APPENDIX 2 – CONCRETE FOR STRUCTURES (SPEC UNSW80) – TABLE OF CONTENTS

APPENDIX 2 – CONCRETE FOR STRUCTURES (SPEC UNSW80) – SCHEDULE OF CHANGES – REVISION 4

As a guide only, attention is drawn to changes that have been made in the following clauses since the last revision

Clause	Date
General revision	
No changes	August 2004

APPENDIX 2 CONCRETE FOR STRUCTURES (SPEC UNSW80)

APP 2.1 PROJECT SPECIFIC CHANGES

Any project specific changes to the base document (ie UNSW80 Ed1/Rev0) have been indicated in the following manner:-

(a) Text which is additional to the base document and which is included in the Specification is shown in bold italics eg ***Additional Text***.

(b) Text which has been deleted from the base document and which is not included in the Specification is shown struck out eg ~~Deleted Text~~ .

APP 2.2 GENERAL

APP 2.2.1 Scope

This Specification sets out the requirements for:

(a) the supply and delivery of all concrete, cement mortar, and grout for in-situ and precast concrete elements used in structures built for the University of New South Wales;

(b) the curing of the concrete, cement mortar and grout.

APP 2.2.2 Reference Documents

Unless otherwise specified the applicable issue of a reference document shall be the issue current at the date one week before the closing date for tenders.

Codes, standards, specifications and test methods are referred to in abbreviated form (eg AS 3600). For convenience, the full titles are given below:

	Structural Design Code
AS 3600	Concrete Structures
	Australian Standards
AS 1012	Methods of Testing Concrete
AS 1141	Methods for Sampling and Testing Aggregates
AS 1379	The Specification and Manufacture of Concrete
AS 1478	Chemical Admixtures for Concrete
AS 2758.1	Aggregates and Rock for Engineering Purposes - Concrete Aggregates
AS 3582	Supplementary Cementitious Materials for Use with Portland Cement
Part 1	Fly Ash
Part 2	Slag - Ground Granulated Iron Blast Furnace
Part 3	Silica Fume
AS 3799	Liquid Membrane - Forming Curing Compounds for Concrete
AS 3972	Portland and Blended Cements
AS/NZS ISO 9002	Quality Systems - Model for Quality Assurance in Production, Installation and Servicing

ASTM Standards

C151	Test Method for Autoclave Expansion of Portland Cement
C295	Standard Practice for Petrographic Examination of Aggregates for Concrete

RTA Test Methods

RTA T363	CSIRO Accelerated Mortar Bar Test for ASR Assessment
RTA T364	Concrete Prism Test for ASR Assessment
RTA T1005	Quantitative Analysis Using the Infrared Spectrophotometer

APP 2.2.3 Abbreviations

CSIRO	Commonwealth Scientific and Industrial Research Organisation, Australia
NATA	National Association of Testing Authorities, Australia
RTA	Roads and Traffic Authority of New South Wales, Australia
UNSW	University of New South Wales

APP 2.2.4 Definitions

The following definitions shall apply to this Specification:-

(a) **Cement.** Material complying with AS 3972. It comprises Portland cement and Blended cements.

(b) **Concrete.** A thoroughly mixed combination of cement, aggregates and water, with or without the addition of chemical admixtures or other materials, all of which separately and when combined comply with the requirements of this Specification.

(c) **Cement Mortar.** A mixture of cement, water and fine aggregate, with or without the addition of chemical admixtures or other materials, proportioned to produce a plastic mixture without segregation of the constituents, all of which separately and when combined comply with the requirements of this Specification, with a compressive strength at 28 days not less than 40 MPa at bearings and expansion joints, and 32 MPa elsewhere.

(d) **Grout.** A mixture of cement and water, with or without the addition of fine sand or chemical admixtures or other materials, proportioned to produce a pourable liquid without segregation of the constituents, all of which separately and when combined comply with the requirements of this Specification with a compressive strength at 28 days not less than 32 MPa.

(e) **Curing.** The control of temperature and moisture in the concrete until the concrete has developed required properties.

(f) **Standard Moist Curing.** Standard Moist Curing as defined in AS 1012, Part 8.

(g) **Wet Curing.** Curing at ambient temperature in which the concrete surface is effectively covered with water or placed in a fog room/chamber with a relative humidity exceeding 98 %.

(h) **Sealed Curing.** Curing at ambient temperature in which the concrete surface is sealed by at least two coats of curing compounds conforming to this Specification, or in which the concrete surface is sealed by the retention in place of impermeable forms.

(i) **Heat Accelerated Curing.** Curing at mechanically elevated concrete temperatures not exceeding 80 ^{o}C in which the concrete surface is protected against immature drying. Steam curing at atmospheric pressure is typical heat accelerated curing. Steam curing at high pressure (autoclaving) is excluded from this definition.

APP 2.3 MATERIALS FOR CONCRETE, CEMENT MORTAR AND GROUT

APP 2.3.1 General

Materials for concrete, cement mortar and grout shall comply with Section 2 of AS 1379 and with the additional requirements of Clause 2 of this Specification.

APP 2.3.2 Cement

APP 2.3.2.1 General

All Portland cement and Blended cement constituents shall be from a source included in the New South Wales Government Concrete Quality Assurance Scheme applicable to the period covered by the Contract.

If the Contractor intends to use cement which has been stored on site, the cement shall be re-tested to ensure its compliance with this Specification before it is used in the Works.

APP 2.3.2.2 Portland Cement

Portland cement shall be Type SL Shrinkage Limited Cement, complying with AS 3972, and shall have an autoclave expansion, as determined by ASTM Method C151, less than 0.8%.

APP 2.3.2.3 Blended Cement

Blended cement shall be Type GB General Purpose Blended Cement, complying with AS 3972 and the additional requirements of this Specification.

Supplementary cementitous materials (SCM) Fly Ash, Slag and Silica Fume shall comply with AS 3582 Parts 1, 2 and 3 respectively. Grades and/or relative water requirement and relative strength requirements shall be in accordance with Table UNSW80.1.

Blended cement shall contain Portland cement and one SCM (binary Blended cement) or two SCMs (triple Blended cement) within the ranges shown in Table UNSW80.2.

Blending of cement shall be achieved either at the cement manufacturer's facilities and/or at the concrete batching plant except for cements containing silica fume, where blending shall be carried out only at the cement manufacturer's facilities.

Table UNSW80.1 : SCM Grades, Relative Water Requirement and Relative Strength

SCM	Grade	Relative Water Requirement		Relative Strength at 28 Days	
		Maximum %	Limits of Deviation %	Minimum %	Limits of Deviation %
Slag	N/A	100	± 3	90	± 5
Fly Ash	Fine	95	± 3	95	± 5
Silica Fume	N/A	100	± 5	100	± 5

Notes :

1. The reference cement used in the determination of relative water requirement and relative strength shall be Portland cement with a minimum compressive strength at 28 days of 35 MPa and an equivalent alkali content within the range 0.6% to 1.0 %.

2. In the case of slurried or densified silica fume, tests shall be carried out on the raw silica fume from which these products have been made.

Table UNSW80.2 : Range of SCMs in Blended Cement

SCM	Binary Blended Cement		Triple Blended Cement	
	Minimum %	Maximum %	Minimum %	Maximum %
Fly Ash	25	40	20	25
Slag	60	75	40	50
Silica Fume	7	8	5	7

APP 2.3.3 Admixtures

APP 2.3.3.1 2.3.1 General Requirement

Chemical admixtures and their use shall comply with AS 1478. Admixtures shall not contain calcium chloride. Where two or more admixtures are proposed for incorporation into a concrete mix, their compatibility shall be certified by the manufacturers. The Contractor shall also submit details of the requirements for mixing the admixtures. An air entraining agent shall be added when specified in the Drawings or elsewhere in the Contract documents.

APP 2.3.4 2.4 Aggregates

APP 2.3.4.1 General

All aggregates used in the works shall comply with AS 2758.1.

For the purposes of this Specification, the exposure classification of AS 2758.1 shall correspond to Table UNSW80.3.

Table UNSW80.3 - Corresponding Exposure Classification of AS 2758.1

Exposure classification in Drawings	Exposure classification AS 2758.1
A1, A2, B1 and B2	Moderate

APP 2.3.4.2 Additional Requirements for Coarse Aggregate

(a) Lightweight coarse aggregate shall not be used.

(b) Coarse aggregate with nominal sizes of 20, 14 and 10 mm only shall be used.

(c) Coarse aggregate shall comply with the dimensional requirements of AS 2758.1 except that Table UNSW80.4 and Table UNSW80.5 of this Specification shall be applied in lieu of Table 1 and Table 2 of AS 2758.1, respectively.

Where more than one type of coarse aggregate is proposed for use in one mix, the resulting blend shall comply with dimensional requirements of the preceding paragraph.

(d) Water absorption shall be limited to a maximum of 2.5% except for slag aggregate where the maximum limit shall be 6%.

(e) Wet strength and wet/dry strength variation tests shall be used for aggregate durability assessment in accordance with AS 2758.1 with 'duplicate testing' being carried out in accordance with AS1141.22.

(f) Coarse aggregate shall comply with the requirements of Clause 2.5.

Table UNSW80.4 - Coarse Aggregate - Grading Requirements

Sieve aperture	Mass of sample passing, percent		
	Nominal size of aggregate, mm		
	20	14	10
26.5 mm	100	-	-
19.0 mm	85 - 100	100	-
13.2 mm	-	85 - 100	100
9.5 mm	25 - 55	-	85 - 100
6.7 mm	-	25 - 55	-
4.75 mm	0 - 10	-	0 - 20
2.36 mm	0 - 5	0 - 10	0 - 5

Table UNSW80.5 - Coarse Aggregate - Limits of Deviation

Sieve aperture	Limits of deviation, percent		
	Nominal size of aggregate, mm		
	20	14	10
26.5 mm	-	-	-
19.0 mm	± 5	-	-
13.2 mm	± 10	± 10	-
9.5 mm	± 10	± 10	± 10
6.7 mm	-	± 10	± 10
4.75 mm	± 5	± 5	± 10
2.36 mm	-	-	-

APP 2.3.4.3 Additional Requirements for Fine Aggregate

(a) Fine aggregate shall comply with the dimensional requirements of AS 2758.1 except that Table UNSW80.6 of this Specification shall be applied in lieu of Table 3 of AS 2758.1.

Where more than one type of fine aggregate is proposed for use in the mix, the resulting blend shall comply with dimensional requirements of the preceding paragraph.

(b) Water absorption shall be limited to a maximum of 2.5%.

(c) Fine aggregate shall comply with the requirements of Clause 2.5.

Table UNSW80.6 - Fine Aggregate - Grading Requirements and Limits of Deviation

Sieve aperture	Mass of sample passing, percent	Maximum deviation, percent
9.5 mm	100	-
4.75 mm	90 - 100	± 3
2.36 mm	65 - 95	± 10
1.18 mm	40 - 85	± 10
600 μm	24 - 60	± 10
300 μm	8 - 25	± 5
150 μm	1 - 8	± 2

APP 2.3.5 2.5 ALKALI-AGGREGATE REACTION (AAR)

APP 2.3.5.1 General

All aggregates intended for use in concrete to be incorporated into the Works shall be :

- petrographically examined in accordance with Clause 2.5.2, and
- assessed and classified for AAR using either the accelerated test method or the concrete prism test method, in accordance with RTA T363 and RTA T364, respectively.

Actions required for control of AAR shall be in accordance with Clause 2.5.3.

APP 2.3.5.2 Petrographic Examination

Petrographic examination shall be in accordance with ASTM C295. The Contractor may wish to eliminate without further testing those aggregates containing obviously reactive components such as :

- Opaline material even in very small amounts
- Unstable silica minerals such as moderate amounts of tridymite and cristobalite
- Sheared rock containing moderate amounts of strained quartz and microcrystalline quartz

APP 2.3.5.3 Actions Required for Control of AAR

For aggregates classified as non reactive by either the accelerated test method or the concrete prism test method, no action is required.

For other aggregate classifications, actions required for control of AAR shall be in accordance with UNSW80.7 and /or Table UNSW80.8 depending on the test method used for the classification.

Note : Blended cement referred to in Tables UNSW80.7 and UNSW80.8 shall exclude binary blends of cement containing silica fume.

Table UNSW80.7 - Actions Required for Control of AAR - Classification of Aggregate Using Accelerated Test Method

Concrete Exposure Classification	Aggregate Classification	Actions Required
A1 and A2	Mild/Slow AAR	Limit total alkali * in the mix to less than or equal to 2.8 kg/m^3 **or** use Blended cement
	Substantial AAR	Use Blended cement
B1 and B2	Mild/Slow AAR	Use Blended cement
	Substantial AAR	Use an alternative aggregate, **or** use Blended cement and assess aggregate/cement combination using the concrete prism test

* Total alkali is defined as the available alkali content of the cement and other sources expressed as Na_2O equivalent (calculated as the sum of Na_2O and 0.658 K_2O).

Table UNSW80.8 - Actions Required for Control of AAR - Classification of Aggregate Using Concrete Prism Test Method

Concrete Exposure Classification	Aggregate Classification	Actions Required
A1, A2, B1 and B2	Reactive (for concrete prisms made using Portland cement only)	Use an alternative aggregate, **or** use Blended cement and reassess aggregate/cement combination using concrete prism test
	Reactive (for concrete prisms made using Blended cement)	Use an alternative aggregate

APP 2.3.6 2.6 Soluble Salts

Sulphate and chloride ion contents shall be determined by testing of hardened concrete in accordance with AS 1012 Method 20.

The sulphate content of concrete as placed, expressed as the percentage by mass of acid-soluble SO_3 to cement, shall not be greater than 5%.

The mass of acid-soluble chloride ion per unit volume of concrete as placed shall not exceed the values given in Table UNSW80.9.

Table UNSW80.9 - Maximum Values of Acid-Soluble Chloride-Ion Content in Concrete

Exposure classification	Maximum acid-soluble chloride ion content, kg/m^3			
	Type of construction material			
	Unreinforced concrete	Reinforced concrete	Prestressed concrete	Grout
A1 and A2	0.8	0.8	0.4	0.3
B1	0.8	0.4	0.4	0.3
B2	0.8	0.3	0.3	0.3

Note : Chloride ion content may be expressed in percentage weight of oven dried concrete. ($0.1\ kg/m^3$ ion content is approximately equivalent to 0.004% by weight of oven dried concrete)

APP 2.4 DESIGN OF CONCRETE MIXES

APP 2.4.1 General

The Contractor shall ensure that the concrete mix is designed in accordance with the requirements of this Specification. The mix design shall be based on the anticipated conditions which will prevail on site so that under these conditions, concrete of the specified durability, as well as the specified strength, will be produced.

APP 2.4.2 Requirements for Durability

For the exposure classifications specified in the Drawings, the minimum cement content, maximum water/cement ratio, compressive strength and curing regime of concrete shall be in accordance with Annexure UNSW80/2.

For exposure classifications A1, A2 and B1, concrete made with any Blended cement shall contain a minimum of $230\ kg/m^3$ of Portland cement complying with AS 3972.

For exposure classifications A1, A2 and B1, concrete made with Blended cement containing silica fume shall not be used.

For concrete slabs in any exposure classification, concrete made with Blended cement containing silica fume shall not be used.

APP 2.4.3 Target Strength for Mix Design

The concrete mix shall be designed to achieve a target strength $f_{c.md}$ such that:-

$$\mathbf{f_{c.md} \geq f_{c.min} + M_{control}}$$

where $M_{control}$ is the margin nominated by the Contractor for variations in strength as defined in Clause 4.1 and $f_{c.min}$ is the greater of $f_{c.min(s)}$ and $f_{c.min(d)}$ where:-

(a) $f_{c.min(s)}$ is the specified minimum 28 day compressive strength for structural purposes as stated in the Drawings, or elsewhere in the Specification; and

(b) $f_{c.min(d)}$ is the minimum 28 day compressive strength required for durability obtained from Annexure UNSW80/2.

APP 2.4.4 Limitations on the maximum nominated slump

Unless otherwise specified in the Drawings, or approved by the Superintendent, the concrete slump of the nominated mix (nominated slump) shall not exceed 200 mm.

APP 2.4.5 Limitations on the Maximum Compressive Strength

Unless otherwise specified in the Drawings or approved by the Superintendent, the concrete compressive strength (at 28 days) of the nominated mix shall not exceed 80 MPa.

APP 2.4.6 Limitations on Shrinkage

The shrinkage of concrete specimens made from the nominated mix shall be prepared and measured in accordance with AS 1012.13.

Shrinkage of the concrete specimen after either 3 or 8 weeks drying period shall comply with the requirements of Table UNSW80.10. Results need not comply with the limits for both drying periods.

Table UNSW80.10 - Maximum Shrinkage Strain of Nominated Concrete Specimens

Exposure classification	Maximum shrinkage strain, microstrain	
	Drying period	
	3 Weeks	8 Weeks
A1 and A2	570	800
B1 and B2	500	700

APP 2.4.7 Submission of Nominated Mixes

The Contractor shall submit to the Superintendent for approval the details of each concrete mix and the proposed curing regime.

The submission shall include the following details:-

(a) Material Constituents

(i) Source.

(ii) Current test results not more than 12 months old for characteristics and properties specified in Clause 2.

(iii) Method of controlling alkali-aggregate reaction as specified in Clause 2.5.

(b) Mix Design

(i) Constituent quantities.

(ii) Nominated water/cement ratio.

(iii) Condition of constituents used in the mix design eg moisture condition of aggregates.

(iv) $f_{c.md}$, $f_{c.min}$, $f_{c.min(s)}$ and $f_{c.min(d)}$ determined in accordance with Clause 3.3.

(v) Trial mix slump and corresponding nominated slump.

(vi) For concrete containing superplasticiser: initial and final slump, and reversion time.

(vii) For concrete containing superplasticiser and where initial slump is impractical to measure due to low water/cement ratio : method of controlling and verifying the total amount of water in the mix.

(c) Batching, Mixing and Transport

(i) Methods.

(ii) Level of control and accuracy of batching.

(iii) Level of control and accuracy of determination of the aggregate moisture content.

(iv) Method of determination of $M_{control}$.

(v) Minimum mixing time (prior to and after the addition of the superplasticiser where applicable).

(d) Curing regime

(i) Method.

(ii) Anticipated minimum field temperatures during the curing period.

(e) Other Test Results for Hardened Concrete Characteristics

(i) 28 day compressive strength in accordance with AS 1012.

(ii) Shrinkage in accordance with AS 1012.

(iii) Sulphate and chloride ion contents in accordance with Clause 2.6 when the method of testing hardened concrete is used.

(iv) Trial mix report in accordance with AS 1012.2.

Test results for hardened concrete characteristics shall be based on a trial mix prepared in accordance with AS 1012.2 using the proposed materials and mix proportions, including all admixtures, batched at the highest water/cement ratio conforming to the allowable slump range specified for the nominated mix and allowing for batching tolerances and anticipated variations in aggregate moisture content.

APP 2.4.8 Variation to Nominated Mixes

The Contractor may, subject to the following, vary the quantities of the constituents in a nominated mix to improve the concrete quality without re-submitting new concrete mix details. Maximum variations to the nominated mix quantities shall be as follows:

(a) Cement: 3% by mass of each constituent .

(b) Aggregates: 5% by mass of each constituent.

(c) Water: 3% by mass.

(d) Admixture: 50% by mass of each admixture and within the manufacturer's recommendations.

The Contractor shall notify the Superintendent of such variations to a nominated mix before commencing production with the varied quantities.

Notwithstanding the above provisions, the varied concrete mix shall:

(a) not have a water/cement ratio exceeding that nominated under Clause 3.7;

(b) comply with the requirements of Clause 3.2 for minimum cement content and maximum water/cement ratio; and

(c) comply with the requirements of Clauses 2.2.3 for slag, fly ash and silica fume contents in Blended cements.

If the Contractor wishes to vary the quantities of the constituents in excess of the above amounts, or wishes to change the type or source of supply of any constituent, or vary the curing regime, the Contractor shall submit a new nominated mix in accordance with Clause 3.7, unless otherwise approved by the Superintendent.

APP 2.5 SUPPLY AND DELIVERY OF CONCRETE

APP 2.5.1 General

Concrete shall be produced and delivered to the site of the Works or to the precasting yard in accordance with the requirements of AS 1379 and the additional requirements of this Specification.

All concrete for use in the Works shall be classified as Special Class and designated "**S**" in accordance with Clause 1.5 of AS 1379. Project assessment shall be used.

The Contractor shall nominate a margin for strength which shall be consistent with the nominated method of production assessment under which the plant operates. This margin for strength, referred to in this Specification as $M_{control}$, shall be the measure of the level of control for the nominated plant producing the nominated mix.

APP 2.5.2 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, either by a moisture meter or by methods set out in AS 1141. Corresponding corrections shall be made to the mass of all aggregates and the volume of water used in the mix.

APP 2.5.3 Additional Requirements for Mixing

APP 2.5.4 Equipment

Continuous mixers shall not be used.

APP 2.5.5 Discharging of Mixer

The entire contents of the mixer shall be discharged before charging it with a new batch.

APP 2.5.6 Maximum Mixing Time

Where by reason of delay it is necessary to hold a batch in the mixer, mixing may be continued for a maximum of ten minutes except for split drum mixers where the maximum shall be five minutes.

For longer delays the batch may be held in the mixer and turned over at regular intervals, subject to the time limits specified for incorporation of the concrete into the work not being exceeded.

APP 2.5.7 Delivery

Concrete mixed at a remote central mixing plant shall be transported to the point of discharge by truck-mounted drum mixers complying with the requirements of AS 1379 and this Specification. On completion of mixing, the concrete shall be continuously agitated until it is fully discharged. The agitation speed shall be as specified by the manufacturer of the equipment.

APP 2.5.8 Period for Completion of Discharge

Concrete shall be placed and compacted within 1.5 hours from the addition of the cement to the aggregates. Nonetheless, concrete shall not be incorporated into the Works if its consistence is outside the specified limits.

APP 2.6 CONSISTENCE

The consistence of the concrete shall be checked using the slump cone in accordance with AS 1379 except for the frequency of sampling which shall be in accordance with Annexure UNSW80/1 of this Specification.

For batches produced with a high level of control, the Superintendent may accept proposals for a reduced frequency of consistence checking compared to Annexure UNSW80/1 provided the proposals demonstrate that the appropriate high level of control is being achieved during production.

For concrete containing a superplasticiser, tolerances on both initial and final slumps (i.e. before and after addition of the superplasticiser) shall comply with Table 5 of AS 1379. When measurement of the initial slump is impractical due to a low water/cement ratio, the Contractor shall provide other means of controlling and verifying the total amount of water in the mix.

If the measured slump is not within the specified limits, one repeat test shall be made immediately from another portion of the same sample. If the value obtained from the repeat test falls within the specified limits, the concrete represented by the sample shall be deemed to comply with the appropriate specified value, otherwise it shall be rejected.

The consistence of the concrete shall be checked and recorded within 30 minutes of adding cement to the aggregate. The consistence shall also be checked and recorded immediately prior to discharge when the actual haul time exceeds 45 minutes and/or when water is added to a mixed batch in accordance with Clause 4.5.

APP 2.7 ADDITION OF WATER TO A MIXED BATCH

Prior to the commencement of discharge, water may be added to a mixed batch providing the following conditions are satisfied:-

(a) Less than 45 minutes have elapsed since cement was added to the aggregate.

(b) Immediately after the addition of any water, the mixing mechanism shall be operated at mixing speed for a time equivalent to at least 30 revolutions of the mechanism, and for such additional time as may be necessary to re-establish uniformity of the mix.

(c) The quantity of water added shall not be more than 4 kg/m^3 and shall be such that the nominated water/cement ratio is not exceeded.

(d) The quantity of water added shall be measured and recorded.

(e) The consistence of the concrete is checked after the water has been added, in accordance with Clause 4.4.

Once discharge of a batch has commenced, no further water shall be added to that batch.

APP 2.8 TEMPERATURE AT POINT OF DELIVERY

Concrete shall not be used if its temperature at the point of discharge from transport vehicles is less than 10^{o}C or more than 32^{o}C except for precast concrete elements where the minimum and maximum concrete temperatures shall be 5^{o}C and 35^{o}C respectively.

APP 2.9 CURING OF CONCRETE

APP 2.9.1 General

For all types of curing regimes, the concrete surface shall be maintained at a temperature not less than 5^{o}C throughout the curing period.

APP 2.9.2 Minimum Formwork Stripping Times

Unless otherwise specified, the minimum stripping time for the formwork shall be the longest of the times governed by curing requirements in accordance with Clause 3.2, and the times required to achieve the following concrete compressive strength:

for vertical surfaces:	7 MPa ;
for underside of horizontal surfaces:	80 % of $f_{c.min(s)}$; and
for other surfaces:	a compressive strength as approved by the Superintendent

The concrete compressive strength shall be determined either by testing of representative test cylinders cured under same conditions as the concrete in question, or by other approved means.

APP 2.9.3 Wet Curing

Concrete may be covered by canvas, hessian or plastic sheets or other suitable materials provided it is kept continually wet. Water used for curing shall comply with AS 1379.

Wet curing shall be applied to unformed surfaces immediately after the completion of all finishing operations. Wet curing shall be applied in such a manner that staining of the formed surfaces does not produce a nonconforming finish.

Wet curing shall be applied to formed surfaces immediately after the removal of the forms.

APP 2.9.4 Sealed Curing

2.9.4.1.1 Retention of Formwork

All parts of the formwork used under the sealed curing provision shall be kept in place for the minimum periods determined in accordance with Clause 5.1.1. Where it is proposed to strip part of or all the formwork before the required period is completed, a curing compound or wet curing shall be applied to the stripped components for the remainder of the curing period.

2.9.4.1.2 Curing Compounds

Curing compounds shall comply with the requirements of AS 3799 for the classes and types specified in

Table UNSW80.11.

Table UNSW80.11 - Classes and Types of Curing Compounds

Description of curing compound	Class (to AS 3799)	Type (to AS 3799)
Wax-based compounds (Wax emulsion)	A	1-D
Resin-based compounds (Hydrocarbon resin)	B	
Synthetic rubber-based compounds (Chlorinated rubber)	C	
Water-borne compounds	Z	

The curing compound supplier shall implement and maintain a quality system in accordance with AS/NZS ISO 9002 or AS 3902, as a means of ensuring that the product conforms to the Specification requirements.

For each curing compound proposed for use in the Works, the Contractor shall provide to the Superintendent a Certificate of Compliance from the supplier, supported by test certificates from a laboratory with appropriate NATA registration, certifying that the curing compound complies with this Specification.

This Certificate of Compliance shall relate only to the formulation on which the tests were made and shall be valid for not more than three years from the date of issue. The test certificates shall report the non-volatile content, the efficiency index and the density and shall provide a reference for the infrared spectrum as determined in accordance with RTA T1005.

For each batch delivered, the Contractor shall provide to the Superintendent a Certificate of Uniformity from the supplier, supported by uniformity testing on both non-volatile content and density in accordance with AS 3799 Clause 3.2, and on viscosity in accordance with AS 3799 Clause 3.1.5. Additionally, an infrared spectrum shall be provided and shall match the abovementioned reference infrared spectrum. The Certificate of Uniformity shall state that the same formulation has been used for the batch as is represented by the Certificate of Compliance.

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

The use of wax emulsion shall not be permitted on slabs.

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

The curing compound shall be applied using a fine spray at the rate stated on the certificate of compliance, or at a rate of 0.2 litres/m^2 per coat, whichever is the greater. The application rate shall be checked by calculating the amount of curing compound falling on felt mats, each approximately 0.25 m^2 in area, placed on the concrete surface.

Two coats shall be applied at the full rate.

For chlorinated rubber curing compound the second coat shall be applied between ¼ hour and 1 hour after the first coat. For other curing compounds, the time between the first and

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

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

The curing membrane shall be maintained intact after its initial application, for the period determined in accordance with Clause 3.2. Any damage to the curing membrane due to the Contractor's or others' activities shall be made good by respraying of the affected areas.

APP 2.9.4.2 Heat Accelerated Curing

2.9.4.2.1 General

Heat accelerated curing, as defined in Clause 1.4, shall comply with the following conditions:-

(a) The duration of the presetting period (i.e. the interval between placing the last concrete and commencement of heat application) shall be not less than two hours or longer than five hours.

(b) Unformed exposed concrete surfaces shall be kept wet with a relative humidity exceeding 98 % at all times after the presetting period and until the completion of the heat curing.

(c) The rate at which the temperature of the concrete increases shall not exceed $24^{o}C$ per hour.

(d) The maximum temperature of the concrete during the application of heat shall not exceed $80^{o}C$.

(e) After completion of curing, the concrete shall be allowed to cool gradually and evenly. The concrete shall not be exposed to the surrounding environment or operated on in any way until the temperature at the surface of the concrete has fallen to within $40^{o}C$ of the ambient temperature.

(f) The maximum and minimum temperatures occurring, and the variation of temperature with time, shall be recorded using a suitable thermograph.

2.9.4.2.2 Steam Curing - Additional requirements

Distribution pipes shall be used to assist in the uniform distribution of heat. The distribution pipes shall be arranged in such a manner and/or the concrete members shall be protected in such a way that steam will not be blown directly against the concrete, or cause uneven heating of the members at any point.

The enclosing arrangements shall be kept sufficiently airtight during the whole period of steam curing to prevent the entry of cool air at any time.

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

2.9.4.2.3 Concrete Cracking

At the completion of the curing period the concrete shall have no cracks of width greater than 0.1 mm, measured at the concrete surface.

APP 2.9.5 Annexure - Minimum Frequency of Testing

Clause	Characteristic Analysed	Test Method	Minimum Frequency of Testing
Supply And Delivery Of Concrete			
2.4.2 (c)	Grading of coarse aggregate - deviation from nominated grading	AS 1141.11	One per quarter
2.4.3 (a)	Grading of fine aggregate - deviation from nominated grading	AS 1141.11	One per quarter
4.4	Consistence*	AS 1012.3 Method 1	One per batch

* For concrete containing a superplasticiser, requirements for test method and minimum frequency of testing shall be applied to both initial and final slump.

APP 2.9.6 Annexure - Concrete Mix Design Requirements

APP 2.9.6.1 Wet Curing

For the exposure classifications specified in the Drawings, the wet curing period, the minimum cement content, maximum water/cement ratio and the minimum compressive strength for durability shall be in accordance with Table UNSW80/2.1.

For formed surfaces, this provision shall only apply when formwork is removed within 48 hours of completion of concrete placement followed by immediate application of wet curing.

Table UNSW80/2.1 - Wet Curing Requirements

Exposure classification	**Curing period requirement (days)**			**Other requirements**		
	Portland cement PC	Blended cement containing BFS and/or FA	Blended cement containing SF	Minimum cement content (kg/m^3)	Maximum w/c ratio (by mass)	Minimum strength for durability $f_{c.min(d)}$ (MPa)
A1 and A2	7	7	N/A	-	0.56	25
B1	7	7	N/A	320	0.50	32
B2	N/A	14	7	390	0.46	40

Notes:
- PC denotes Portland cement in accordance with this Specification
- BFS denotes blast furnace slag in accordance with this Specification
- FA denotes fly ash in accordance with this Specification
- SF denotes silica fume in accordance with this Specification
- w/c denotes total water to total cement ratio
- N/A Not applicable. This combination is not permitted under this Specification

APP 2.9.6.2 Sealed Curing

For the exposure classifications specified in the Drawings, the sealed curing period, the minimum cement content, the maximum water/cement ratio and the minimum compressive strength for durability shall be in accordance with Table UNSW80/2.2.

Table UNSW80/2.2 - Sealed Curing Requirement

Exposure classification	Curing period requirement (days)			Other requirements		
	Portland cement PC	Blended cement containing BFS	Blended cement containing FA	Minimum cement content (kg/m^3)	Maximum w/c ratio (by mass)	Minimum strength for durability $f_{c.min(d)}$ (MPa)
A1 and A2	7	7	7	320	0.50	32
B1	7	7	7	390	0.46	40
B2	N/A	N/A	N/A	450	0.40	50

Notes: PC denotes Portland cement in accordance with this Specification
BFS denotes blast furnace slag in accordance with this Specification
FA denotes fly ash in accordance with this Specification
w/c denotes total water to total cement ratio
N/A Not applicable. Durability Provision B shall not apply for this case.

APP 2.9.6.3 Heat Accelerated Curing

For the exposure classifications specified in the Drawings, the application of heat accelerated curing, the minimum cement content, the maximum water/cement ratio and the minimum compressive strength for durability shall be in accordance with Table UNSW80/2.3.

In addition to the requirements of Clause 5.11.4, the concrete shall be kept at a temperature, T (^{o}C) not less than 60 ^{o}C, for a period, P (hours), so that the result of the multiplication P x T shall be not less than 350 ^{o}C.hours.

Table UNSW80/2.3 - Heat Accelerated Curing Requirements

Exposure classification	Curing requirement			Other requirements		
	Portland cement PC	Blended cement containing BFS	Blended cement containing FA	Minimum cement content (kg/m^3)	Maximum w/c ratio (by mass)	Minimum strength for durability $f_{c.min(d)}$ (MPa)
A1 and A2	√	√	√	320	0.50	32
B1	√	√	√	390	0.46	40
B2	N/A	√	√	450	0.40	50

Notes: PC denotes Portland cement in accordance with this Specification
BFS denotes blast furnace slag in accordance with this Specification
FA denotes fly ash in accordance with this Specification
w/c denotes total water to total cement ratio
N/A Not applicable. Durability Provision B shall not apply for this case.
√ Applicable. Durability Provision B may be applied for this case.