 Supports

The Contractor shall check the positioning of supports for floor plates, floor gratings, or other fixtures requiring even and uniform bearing, before setting the supports with concrete or mortar. Failure to obtain satisfactory uniformity of bearing shall be rectified by the Contractor, as directed by the Designer and approved by SA Water's Representative, at the Contractor's expense.

28 Bar Chairs and Spacers

All bar chairs and spacers shall comply with AS/NZS 2425 and this Standard, subject to approval by the SA Water Representative. All spacers and chairs shall be manufactured in an AS/NZ ISO 9001 approved production facility.

Bar chairs and spacers for concrete in water retaining or water excluding structures shall be:

1. Concrete of not lesser durability characteristics than the concrete to be placed around them, and shall otherwise comply with the requirements of AS/NZS 2425; and

2. High durability proprietary fibre-cement mouldings or extrusions.

Note: Responsibility for fixing reinforcement with the correct cover and for ensuring that spacers and chairs are correctly spaced and have the required performance characteristics rests with the Contractor.

29 Reinforcement

29.1 Steel Reinforcement

29.1.1 Materials

All steel reinforcement materials shall conform to AS/NZS 4671 and this Standard.

The reinforcement material supplier including but not limited to manufacturers and processors, shall be certified by the Australasian Certification Authority for Reinforcing and Structural Steels for the supply of the steel reinforcement.

If requested, the Contractor shall supply to SA Water's Representative copies of the manufacturer's test certificates identifiable with the reinforcement supplied or provide documentary evidence that all products meet the requirements of AS/NZS 4671 and that the supplier has a system in place to prevent non-conforming material from being supplied.

29.1.2 Schedules

The Contractor shall be responsible for the production of all reinforcement schedules, shop drawings of all prefabricated reinforcement cages that may be necessary for the fabrication of the reinforcement, including all tie wire, support bars, spacer bars and the like.

A copy of the reinforcement schedules and prefabricated reinforcement cage shop drawings shall be submitted to SA Water Representative.

29.1.3 Fixing

Reinforcement shall be adequately tied together such as to form a rigid cage, which prevents displacement of bars or meshes and maintains dimensional tolerances under all loads applied before and during the concrete placement. The requirements set out in BS 7973-2 shall be regarded as a minimum for fixing the reinforcement. All steel reinforcement in position shall be inspected and approved by SA Water's Representative before the concrete placement commences.

Note: Responsibility for securely fixing reinforcement rests with the Contractor.

Tie wire shall be annealed steel wire having a diameter of not less than 1.2 mm. Plastic ties or clips are not permitted.

The minimum clear cover to the tie wire shall be equal to that specified in this Standard or that designated in the Contract for the reinforcement being tied, less the diameter of the tie wire. Projecting ends of ties shall not encroach into the concrete cover zone.

The ends of reinforcement forming a lapped splice shall be tied together in at least two places.

Tack welding shall comply with Clause 29.1.6.

29.1.4 Bending

Reinforcement shall be cut and bent to comply with the dimension shown on the Drawings. Reinforcement shall not be bent or strained in a manner that shall damage it. Where bending of reinforcement is required by the Drawings the diameter of such bends and the method of bending shall be restricted to the requirements of AS 3600 and AS 5100.5, where appropriate.

Ductility class L reinforcement shall not be heated or hot bent.

29.1.5 Splicing

Where splices in reinforcement are not shown on the Drawings and are required by the Contractor, it constitutes a change in design details and all locations of such splices shall be submitted to SA Water Representative for approval. All splices shall be in accordance with the requirements of AS 3600 and AS 5100.5, where appropriate.

29.1.6 Welding

Reinforcement shall not be welded unless:

1. Is required by the Project;
2. Is approved in writing by SA Water Representative; or
3. Is required for cathodic protection as per Clause 29.1.8.3.

Where welding is approved, all welding shall be undertaken in accordance with AS/NZS 1554.3 and this Standard. The term "Principal" in AS/NZS 1554.3 shall mean SA Water Representative.

For all load bearing welds for lifting and transport of prefabricated reinforcement, the Contractor shall design and submit the welding and handling details, taking into account static and dynamic loadings and any stress reversals that may occur during lifting, moving and transport, to SA Water Representative.

With the exception of fabricating reinforcing mesh by an Australasian Certification Authority for Reinforcing and Structural Steels certified fabricator, Ductility class L reinforcement shall not be

welded unless the Contractor can demonstrate by way of testing that the weld procedure does not result in the loss of ductility.

29.1.7 Surface condition of reinforcement

Reinforcement shall be free from damage, kinks and other unwanted bends and deformations.

The reinforcement shall also be maintained free from surface contamination, loose mill scale, loose rust, mud, oil, grease and other coatings that would reduce the bond between the concrete and the reinforcement.

In addition, the surface condition of steel reinforcement shall comply with the following requirements:

1. Any steel reinforcement projecting from a previous concreting operation shall be cleaned free of adhering concrete or slurry prior to any further embedment;

2. Any steel reinforcement installed within 1 km of the coastline shall be thoroughly washed with a high pressure potable water jet immediately prior to pouring concrete to remove any salts deposited during storage and placement;

3. Steel reinforcement which has been accidently submerged by tidal or flood waters shall be cleaned with a high pressure potable water jet as soon as possible after recovery, or in any case prior to pouring concrete;

4. With the exception of cast-in-place concrete elements, construction or placement of steel reinforcement in tidal water or liquid, or submerged in standing liquid shall not be permitted.

29.1.8 Protection of Steel Reinforcement

29.1.8.1 Galvanising

Where required by the Project, steel reinforcement shall be hot dip galvanised to at least Grade HDG600 in accordance with AS/NZS 4680. The hot-dip galvanized coating shall have a minimum average weight of 600 g/m^2 and a minimum average coating thickness of 85 µm.

The galvanising of reinforcement shall be undertaken after all cutting, bending and welding of reinforcement cages is complete. Repairs to cut ends and beaks in the coating shall be undertaken in accordance with AS/NZS 4680.

After galvanising, the reinforcement shall be passivated using a 0.2% sodium dichromate solution by the galvaniser.

The use of galvanised reinforcement in conjunction with stainless steel reinforcement is prohibited.

29.1.8.2 Epoxy Coating

Unless otherwise designated in the Contract and approved by the SA Water Representative, epoxy coated steel reinforcement shall not be used.

29.1.8.3 Cathodic Protection

Cathodic protection of reinforced concrete may be a future maintenance repair option in very aggressive chloride exposure environments. Design stage durability assessment shall determine the need for cathodic protection repair installation during the design life, plus any likely extended service life, and consequent reinforcement electrical continuity design requirements for future cathodic protection. The Contractor shall install all reinforcement continuity details shown on the drawings including welding of reinforcement, additional reinforcement and electrical continuity testing.

29.2 Stainless Steel Reinforcement

29.2.1 Materials

Where the use of stainless steel reinforcement is specified, stainless steel reinforcement shall comply with the requirements of BS 6744 or ASTM A955M.

The stainless steel reinforcement shall be designed by taking into account its physical and mechanical properties.

The stainless steel reinforcement shall be manufactured, processed, fabricated and supplied only by an Australian Stainless Steel Development Association accredited supplier.

The Contractor shall supply to SA Water's Representative copies of the manufacturer's test certificates identifiable with the reinforcement or provide documentary evidence that all products meet the requirements of BS 6744 and that the manufacturer has a system in place to prevent non-conforming material from being supplied. Where such certificates cannot be supplied, the Contractor shall arrange testing of reinforcement for tension, bending and ductility to BS 6744.

29.2.2 Schedules

Refer to Clause 29.1.2.

29.2.3 Fixing

Stainless steel reinforcement shall be adequately tied together such as to form a rigid cage, which prevents displacement of bars or meshes and maintains dimensional tolerances under all applied loads applied before and during the concrete placement. The requirements set out in BS 7973-2 shall be regarded as a minimum for fixing the reinforcement. All stainless steel reinforcement in position shall be inspected and approved by SA Water's Representative before the concrete placement commences.

Note: Responsibility for securely fixing reinforcement rests with the Contractor.

Tie wire used to tie stainless steel shall be of the same grade with the reinforcement and shall have a diameter of not less than 1.2 mm. Plastic ties or clips are not permitted.

The use of metal chairs or spacers as per Clause 28 other than those made stainless steel of same grade is prohibited.

The minimum clear cover to the tie wire shall be equalled to that of specified in this Standard or that of designated in the Contract for the stainless steel reinforcement being tied, less the diameter of the tie wire. Projecting ends of ties shall not encroach into the concrete cover.

The ends of stainless steel reinforcements forming a lapped splice shall be tied together in at least two places.

Tack welding shall comply with Clause 29.2.6.

29.2.4 Bending

Stainless steel reinforcement shall be cut and bent to comply with the dimension shown on the Drawings with the dimensional tolerance complying with AS 3600 and AS 5100.5, as appropriate. Stainless steel reinforcement shall not be bent or strained in a manner that shall damage it. Where bending and forming of stainless steel reinforcement is required by the Drawings the diameter of such bends and the method of bending shall be restricted to the requirements of BS 8666.

Hot bending of stainless steel reinforcement shall be in accordance with methods recommended by the manufacturer. Pins used for bending stainless steel shall be made from stainless steel.

29.2.5 Splicing

Refer to Clause 29.1.5.

29.2.6 Welding

Welding of stainless steel reinforcement shall be in accordance with the requirements of AS/NZS 1554.6 and Clause 29.1.6 of this Standard.

In addition, stainless steel reinforcement shall be welded only in a welding workshop specifically set up for the purpose. Such facility shall maintain conditions preventing any contamination of the stainless steel and consumables used in the proper performance of the welding of stainless steel.

Precautions shall be taken to prevent the formation of heat tint at welds. Where heat tint is formed it shall be removed by pickling and passivation in accordance with ASTM A380 to the approval of the SA Water Representative.

29.2.7 Surface condition of reinforcement

In addition to the requirements in Clause 29.1.7 of this Standard, stainless steel reinforcement shall not be contaminated by contact with other steel, grease, oil and iron. Grinding, welding or cutting of other steel or any other structural steel shall not occur after any stainless steel reinforcement has been placed.

Tools for fabricating, lifting, fixing or bending stainless steel reinforcement shall not have been used and shall not be used for other materials.

29.3 Pre-stressing Tendons

29.3.1 General

Steel tendons shall be multiple wire stress relieved steel strand complying with AS/NZS 4672.1.

Wire or strand or bar which has been used previously shall not be used in the Works.

All prestressing material installed in the Works shall be clean and free from loose rust, grease and mill scale at the time of fixing in position and subsequent concreting. Slight rusting of the steel is acceptable but the surface shall not be pitted

Each delivery of materials shall be accompanied by documentation showing the lot numbers from which each coil or bar is taken, together with a certificate, from a laboratory with appropriate NATA accreditation, which indicates conformance with the relevant standard.

In addition, testing of wire, strand and bar shall be carried out in accordance with the testing requirements of AS/NZS 4672.2. The frequency of testing shall be at least three samples from each 15 tonne of material or part thereof. Testing samples shall be from the same source.

The following information shall be obtained during testing and submitted to the SA Water's Representative prior to use in the Works:

1. Breaking force;

2. Yield strength and elongation;

3. Load-strain plot;

4. Cross-sectional area of strand, wire or bar;

5. 100 hour relaxation loss at 70% and 80% of maximum breaking load;

6. Source(s) of strand, wire or bar.

High-tensile steel wire and strand shall be supplied in coils conforming to the requirements of AS/NZS 4672.1. Pre-stressing steel and couplers shall be protected from damage and deterioration at all times. Tendons shall be stored off the ground in suitable weatherproof shelters and shall not be kinked or bent.

29.3.2 Pre-stressing Anchorages

No damaged anchorage devices shall be used. All parts shall be protected from corrosion at all times. All threaded parts shall be protected by greased wrappings and all tapped holes shall be protected by suitable plugs until used. The anchorage components shall be kept free from mortar, loose rust and any other deleterious coating.

Anchorages shall be in accordance with AS/NZS 1314.

Gripping efficiency of the combined anchorage shall be maintained by achieving the required manufacturing tolerances for each component as specified in the manufacturer's requirements.

Anchorages shall be positioned and maintained during concreting so that the centreline of the duct shall pass axially through the anchorage assembly and shall be normal to the bearing surfaces.

All bearing surfaces of the anchorages shall be clean prior to concreting and tensioning.

29.3.3 Pre-stressing Sheathing

Sheathing shall be HDPE in accordance with the Drawings, so constructed that ingress of mortar during concreting is prevented.

29.3.4 Inspection of Concrete in Pre-stressing Elements

The Contractor shall give the SA Water's Representative a minimum of five (5) working days notice of the Contractor intention to place concrete. Unless inspection is waived by SA Water's Representative in each specific case, placing of concrete shall be performed only in the presence of the SA Water's Representative. Concrete shall not be placed outside normal working hours without the prior approval of the SA Water's Representative.

29.4 Fibre Reinforced Polymer Reinforcement

29.4.1 Materials

Materials for fibre reinforced polymer (FRP) reinforcement shall comply in all respects with the requirements of ACI 440.6M.

The thermosetting resin system shall be a vinyl ester or epoxy resin based system with a glass-to-rubber transition Tg point or heat distortion temperature (HDT) not less than 100 °C. Higher Tg values might be specified depending on the operating temperature range of the structure.

29.4.2 Schedules

Refer to Clause 29.1.2.

29.4.3 Fixing

The Contractor shall tie all intersections using plastic coated or nylon zip ties, or non-rusting material instructed by the Manufacturer and as approved by SA Water Representative.

The Contractor shall place and fix the FRP reinforcement in accordance with the Manufacturer's instructions.

All FRP reinforcement shall be secured to and supported within formwork as required to prevent displacement by concrete placement or workers.

All FRP reinforcement shall be accurately supported using non-corrosive chairs and spacers before concrete placement is started. The use of plastic chairs and spacers that conform to AS 2425 is permitted. In addition, the Contractor shall use chairs and spacers that incorporate a positive locking mechanism to restrain FRP reinforcement from floating during concrete placement.

The Contractor will be allowed to cut the FRP reinforcement with a high speed grinding cutter, fine blade saw, diamond blade or masonry blade with the prior approval of SA Water Representative.

Shearing FRP reinforcement will not be allowed.

The Contractor shall place the FRP reinforcement within the tolerances as specified in ACI 117.

The Contractor shall remove form oil from FRP bars using a method approved by the Manufacturer before placing concrete.

29.4.4 Handling and Storage

The Contractor shall load, haul, store, and handle the FRP reinforcements in accordance with the Manufacturer's instruction to prevent damage. Special care is required in the loading, hauling, storage and handling of the reinforcement to prevent damage.

Bundling bands shall be padded or suitable banding shall be used to prevent damage to the reinforcement.

If the reinforcements are to be stored on-site for more than 3 months, the reinforcements shall be covered with an opaque material to avoid UV radiation and exposure to chemical substances.

FRP reinforcements are very light and flexible; therefore, hoisting bundles of FRP reinforcements shall be performed with a strong back spreader bar or multiple supports to avoid excessively bending of the reinforcements. The FRP reinforcement shall not be dropped or dragged.

29.4.5 Bending

FRP reinforcement shall be bent to the proper shape by the manufacturer during fabrication, minimum bend radii shall conform to Table 10.1 of ACI 440.6M. Absolutely no field bending of the bars is permitted. Should modifications to the FRP reinforcement be required, the Contractor shall notify SA Water Representative.

29.4.6 Splicing

Lap slices shall be used wherever detailed or specified on the Drawings and where continuity is required in the reinforcement. The use of mechanical connection or adhesive bonded splices is not permitted.

29.4.7 Surface condition of reinforcement

The surface finish of the reinforcement shall be sanded (sand applied during manufacture), sanded-braided or deformed. Properties of the proposed reinforcement shall be submitted to the SA Water Representative for approval prior to use.

The surface shall be clean and dry, free of physical damage, free of contaminants and indications of exposure to UV light during storage (e.g. chalking, crazing, etc.).

Material that has chalked or shows other damage due to UV exposure shall not be used.

30 Dissimilar Metals Embedded in Concrete

Contact between different types or grades of metal embedments and reinforcements shall not be allowed unless the expected potential difference is such that corrosion effects will be negligible. For example, Grades 304 and 316 stainless steel can be coupled to carbon steel reinforcement provided that all components are fully embedded in the concrete. If the stainless steel element is exposed at the concrete surface (e.g. as ferrules or hold-down bolts) the two metals shall be electrically isolated.

Where potentially deleterious contact between such dissimilar metals embedded in concrete is unavoidable, the two different metals shall be electrically isolated to prevent galvanic or bimetallic corrosion.

Electrical isolation may be effected by utilising PVC conduit sleeves, suitable soft plastic wrapping or tapes or by other approved means.

31 Fibre Reinforced Concrete

31.1 Steel Fibre Reinforced Concrete (SFRC)

31.1.1 General

This Clause shall apply where steel fibres are used to improve the performance and capacity of a concrete element. The Contractor shall comply with Clauses 7 and 8 of this Standard and demonstrate that the design meets the intended performance requirements.

Structural applications of steel fibres are currently outside the scope of this Standard. Design procedures for some steel fibres have been established by the steel fibre manufacturers/suppliers, but to date, no independent generic design rules have been developed for common use of these materials (i.e. no design in Australian Codes/Standards or Recommended Practices).

Steel fibre requirements shall include:

1. Steel fibres shall be cold drawn wire in accordance with BS EN 14889-1;
2. All fibres shall be crimped or otherwise deformed to provide an end anchorage;
3. The minimum tensile strength of the wire shall be 1,050 MPa;
4. The minimum length of the fibres shall be determined for the project with particular consideration for sprayed application (e.g. consider 50 mm or less normally and 35/25 or 2.5 time aggregate size for sprayed application);
5. The typical minimum aspect ratio (length: diameter) shall be 65:1;

6. The typical minimum dosage shall be 25 kg/m³; the dosage of steel fibres shall be determined by trial mixes (refer Clause 8.3) to meet the performance criteria set out in this Standard;

7. Fibres shall be stored in dry sealed containers until required for use and shall be free from corrosion, oil, grease, chlorides and deleterious materials which may reduce the bond between the fibres and the concrete;

8. Fibres which tend to form fibre balls during batching and mixing shall not be used and fibre shaking tables/separators can be implemented to avoid balling of fibres prior to batch addition;

9. Visual inspection of batch mixes shall be undertaken to ensure balling does not occur;

10. Approval to AS/NZS 4020 products for use in contact with drinking water plus acceptable to SA Water's Representative in accordance with the Department of Health requirements;

11. Use of fibres shall consider the impact of fibres partially exposed on the concrete surface that can give corrosion staining, the fibre (or part) becoming dislodged from the concrete during the design life and the application of any surface coatings on the concrete with fibres exposed); and

12. Concrete trial casting (refer Clause 8.4.2) of elements shall be completed to SA Water's Representative requirements where any uncertainty exists on the likely concrete performance.

NOTE: There is no Australian Standard for designing steel fibre reinforced concrete at the time of publishing this Standard. The Contractor is encouraged to discuss with SA Water Representative prior to undertaking design. The Draft for Public Comment Australian Standard for Bridge Design Part 5: Concrete dated 2014 (DR AS 5100.5) has the provision for Steel Fibre Reinforced Concrete. It is intended that this Clause of this Standard will be revised upon the Standard is published in its final state.

Steel fibres shall not be relied upon at constructions joints. The Contractor shall provide the construction joint details to SA Water's Representative demonstrating that that the continuity of the load transferring and carrying capacity of the concrete element.

31.1.2 Supply and Delivery

Fibres shall be free from corrosion, oil, grease, chlorides and deleterious materials which may reduce the efficiency of mixing or placement process, or which may reduce the bond between the fibres and the concrete.

Some fibres may have a film that provides limited corrosion protection before placing in concrete while others may have no protection (guidance from CIA Z7/04). During storage fibres are prone to corrosion and unlike reinforcing bar even a small amount of corrosion can have a significant effect on performance. Corrosion of the fibres may not be immediately apparent, particularly where bags are dispensed directly into the concrete mixer. Hence part of the quality assurance procedures should be to open sufficient bags of fibres and to check that the batch of fibres to be used are free from corrosion.

Fibres of the type and quantity specified shall be added in a controlled process ensuring that they are dispersed uniformly through the concrete mix. If added after the main mixing process, the concrete shall be remixed until the fibres have been completely dispersed throughout the batch.

Balling of steel fibres shall be avoided.

The steel fibre reinforced concrete mix shall remain workable until it is fully placed.

In addition to the information required in Clause 9.2, fibre type and dosage shall be shown on the delivery docket.

Determining the steel fibre content

Where steel fibres have been specified in a concrete mix, testing and reporting of homogeneity of the steel fibres in the fresh concrete shall be carried in accordance with BS EN 14721 Method B.

1. The first batch for 50 m^3 of SFRC in the Works shall be tested, unless otherwise directed by SA Water's Representative;
2. One test is made up of three samples, one in each third of the same load as follows:
   a. at the beginning of the load (from the first third of the mix), after 0.5 m^3 is unloaded;
   b. in the middle of the load (from the second third of the mix); and
   c. at the end of the load (from the last third of the mix), with min 0.5 m^3 left in truck;
3. All samples shall be taken directly out of the "concrete stream" at the end of the chute (not out of a wheelbarrow, because that gives segregation);
4. Each sample requires a minimum concrete volume of 10 litres;
5. The result of a test taken as the average of 3 samples shall not be less than 90% of the specified steel fibre content;
6. The result of a single sample shall not be less than 85% of the specified steel fibre content;
7. SA Water's Representative shall determine test requirements after the first 50 m^3 of SFRC in the Works taking into account the trial mix testing and first batch tested.

31.2 Synthetic Fibre Reinforced Concrete

This Clause shall apply where synthetic fibres, commonly termed monofilament fibres, are used to improve the performance and capacity of a concrete element. There are two types of synthetic fibre, structural synthetics or macro fibres, and micro-fibres (refer CIA Z7/04):

1. Structural synthetics that can be similar to that of steel fibre concrete however, all structural design matters shall be assessed. Typical fibre length can be 40+ mm. Structural applications of synthetic fibres are currently outside the scope of this Standard;
2. Micro synthetic fibres are used to assist with plastic crack control or to assist with water blockage and explosive spalling in the event of fires. Typical fibre length can be 18+ mm. The use of synthetic fibres to control plastic shrinkage cracking, or to prevent explosive spalling of cover concrete during severe fires, is a potential risk mitigation measure however, the design is outside the scope of this Standard (their efficacy in these applications is well documented, but is proprietary information). Examples for consideration are use in water tank floor slabs for plastic crack control and walls of water tank walls in bush fire risk locations.

Synthetic fibre requirements shall include:

1. 100% virgin polypropylene monofilament fibre containing no reprocessed materials and comply with the requirements of BS EN 14889-2;
2. The typical minimum fibre content shall be 1.0 kg/m^3;
3. Only the fibre type, coating, diameter, length and dosage shall be determined to meet the performance requirements set out this Standard;

4. Approved to AS/NZ 4020 products for use in contact with drinking water plus acceptable to SA Water's Representative in accordance with the Department of Health requirements;

5. The fibre type, coating, diameter, length and dosage shall be determined to meet specific Works performance requirements; and

6. Use of fibres shall consider the impact of fibres partially exposed on the concrete surface, the fibre (or part) becoming dislodged from the concrete during the design life and the application of any surface coatings on the concrete with fibres exposed (e.g. an epoxy protective coating application).

The Contractor shall comply with Clauses 7 and 8 of this Standard and demonstrate that the design meets the intended performance requirements.

NOTE: The Contractor is encouraged to discuss use of synthetic fibres in reinforced concrete with SA Water Representative prior to undertaking design with synthetic fibres.

Design procedures for some high performance synthetic fibres have been established by the monofilament fibre manufacturers/suppliers, but to date, no independent generic design rules have been developed for common use of these materials (i.e. no design in Codes/Standards or Recommended Practices).

The Contractor using synthetic fibres should follow the manufacturer/suppliers design guidelines, and confirm the results by special studies for the specific Works.

The Contractor shall be responsible for the synthetic fibres cast in the concrete, all concrete placements and finishing procedures to achieve concrete in accordance with this Standard.

Concrete trials mixes (refer Clause 8.3) and trial casting (refer Clause 8.4.2) of elements shall be completed to SA Water's Representative requirements where any uncertainty exists on the likely concrete performance.

32 Contractor Works Method Statement for Concrete including Early Age Thermal Crack Assessment

The Contractor shall issue a Contractor Works Method Statement for Concrete to SA Water's Representative at least 20 working days prior to commencing any concrete works covering all concrete supply, testing, placement compaction and curing matters in accordance with this Standard and the Drawings, including but not limited to the below:

1. Premix supplier name, location, plant supply capability, agitator fleet capacity including breakdown impact (refer Clause 9.1);

2. Concrete mix design from premix supplier (refer Clause 8.2);

3. Concrete pour size and sequence (refer Clause 10.1.6);

4. Constructability approach for slump, workability, setting time, reinforcement congestion, reinforcement cover spacers, etc. (refer Clauses 7.1.1 and 7.1.2);

5. Concrete placement method (refer Clauses 9, 10, 11 and 12, with pour start and finish times (selected to minimise the risk of concrete cracks), placement method (e.g. pump or crane), compaction method, expected finishing time, finishing method, etc. Method to include equipment and manpower planning to achieve acceptable concrete quality;

6. Curing method (refer Clause 13.1);

7. Precast concrete requirements (refer Clause 16) including shop drawings; and

8. Quality control testing to be completed before, during and after concrete placement (refer Clause 22).

The Contractor shall obtain written approval of SA Water's Representative acceptance of the Contractor Works Method Statement for Concrete, prior to commencing any concrete construction works.

The Concrete Trial Mix Report (refer Clause 8.3) and approved mix design (refer Clause 8.4) shall be issued to SA Water's Representative at least 10 working days prior to commencing any concrete works. Any amendments to the Contractor Works Method Statement for Concrete from the concrete trial mix results shall be issued in a Revision 1 with all changes marked SA Water's Representative review, at least 10 working days prior to commencing any concrete works.

The Contractor shall commission a Durability Consultant to assess the concrete early age thermal crack risk assessment for all concrete elements greater than 500 mm in minimum dimension, and concrete elements with high restraint incorporating each mix design. The assessment shall consider:

1. Cement content and type;

2. Concrete element thickness, length and width;

3. Element type (floor, wall roof);

4. Element restraint;

5. Concrete placement temperature;

6. Concrete adiabatic temperature predicted from thermal block testing when relevant data is not available;

7. Concrete thermal expansion/contraction strain from thermal block data when relevant data is not available;

8. Concrete shrinkage from trial mix data;

9. Reinforcement ratios, diameter and spacing;

10. Time of water contact after concrete construction for liquid retaining or excluding structures;

11. Environmental conditions at time of construction;

12. Formwork type and stripping time;

13. Temperature of adjacent concrete; and

14. All other matters influencing concrete temperature and restraint.

The Durability Consultant shall produce a statement of outcomes from the assessment and recommendations on items to be addressed, if any, that the Contractor shall submit to SA Water's Representative.

The Contractor shall make any necessary changes to materials or methodology to comply with the assessment and obtain written approval from SA Water's Representative prior to proceeding with concrete works.

The above requirements are not applicable where the Contractor has completed a design stage concrete early age thermal crack risk assessment with a Durability Consultant and the Principal, and

approved by SA Water's Representative. The Contractor shall provide evidence of such concrete early age thermal crack risk assessment to SA Water's Representative and apply for the requirement to be waived.