

## SECTION 610 - STRUCTURAL CONCRETE

~~##This section cross-references Sections 175, 204, 606, 611, 613, 614, 680, 684, 686, 687, 689, 691, 703 and 801.~~

~~If any of the above sections are relevant, they should be included in the specification.~~

~~If any of the above sections are not included in the specification, all references to those sections should be struck out, ensuring that the remaining text is still coherent.~~

### 610.01 GENERAL

This section specifies the requirements for durability, strength and surface finish for structural concrete including the requirements for mix design, supply and delivery of concrete, sampling and testing, placing, compaction, finishing, curing and protection.

Additional requirements for concrete for post-tensioned, pre-tensioned, precast, sprayed concrete and other types of concrete construction are specified in the relevant sections. Requirements for general non-structural concrete paving Works are specified in Section 703.

Concrete using general purpose portland cement Type GP or blended cement Type GB shall comply with the requirements of AS 3972 *General purpose and blended cements*. In addition, blended cement Type GB shall consist of a specified minimum quantity of portland cement in combination with any one or two of Ground Granulated Blast Furnace Slag (Slag), Fly Ash (FA) or Amorphous Silica (AS) and as specified in this section.

All concrete shall be special class performance concrete in accordance with Appendix B of AS 1379 *Specification and Supply of Concrete* and the requirements of this section.

Structural concrete shall be designed and constructed in accordance with the requirements of this specification to prevent the occurrence of nonconforming drying shrinkage and cracking, alkali-aggregate reactivity, soluble salts, inadequate cover, curing and compaction and to provide the required protection against exposure to the specified in-service conditions.

### 610.02 STANDARDS

Australian Standards and VicRoads Codes of Practices are referenced in an abbreviated form (e.g. AS 1379 and RC 500.00).

#### (a) Australian Standards

AS 1012	Methods of testing concrete
AS 1141	Methods of sampling and testing aggregates
AS 1379	Specification and supply of concrete
AS 1478	Chemical admixtures for concrete, mortar and grout – Admixtures for concrete
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 3582	Supplementary cementitious materials for use with portland and blended cement
AS 3582.1	Part 1 : Fly ash
AS 3582.2	Part 2 : Slag - Ground granulated iron blast-furnace
AS 3582.3	Part 3 : Amorphous silica
AS 3799	Liquid membrane-forming curing compounds for concrete
AS 3972	General purpose and blended cements
AS 5100	Bridge Design

#### (b) VicRoads Codes of Practices

Code of Practice RC 500.00 Code of Practice for Source Rock Investigations.

Code of Practice RC 500.16 Code of Practice for Selection of Test Methods for the Testing of Materials and Work.

## (c) VicRoads Test Methods

RC 253.01 Determination of aggregate moisture content and estimated free water (using microwave or hot plate)

RC 376.03 Accelerated Mortar Bar Test - Alkali-Silica reactivity of aggregate

RC 376.04 Alkali Aggregate Reactivity Assessment - using the Concrete Prism Test.

## (d) Additional Test Methods

ASTM C295/C295M Standard Guide for Petrographic Examination of Aggregates for Concrete.

## (e) Additional Referenced Specifications

ATIC-SPEC SP43 – Cementitious Materials for Concrete published by ATIC (Australian Technical Infrastructure Committee)

Section 175 details the relevant references to these documents.

**610.03 DEFINITIONS**

**Batch:** One load or charge of a transit concrete mixer or agitator.

**Blended Cement:** General purpose blended cement Type GB complying with the requirements of AS 3972 and as specified in this section.

**Cement:** Material complying with the requirements of AS 3972 and as specified in this section.

**Cementitious Material:** Portland cement or a mixture of portland cement with one or more supplementary cementitious materials **or in combination with other supplementary material as approved by the Superintendent Council.**

**Concrete Cover:** Distance between the outside of the reinforcing steel and the nearest permanent surface of the concrete member excluding any surface finishing material.

**Water/Cementitious Material (W/C) Ratio:** The ratio of the amount of water to the total amount of cementitious materials by mass in a freshly mixed cubic metre of concrete. The water shall be the total free water contained in the batch aggregates in excess of their saturated surface-dry condition.

**Concrete Grade:** A grade of concrete with a specified minimum cementitious material content, a maximum W/C ratio and a minimum compressive strength at 3, 7 and 28 days. It is designated by the letters VR (VicRoads) followed by a three digit number indicating the minimum cementitious material content in kg/m<sup>3</sup> and a two digit number indicating the specified minimum compressive strength at 28 days.

**Exposure Classifications:** Designation indicative of the most severe environment to which a concrete member is to be subjected during its design life, in accordance with the exposure classifications A, B1, B2, C1, C2 and U, as stated in Table 4.3 of AS 5100.5, and which are used to determine the concrete quality requirements.

**Intense compaction:** Compaction of the fresh concrete using external vibrators attached to steel forms in conjunction with the use of internal vibrators.

**Marine and other saline environments:** Environmental exposure of surfaces of concrete members exposed to sea water, brackish water, coastal zone and saline soils as represented by the relevant exposure classifications B2, C1 and C2 in accordance with Table 4.3 of AS 5100.5.

**Portland Cement:** General purpose portland cement Type GP complying with the requirements of AS 3972.

**Sample:** A portion of fresh concrete drawn from a batch and from which test cylinders and other test specimens are made, and from which other concrete testing is undertaken as required. All sampling is carried out in accordance with AS 1012.

**Self Compacting Concrete (SCC):** Concrete that is able to flow and consolidate under its own weight, completely fill the formwork or bore hole even in the presence of dense reinforcement, whilst maintaining homogeneity and without the need for additional compaction, and which complies with the requirements of Table 610.131. Also called self-consolidating concrete or super-workable concrete.

**Standard compaction:** Compaction of the fresh concrete using internal vibrators with or without the use of vibrating screeds as specified.

**Supplementary Cementitious Material:** Fly Ash (FA), Ground Granulated Blast Furnace Slag (Slag), or Amorphous Silica (AS) complying with the requirements of AS 3582.1, AS 3582.2 and AS 3582.3 respectively.

**Triple Blend:** Blended cement Type GB consisting of a minimum quantity of portland cement in combination with any two Supplementary Cementitious Materials (i.e. any two of Fly Ash, Slag or Amorphous Silica).

**VPV:** % Apparent Volume of Permeable Voids as determined by test method AS 1012.21.

**610.04 DURABILITY**

Durability requirements with respect to exposure classification as detailed in AS 5100.5 Bridge design – Concrete and concrete grade shall be as shown on the drawings and as specified in this section.

The durability requirements for concrete in exposure classification U shall be as shown on the drawings and this specification.

The concrete shall be designed, manufactured and delivered, sampled and tested, placed, compacted, finished and cured in accordance with the requirements of this section to achieve a service life of at least 100 years in the specified in-service exposure conditions with minimal maintenance.

**610.05 MINIMUM COMPRESSIVE STRENGTH**

The minimum compressive strength requirements for each concrete grade are shown in Table 610.051.

**Table 610.051**

Concrete Grade	Minimum Compressive Strength (MPa)		
	3 days	7 days	28 days
VR330/32	14	20	32
VR400/40	17	26	40
VR450/50	23	35	50
VR470/55	25	40	55
VR520/60	27	45	60
VR535/65	29	48	65
VR550/70	31	52	70
VR580/80	34	60	80
VR610/90	38	67	90
VR640/100	42	75	100

The 3 day minimum compressive strength requirement shall not apply to concrete mixes containing supplementary cementitious materials which exceed the cement replacement values stated in clause 610.07(f).

**610.06 MAXIMUM VPV VALUES AT 28 DAYS**

The maximum VPV values at 28 days for each concrete grade for both test cylinders and concrete test cores cut from cast in situ and sprayed concrete shall be as shown in Table 610.061.

**Table 610.061**

Concrete Grade	Maximum VPV Values at 28 days (%)		
	Test Cylinders (compacted by vibration)	Test Cylinders (compacted by rodding)	Test Cores
VR330/32	14	15	17
VR400/40	13	14	16
VR450/50	12	13	15
VR470/55	11	12	14
VR520/60	11	12	14
VR535/65	10	11	13
VR550/70	10	11	13
VR580/80	9	10	12
VR610/90	9	10	12
VR640/100	9	10	12

For the purpose of satisfying the requirements of this clause, VPV test results may be rounded down to the nearest whole number for the corresponding concrete grade.

**610.07 CONCRETE MIX DESIGN**

(a) General

The Contractor shall be responsible for the mix design of all concrete, including any other nominated requirements, so that the specified durability, strength and other requirements of the hardened and plastic concrete are achieved.

The Contractor shall ensure that arrangements for the supply of concrete are made with the concrete supplier at the commencement of the Works, to ensure that a fully compliant concrete mix design which is supported with all required test results meets the specified time frames of this section.

(b) Mix Design Details

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**The Contractor shall submit the concrete mix design details for review by the Superintendent Council not less than 4 weeks prior to the placement of concrete. Concrete shall not be placed until the mix design has been reviewed by the Superintendent Council, and allocated a registration number on the Register of VicRoads approved concrete mixes.**

**Concrete mix designs shall remain valid for 12 months from the date of registration, unless constituent materials and material proportions cease to comply with the specified requirements.**

The concrete mix design details shall include the following:

- (i) the source, type and proportions of the constituent materials
- (ii) the Cementitious Material Registration Scheme (CMRS) registration number(s) for the cementitious material(s) used in the mix as specified in clause 610.08(c)
- (iii) aggregate gradings, water absorption and saturated surface-dry densities
- (iv) chemical admixtures details and manufacturer's recommended dosage rates and method of use

- (v) the nominated slump and where a superplasticiser is used the final slump
- (vi) for self compacting concrete (SCC) additional details as specified in clause 610.07(m)
- (vii) the maximum water content and maximum W/C ratio
- (viii) level of control, accuracy and method of determination of both the coarse and fine aggregate moisture content, consistent with the requirements of clause 610.13(d)
- (ix) documentary evidence of previous performance and relevant test results which shall not be more than 12 months old including -
  - (1) 3, 7 and 28 day compressive strengths complying with the minimum compressive strength requirements given in Table 610.051 and clause 610.05
  - (2) VPV values at 28 days complying with the requirements given in Table 610.061 and clause 610.07(l)
  - (3) drying shrinkage test results as specified in clause 610.07(j)
  - (4) soluble salts content as specified in clause 610.07(k)
- (x) alkali aggregate reactivity test results as specified in clause 610.11(e) and which shall not be more than 3 years old in accordance with the minimum frequency of testing as stated in Table 610.121
- (xi) the method of placement and the member(s) of the structure in which the concrete is to be placed
- (xii) full details of concrete curing methods as specified in clause 610.23
- (xiii) a unique identification number for the concrete mix design to satisfy the requirements of clause 610.15.

**Concrete mix designs not complying with the requirements of this section will require the approval of the ~~Superintendent~~ Council.**

**The concrete mix design shall be strictly adhered to by the Contractor. In the event of changes to the agreed concrete mix design, the Contractor shall submit a new concrete mix design to the ~~Superintendent~~ Council for review or approval as appropriate.**

~~(c) Trial Mix~~

~~In the absence of recent documentary evidence that the concrete mix design complies with the requirements of this section, a trial mix shall be undertaken in accordance with AS 1012.2.~~

~~**The test results of the trial mix and the associated concrete mix design details indicating compliance with the specified requirements shall be submitted for review by the Superintendent.**~~

(d) Mix Constituents

The concrete shall consist of a mixture of cementitious material, fine aggregate, coarse aggregate and water.

The concrete may also contain chemical admixtures, details of which shall be submitted with the mix design.

If the coarse aggregate or fine aggregate is composed of more than one material or size of material, the mix proportions for each shall be specified separately.

(e) Cementitious Material Content and Water/Cementitious Material (W/C) Ratio

The minimum mass of total cementitious material per cubic metre of finished concrete and the corresponding maximum W/C ratio shall be as shown in Table 610.071.

**Table 610.071**

<b>Concrete Grade</b>	<b>Cementitious Material Content (min) (kg/m<sup>3</sup>)</b>	<b>W/C Ratio (max)</b>
VR330/32	330	0.50
VR400/40	400	0.45
VR450/50	450	0.40
VR470/55	470	0.36
VR520/60	520	0.35
VR535/65	535	0.34
VR550/70	550	0.34
VR580/80	580	0.33
VR610/90	610	0.33
VR640/100	640	0.32

The cementitious material content of concrete to be placed under water shall not be less than 400 kg/m<sup>3</sup>, with a maximum W/C ratio of 0.45.

The W/C ratio of the proposed concrete mix design shall not be less than 0.26 for both concrete cast in situ works and for concrete utilised in precast works.

(f) Minimum Portland Cement Content

The minimum mass of portland cement in concrete mixes containing Slag, Fly Ash or Amorphous Silica shall be 60%, 75% or 90% respectively, of the total mass of cementitious material in the concrete mix. The inclusion of Slag, Fly Ash or Amorphous Silica in concrete mixes shall only be in single or double combination with portland cement. In a triple blend concrete mix, the portland cement content shall be a minimum of 60% and the individual contribution of Slag, Fly Ash or Amorphous Silica shall be a maximum of 40%, 25% or 10% respectively, of the total mass of the cementitious material in the concrete mix.

**~~Other cementitious materials may be used subject to approval by the Superintendent.~~**

(g) Concrete Structures in Marine and other Saline Environments

Concrete structures located in marine and other saline environments shall be constructed in accordance with the minimum compliant cementitious material options as shown in Table 610.072.

**Where proportioning of cementitious material in concrete mixes uses higher replacement levels of supplementary cementitious materials than those stated in Table 610.072, the Contractor shall submit for review by the Superintendent Council a supporting documented detailed methodology addressing potential lower early strength development, longer formwork removal times and development of lower lifting strengths to ensure compliance with the specification.**

Additional protective measures for concrete structures constructed in marine and other saline environments are covered in clause 610.29.

(h) Concrete Structures Subject to Sulphate and Chemical Attack

Concrete structures subject to sulphate and chemical attack represented by an acidity of pH of 5 and higher shall be constructed in accordance with the minimum compliant cementitious material options as shown in Table 610.072, provided that the mobility of any groundwater if present is in an approximately static condition. For pH lower than 5.0, the environment shall be assessed as exposure classification U and be subject to special consideration in accordance with clause 610.30.

**Where proportioning of cementitious material in concrete mixes uses higher replacement levels of supplementary cementitious materials than those stated in Table 610.072, the Contractor shall submit for review by the Superintendent Council a supporting documented detailed methodology addressing potential lower early strength development, longer formwork removal times and development of lower lifting strengths to ensure compliance with the specification.**

**Table 610.072**

Concrete Members	Exposure Classification	Concrete Grade	W/C Ratio (max)	Proportioning of Cementitious Material (% mass) in concrete mixes
Piles Fender/keeper walls Wing walls Head walls Above Deck (Parapets etc) Base slabs	C1, C2	VR450/50	0.40	<ul style="list-style-type: none"> <li>• 90% GP / 10% AS; or</li> <li>• Higher replacement levels of:                             <ul style="list-style-type: none"> <li>- at least 30% FA; or</li> <li>- 30%GP / 60% Slag / 10% AS; or</li> <li>- 65% Slag / 35% GP</li> </ul> </li> </ul>
Pile Caps Pier Columns Pier Crossheads Abutment Crossheads	C1, C2	VR470/55	0.36	
Deck slab Approach slab	B2	VR400/40	0.45	Moderate replacement levels in accordance with clause 610.07(f)
Beams Crown Units	C1, C2	VR470/55	0.36	90% GP / 10% AS; or 80% GP / 20% FA
Where required concrete grades higher than those stated in this table may be used.				

(i) Use of Supplementary Cementitious Materials for Special Applications

Supplementary cementitious materials requirements for other special applications shall be as specified in the drawings and specification.

(j) Limitations on Drying Shrinkage

One sample per trial mix shall be taken. Each sample shall consist of 3 specimens tested in accordance with AS 1012.13. The shrinkage strain of each sample, as determined from the average value of the 3 specimens, shall not exceed 550 microstrain and 750 microstrain after 21 days and 56 days of drying respectively.

For concrete grades with minimum 28 day compressive strength in the range of 60 MPa to less than 80 MPa the shrinkage strain shall not exceed 500 microstrain and 700 microstrain after 21 days and 56 days of drying respectively.

For concrete grades with minimum 28 day compressive strength in the range of 80 MPa to 100 MPa the shrinkage strain shall not exceed 400 microstrain and 600 microstrain after 21 days and 56 days of drying respectively.

Drying shrinkage requirements for special applications shall be as specified in the drawings and specification.

## (k) Soluble Salts

## (i) Chloride-ion Content

The maximum acid-soluble chloride-ion content of concrete as placed, expressed as the percentage of the total mass of cementitious material in the concrete mix shall not be greater than:

- 0.1% for prestressed concrete
- 0.15% for reinforced concrete
- 0.07% for all mortars and grouts, including post-tensioning grout.

## (ii) Sulphate Content

The sulphate content of concrete as placed, expressed as the percentage by mass of acid-soluble SO<sub>3</sub> to the total cementitious material in the concrete mix shall not be greater than 5%.

Notwithstanding the requirements of this clause the sulphate content for steam and heat accelerated cured concrete, expressed as the percentage by mass of acid-soluble SO<sub>3</sub> to the total cementitious material in the concrete mix shall not be greater than 4%.

Sulphate and chloride-ion content shall be determined by testing of hardened concrete in accordance with AS 1012.20.1.

## (l) Testing and Acceptance of Concrete Mix Design on the Basis of 28 Day VPV Value

Test cylinders shall be cured in accordance with AS 1012. A minimum of 2 cylinders per sample per trial mix shall be taken. Each cylinder shall be tested for VPV at 28 days in accordance with test method AS 1012.21. The specification will be satisfied if the VPV value for each sample, as determined from the average value of the test cylinders, is not greater than the specified maximum 28 day VPV value in Table 610.061.

Should the VPV value of any one sample representing the concrete exceed the specified maximum 28 day VPV value as shown in Table 610.061, the Contractor shall take steps to modify the concrete mix design and re-test to ensure that the maximum specified VPV value is not exceeded.

## (m) Mix Design for Self Compacting Concrete (SCC)

The mix design requirements for SCC shall be as specified in this clause and clause 610.13(b), except that the nominated slump requirements as stated in clause 610.07(b)(v) shall not apply for SCC.

Further to the requirements of clause 610.07(b), mix design details of SCC shall include the nominated slump flow, T500 (measure of viscosity) and passing ability which shall comply with the requirements for SCC given in Table 610.131.

Notwithstanding the requirements of clause 610.07(f), higher amounts of fly ash and slag may be used in SCC mixes where further optimisation of the mix is required to comply with this section, including the required cohesiveness, workability, flowability and self-compactability of the concrete, without segregation.

**SCC shall be used only for the manufacture of precast concrete members and the construction of bored piles as specified in clause 610.18(c).**

**610.08 CEMENT, FLY ASH, SLAG AND AMORPHOUS SILICA**

## (a) Cement

Cement shall comply with the requirements of AS 3972 and ATIC-SPEC SP43. Cement per batch of concrete shall be from one manufacturer and of one brand, type and grind. Cement more than 3 months old shall not be used in the Works unless it is re-tested to demonstrate compliance with the requirements of AS 3972 and ATIC-SPEC SP43.



## (b) Fly Ash, Slag and Amorphous Silica

Fly Ash, Slag and Amorphous Silica shall comply with the requirements of AS 3582.1, AS 3582.2 and AS 3582.3 respectively and ATIC-SPEC SP43 and shall be from one manufacturer and of one brand, type and fineness.

## (c) Pre-Registration and Testing of Cementitious Materials

Cementitious materials used in the works shall be pre-registered under the Cementitious Material Registration Scheme (CMRS) in accordance with ATIC-SPEC SP43.

**The CMRS registration number(s) for the cementitious material(s) used in the Works shall be submitted as part of the concrete mix design review as specified in clause 610.07.**

**In addition to the information required as part of routine quality control, test certificates endorsed in accordance with the AS ISO/IEC 17025 accreditation for the testing laboratory demonstrating compliance with the requirements of this section shall be submitted for review by the Superintendent Council.**

**Summaries of cementitious material test data shall be submitted for review by the Superintendent Council.** The data shall be traceable to the concrete supplier's batching plant(s).

**610.09 WATER**

The quality of water to be used in the concrete mix and for the curing of concrete shall comply with the requirements of clause 2.4 of AS 1379. However, the amounts of chloride in the water shall be not greater than 0.03% (300 ppm). The amount of sulphate (as SO<sub>4</sub>) in water shall not be greater than 0.04% (400 ppm).

In addition, recycled water used in the concrete mix shall have total dissolved solids of not greater than 1700 milligrams per litre.

**Sources of recycled water containing differing levels or other contaminants shall be subject to approval by the Superintendent Council on the basis of predetermined test results and evidence of previous performance.**

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

**610.10 CHEMICAL ADMIXTURES**

Chemical admixtures shall comply with the requirements of AS 1478 unless otherwise specified in this section. They shall be used in accordance with the requirements of clause 2.5 of AS 1379 and the manufacturer's recommended method of use and shall not reduce the strength of concrete below that specified. Chemical admixtures shall be accurately measured by means of dispensers which are subject to regular maintenance and are calibrated as a minimum at three monthly intervals.

Chemical admixtures shall not contain calcium chloride, calcium formate, chlorine, sulphur, sulphides or sulphites. Where two or more chemical admixtures are proposed for incorporation in a concrete mix, their compatibility shall be certified by the manufacturers.

**Air entraining admixtures shall not be used unless approved by the Superintendent Council.**

Where the use of air entraining admixture is approved, the Contractor shall determine the air content of the freshly mixed concrete at the point of discharge in accordance with AS 1012.4 and clause 5.4 of AS 1379, and it shall not exceed the nominal value of 5%.

The concrete represented by a sample taken in accordance with clause 610.16 shall be deemed to comply with the approved air content if the measured air content is within 1.5% of the approved air content.

**610.11 AGGREGATES**

(a) General

Fine and coarse aggregate for concrete shall comply with the requirements of AS 2758.1.

The maximum amount of water absorption for fine aggregate, coarse aggregate, combined coarse aggregate and combined fine aggregate shall not exceed 2.5%.

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

(b) Fine Aggregate

(i) Description

The fine aggregate shall consist of clean, hard, durable, naturally occurring sands, or a combination of naturally occurring sands and manufactured sands, and shall be free from clay, dust, lumps, soft or flaky particles, shale, salt, alkali, organic matter, soil or other deleterious substances. Any manufactured sands used as fine aggregate shall be crushed from rock that produces aggregate complying with the requirements of clause 610.11. Manufactured sands produced from any igneous or metamorphic rock shall have a Degradation Factor - Crusher Fines of not less than 60.

**A maximum of 25% of manufactured sand from a an approved source approved by the Superintendent will be permitted.**

Consideration may be given by ~~the Superintendent~~ Council to approve the use of up to a maximum of 50% of manufactured sand if objective documented evidence is provided that concrete made with such higher amount of manufactured sand complies with all other requirements of this section both in the fresh and hardened state, including evidence of acceptable performance regarding tendency for segregation, bleeding, plastic shrinkage, satisfactory compaction and finishing properties.

(ii) Testing for Impurities

Fine aggregate shall be tested for impurities in accordance with AS 1141.

**The clay and fine silt levels of natural sands shall be monitored as a routine quality control measure and records shall be available for review by the ~~Superintendent~~ Council.** Action shall be taken where levels exceed normal consistency limits derived from routine quality control testing.

(iii) Grading of Fine Aggregate

Fine aggregate shall be uniformly graded and shall comply with the limits in Table 610.111 when tested with standard sieves.

If required fine aggregates can be combined in such proportions that the resulting fine aggregate mix shall comply with the grading requirements.

**Table 610.111**

<b>Sieve Size AS (mm)</b>	<b>Percentage Passing (by mass)</b>
9.5	100
4.75	90 - 100
2.36	75 - 100
1.18	50 - 90
0.6	30 - 75
0.3	10 - 50
0.15	2 - 15
0.075	0 - 5

(iv) Consistency of Grading

The grading of fine aggregate shall not deviate from the submitted grading by more than  $\pm 5\%$ .

Consideration may be given by the ~~Superintendent~~ Council to approve the use of fine aggregate with grading outside the specified limits if objective documented evidence is provided that concrete made with such fine aggregate grading complies with all other requirements of this section both in the fresh and hardened state, including evidence of acceptable performance regarding tendency for segregation, bleeding, plastic shrinkage, satisfactory compaction and finishing properties.

(c) Source Rock

Source rock shall comply with the requirements of Section 801.

(d) Coarse Aggregate

(i) Description

Coarse aggregate shall consist of clean, hard, durable angular rock fragments of uniform quality. It shall be free from clay, clay lumps, salt, organic matter or other substances deleterious to concrete or steel.

(ii) Testing Requirements for Coarse Aggregate.

Coarse aggregate shall not contain:

- (1) more than 5% by mass of unsound rock; or
- (2) more than 10% total by mass of unsound rock plus marginal rock.

The flakiness index of the coarse aggregate shall not exceed 35%.

(iii) Grading of Coarse Aggregate

Coarse aggregate size ranges, when tested by means of standard sieves, shall have a maximum nominal size between 10 and 20 mm and shall comply with the requirements of AS 2758.1.

(iv) Effective Size of Coarse Aggregate

Concrete in various parts of the structure shall contain coarse aggregate with the following effective maximum sizes:

Joint and pedestal concrete .....	14 mm
Precast concrete .....	14 mm for minimum cover of 25 mm 20 mm for minimum cover greater than 25 mm
All other concrete .....	20 mm

The effective minimum size will be 10 mm for crushed material and 5 mm for rounded materials.

(v) Use of Pebble Aggregate

Notwithstanding the requirements of clause 610.11(d) and Section 801, pebble aggregate may be used in the manufacture of structural concrete including concrete intended for use in pre-stressed and post-tensioned members subject to the following requirements:

- (1) where the LA of pebble aggregate or blended aggregate containing pebbles is greater than 35 but equal to or less than 45 the Wet and Dry Strength variation shall be equal to or less than 25 and the Sodium Sulphate Soundness shall be equal to or less than 8
- (2) pebble aggregate or blended aggregate containing pebbles with an LA greater than 45 shall not be used in the works
- (3) the minimum frequency of testing for Wet and Dry Strength and Sodium Sulphate Soundness shall be in accordance with the requirements of Table 610.121.

(e) Alkali Aggregate Reactivity

**Unless otherwise approved by the Superintendent Council, all aggregates shall be assessed and tested for alkali reactivity as follows:**

(i) Petrographic Examination

Aggregates shall be assessed for any unstable silica minerals by petrographic examination in accordance with ASTM Test Method C295.

(ii) Potential Alkali Silica Reactivity

The potential alkali silica reactivity of the coarse and fine aggregates shall be determined using either the VicRoads accelerated mortar bar test method RC 376.03 or the VicRoads concrete prism test method RC 376.04 as described in the VicRoads Code of Practice RC 500.16.

(1) Accelerated Mortar Bar Test Method (RC 376.03)

Coarse and fine aggregates shall be deemed to be non-reactive if the average expansion of the mortar bars made with the proposed aggregates and General Purpose portland cement Type GP does not exceed 0.1% at 21 days in the case of coarse aggregates and 0.15% at 21 days in the case of fine aggregates. Individual results shall not differ from the mean by more than 15%.

Should the average expansion of the mortar bars exceed 0.1% at 21 days in the case of coarse aggregates and 0.15% at 21 days in the case of fine aggregates, the aggregates will be classed as reactive and either new aggregates shall be proposed for use and re-tested for compliance, or if it is proposed to use aggregates that have been classed as reactive, all of the following requirements shall be satisfied:

- the concrete mix be designed such that the alkali content does not exceed 2.8 kg/m<sup>3</sup> (Na<sub>2</sub>O equivalent)
- a blended cement be used in the concrete mix that satisfies the minimum requirements of Table 610.112. Concrete mixes containing the minimum proportions of supplementary cementitious material as shown in Table 610.112 shall be deemed to comply with this clause.

(2) Concrete Prism Test Method (RC 376.04)

Aggregates shall be classified reactive when the average expansion at 12 months is greater than 0.03%, and non reactive when it is equal to or less than 0.03%.

Aggregates classified as reactive by the concrete prism test method in a concrete mix design, shall not be used in that particular concrete mix design. Alternative aggregates and/or alternative concrete mix designs shall be used subject to compliance with the requirements of this specification.

**Table 610.112**

Supplementary cementitious material	Minimum proportion of supplementary cementitious material in single combination with portland cement in the concrete mix to mitigate alkali aggregate reactivity (%)	Minimum proportion of supplementary cementitious material in double combination with portland cement in the concrete mix to mitigate alkali aggregate reactivity (%)		
		Fly Ash	Slag	Amorphous Silica
Fly Ash	20	-	-	-
Slag	50	-	-	-
Amorphous Silica	8	-	-	-
Fly ash + Slag	-	15	15	-
Fly Ash+ Amorphous Silica	-	15	-	5
Slag + Amorphous silica	-	-	40	5

Where blended aggregates are used, the aggregates from different sources shall be tested individually.

Notwithstanding the requirements of this clause when fine and coarse aggregates are procured from the same source, only one alkali silica reactivity evaluation per source shall be undertaken.

Any proposed blended cement deviations from the minimum blended cement requirements of Table 610.112 shall demonstrate compliance with both the maximum mortar bar and concrete prism expansion limits stated in this clause, and as determined by both the VicRoads accelerated mortar bar test method RC 376.03 and the VicRoads concrete prism test method RC 376.04.

**610.12 MINIMUM TESTING REQUIREMENTS FOR AGGREGATES**

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 610.121. 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, the Superintendent Council may agree to a lower frequency than that shown in Table 610.121.

**Table 610.121**

Test	Minimum Frequency of Testing
Grading of Fine Aggregates	On each day one per 500 tonne or part thereof
Grading of Coarse Aggregates	On each week one per 1500 tonne or part thereof
Water Absorption of Fine and Coarse Aggregates	At 3 monthly intervals
Unsound Rock Content	On each day one per 500 tonne or part thereof
Flakiness Index of Coarse Aggregate 10 mm and Larger	At monthly intervals
Degradation Factor of Crusher Fines	At monthly intervals
Organic Impurities other than sugar	At monthly intervals
Alkali Reactivity of Aggregate Sources	At 3 yearly intervals
Wet and Dry Strength and Sodium Sulphate Soundness for Pebble Aggregates	At 3 monthly intervals

**610.13 MANUFACTURE AND DELIVERY OF PREMIXED CONCRETE**

(a) General

The Contractor shall be responsible for the manufacture and delivery of all concrete which shall comply with the approved or registered concrete mix design and the requirements of AS 1379.

The minimum quantity of a load of premixed concrete in the mixer or agitator delivered to site shall be 1 m<sup>3</sup>. The quantity of concrete delivered in any mixer or agitator shall not exceed the rated capacity of the agitator drum.

Concrete shall not be mixed when the air temperature is lower than 5°C or greater than 35°C.

Water may be added to the freshly mixed concrete prior to commencement of discharge provided no more than 60 minutes have elapsed from the time of adding cement to the aggregate and a means of accurately measuring the volume of water is available to ensure that the maximum design amount of water and the agreed maximum W/C ratio are not exceeded. In addition, concrete samples shall be taken after the water has been added, in accordance with clause 610.16(b). The consistency of the concrete shall be measured by a slump test after the water has been added, in accordance with clause 610.16(c).

No water shall be added after the commencement of discharge of concrete.

Concrete which has begun to stiffen shall not be used in the works.

Concrete which has been dried-out after leaving the mixing plant shall not be used in the works. Notwithstanding this requirement concrete may be dried-out after leaving the mixing plant provided the site of intended discharge is located within a close proximity to the mixing plant, to ensure the maximum discharge time of 60 minutes as stated in clause 610.13(f) from the time of original mixing of the concrete is not exceeded and quality documentation is provided to verify that the affected load of concrete fully complies with this section.

Prior to the discharge of concrete at the site, the mixer or agitator shall be operated at mixing speed until the concrete achieves the required uniformity but for not less than a period of three minutes. Where superplasticisers or other admixtures are added to the concrete on site, the concrete shall be mixed for a period of not less than five minutes prior to the discharge at the site

(b) Self Compacting Concrete (SCC)

Further to the requirements of clause 610.07, SCC shall incorporate the various cementitious materials, coarse and fine aggregate and any additional fine materials, water and chemical admixtures in proportions to achieve the rheological characteristics of flow and self-compaction. SCC shall be produced using High Range Polycarboxylate Type Water Reducers which include a viscosity modifying capability that impart pseudoplastic or thixotropic behaviour upon the concrete in order to inhibit segregation.

Conventional superplasticisers may be used provided a viscosity modifying admixture is also used and it is clearly demonstrated that the required flow is being achieved without segregation.

SCC shall not be vibrated or subjected to any physical disturbance after deposition.

The slump flow, T500 time (measure of viscosity) and passing ability of the self compacting concrete (SCC) shall be determined in accordance with the AS 1012.3.5. The slump flow, T500 time and passing ability of the SCC shall comply with the requirements of Table 610.131.

Sampling and testing for SCC shall be in accordance with the requirements of clause 610.16(n).

**Table 610.131**

Properties of SCC	Measurement	Observations
Slump Flow	550 – 800 mm spread	The aggregate shall be evenly distributed throughout the concrete paste within the spread and shall not exhibit signs of segregation
T <sub>500</sub> time (measure of viscosity)	Achieve a spread of 500 mm within 1 to 5 seconds	The final spread shall not exceed 800 mm in diameter
Passing Ability	≤ 10 mm	The concrete shall not exhibit signs of segregation

(c) Highly Workable Concrete

Highly workable concrete shall be superplasticised with a nominated slump of between 160 mm and 220 mm and shall be compacted in accordance with this section. Highly workable concrete placed under water shall contain an anti-dispersing admixture.

Sampling and testing for highly workable concrete shall be in accordance with clause 610.16, including the requirements for superplasticised concrete as stated in clause 610.16(c).

(d) 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. Corresponding corrections shall be made to the mass of all aggregates and the volume of water used in the mix.

The moisture content of the fine and coarse aggregates shall be determined to constant mass in accordance with the VicRoads aggregate moisture content test method RC 253.01 as described in the VicRoads Code of Practice RC 500.16. Moisture meters or other equivalent devices may also be used provided they are calibrated as a minimum, on a monthly basis.

## (e) Delivery Docket

In addition to the information required by clause 1.7.3 of AS 1379 the following information shall also be recorded on the delivery docket:

- (i) the total water in the batch, including -
  - (1) the moisture content of both fine and coarse aggregates as specified in clause 610.13(d)
  - (2) batch water
  - (3) water added at the slump stand
  - (4) total amount of water permitted to be added on site
  - (5) water added on site before commencement of discharge, including water used to wash down the mixing blades of the mixer or agitator
- (ii) total specified mass of cementitious material
- (iii) slumps, including -
  - (1) nominated slump
  - (2) estimated slump
  - (3) measured slump
- (iv) any other additions to a batch
- (v) the unique identification number allocated to the concrete mix design in accordance with clause 610.07(b)(xiii).

Further to the above requirements, the following information shall be traceable to the concrete supplier's batching plant(s) for each batch (truck load) of concrete used in the works, and shall be made available for review upon request by the Superintendent Council.

- (vi) cementitious material brand and type, including -
  - (1) proportions of components (by mass)
  - (2) total actual mass of cementitious material
- (vii) chemical admixtures, including -
  - (1) types
  - (2) amounts.

## (f) Period for Completion of Discharge

Concrete shall be placed and compacted within 60 minutes of the commencement of mixing. This time may be extended beyond the 60 minutes provided a hydration control admixture is added to the concrete mix to delay the hydration process and provided the concrete complies with the specified requirements. Where a hydration control admixture is added to the concrete mix to delay hydration the stated extended discharge time shall not be exceeded.

Concrete shall not be incorporated into the works if its consistency is outside the acceptable limits as specified in clause 610.16(c).

## (g) Water Left in the Mixer or Agitator

Water left in the mixer or agitator from the previous load shall be discharged prior to reloading new concrete in accordance with the requirements of clause 4.1.3(c)(ii) 'water in mixing chamber' of AS 1379 and in order to ensure that the maximum W/C ratio is not exceeded in accordance with requirements of this section. For the purposes of verification of this requirement quality documentation shall be signed and dated by the batcher of the mixing plant.

## (h) Addition of Water at the Slump Stand

Addition of water to the mixed batch of concrete at the slump stand shall be undertaken in a disciplined manner, such that slump stand water meters are initially zeroed and actual amounts of water added into the agitator drum are accurately recorded. Only hoses connected to a functioning and accurately calibrated slump stand water meter shall be used to add water to the freshly mixed concrete in the agitator drum. **Records of actual amounts of water added into the agitator drum at the slump stand shall be available for review by the Superintendent Council.**

(i) Calibration of weighing and metering equipment

All batch plant weighing and all water metering equipment shall be subject to regular maintenance and independently calibrated by an accredited organisation, as a minimum at three monthly intervals.

Chemical dispensers shall be calibrated as a minimum at three monthly intervals.

The accuracy of all weighing and metering equipment shall comply with the requirements of Section 3 of AS 1379.

#### **610.14 STAND-BY MIXING PLANT**

The Contractor shall arrange for alternative supplies of concrete from stand-by mixing plant(s) capable of being operated immediately in case of breakdown, together with adequate supplies of cementitious material, fine and coarse aggregates for an approved compatible mix(es).

Hand mixing will not be permitted.

#### **610.15 TRACEABILITY OF CONCRETE**

All concrete batches (truckloads) used in the works shall be traceable from the batch plant to its general location in the structure by a unique identification number.

#### **610.16 CONCRETE CONTROL, SAMPLING AND TESTING**

(a) General

All concrete shall be sampled and tested in accordance with AS 1012 unless otherwise specified in this section.

Each sample of concrete shall be tested for compressive strength, slump, air entrainment (when required), slump flow, T500 time and passing ability (when SCC is used), VPV value, drying shrinkage and soluble salts (at concrete mix design stage), as specified in this section.

(b) Frequency of Sampling and Testing

Whenever concrete is being cast in a structural member or a portion of it in one continuous casting operation, the minimum number of test samples shall be in accordance with Table 610.161.

A continuous casting operation is one in which the maximum time interval between the end of discharge of one truckload of concrete and the beginning of discharge of the next truckload does not exceed 45 minutes.

Whenever a group of structural members is being cast in separate operations, where the time interval between the end of discharge of one truckload of concrete and the beginning of discharge of the next truckload exceeds 45 minutes, the minimum number of test samples shall be one (1) per truckload of concrete

Samples shall be taken at the point of discharge prior to placement in a random and representative manner and at approximately equal portions of the volume of concrete cast in one continuous operation. Unless otherwise specified in this section or directed by the Superintendent Council, no sampling shall be undertaken from consecutive truckloads of concrete cast in one continuous operation.



**Table 610.161**

<b>Volume Cast in One Continuous Operation (cubic metre)</b>	<b>Minimum Number of Samples</b>
0 to 10	1
10 to 25	2
25 to 50	3
50 to 100	4

For each additional 50 m<sup>3</sup> one additional sample shall be taken.

The Contractor shall develop and implement a site sampling and testing procedure in accordance with the minimum frequency requirements of this section for assurance of concrete quality, **and shall ensure that records are available for review by the Superintendent Council.**

(c) Consistency

The consistency of the concrete shall be determined by a slump test of a concrete sample in accordance with AS 1012.3.1.

The concrete represented by a sample shall be deemed to comply with the specified slump if the measured slump is within the limits stated in Table 610 162 for the corresponding specified slump.

**Table 610.162**

<b>Specified slump, mm</b>	<b>Tolerance, mm</b>
<60	±10
≥60 ≤80	±15
>80 ≤110	±20
>110 ≤150	±30
>150	±40

**For concrete containing a superplasticiser, the consistency of all batches of concrete after the addition of the superplasticiser shall be determined by a slump test of a concrete sample. Testing of every batch of superplasticised concrete shall continue until five consecutive batches of concrete have achieved the specified requirements.**

**After satisfying this requirement, the Contractor may then make a submission to the Superintendent Council for agreement to reduce the frequency of slump testing of superplasticised concrete to be in accordance with Table 610.161, provided a high level of process control, including a high level of control of total water content in the mix in accordance with specified requirements, is supported with objective documented evidence.**

If the Contractor has satisfied the above initial testing requirement and is slump testing superplasticised concrete at the frequency in Table 610.161 and any batch fails to achieve the specified standard, the Contractor shall test all subsequent batches of superplasticised concrete until three consecutive batches have achieved the specified standard, at which time the frequency of slump testing may again be reduced to the minimum frequency requirements of Table 610.161.

The consistency of SCC as represented by the three defining parameters of slump flow, T<sub>500</sub> time (measure of viscosity) and passing ability as stated in clause 610.13(b), shall be subject to the same frequency of testing requirements as for superplasticised concrete.

For the purpose of determining the actual slump of superplasticised concrete and the required testing parameters for SCC as stated in clause 610.13(b) and clause 610.16(n), the discharge of the first 0.2 m<sup>3</sup> of concrete prior to taking the test sample shall not be required.

The concrete represented by the samples shall be deemed to comply with the nominated mix design slump if the measured slump is within the limits specified in Table 610.162.

If the measured slump is not within the limits specified in Table 610.162, 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 limits given in Table 610.162, the concrete represented by the sample shall be deemed to comply with the appropriate nominated mix design slump, otherwise it shall be rejected.

The slump of the concrete shall be checked and recorded within 45 minutes of adding cement to the aggregate, or immediately prior to discharge when the actual haul time exceeds 45 minutes and/or when water is added to the mixed batch in accordance with clause 610.13(a).

Concrete used for the slump test and the required testing for SCC shall not be re-used to make concrete test cylinders.

Each batch (truckload) of concrete delivered to site shall be visually inspected to ensure consistency of concrete supply, and the estimated slump shall be recorded on the identification certificate for the batch. Both the visual inspection and slump estimate shall be carried out prior to the addition of any water which may be added on site and prior to any addition of a superplasticiser.

(d) Test Cylinders for Compressive Strength

Each sample of concrete for standard compression tests shall comprise a minimum number of:

- (i) 3 cylinders for reinforced and prestressed pre-tensioned concrete
- (ii) 3 or 5 cylinders for prestressed post-tensioned concrete when application of the post-tensioning force will be after or before 28 days respectively.

A minimum of 2 cylinders per sample shall be tested at 28 days.

For all concrete, a minimum of 1 cylinder per sample shall be tested at 7 days. This requirement shall not apply for pre-tensioned concrete.

For prestressed pre-tensioned concrete, a minimum of 1 cylinder per sample shall be tested prior to the application of the pre-tensioning force.

For prestressed post-tensioned concrete, a minimum of 2 cylinders per sample shall be tested prior to the application of the post-tensioning force.

(e) Curing of Test Cylinders

Test cylinders shall be cured in accordance with AS 1012. Cylinders shall be transported to the testing laboratory in moisture proof containers.

For steam or radiant heat cured members test cylinders shall be cured with the members or in the test cylinder heating box respectively for the duration of the curing cycle as specified in clause 610.23(g) and clause 610.23(h). Following the steam curing cycle curing of the cylinders shall continue in accordance with the requirements of AS 1012.

(f) Compression Testing Prior to Application of Prestress

For post-tensioned concrete members, the post-tensioning force shall only be applied when two cylinders per sample are tested and the average compressive strength of these cylinders is equal to or greater than the specified compressive strength as shown on the drawings, and the lower cylinder result is greater than 90% of the specified compressive strength.

For pre-tensioned concrete members(s) the pre-tensioning force shall only be applied when each cylinder per sample tested has achieved the specified compressive strength as shown on the drawings.

In the event that the above requirements are not satisfied, application of prestress shall be deferred until such time as the compressive strength of an additional cylinder per sample achieves the specified compressive strength for pre-tensioned concrete or the cylinders tested at 28 days satisfy the requirements of clause 610.16(g) for post-tensioned concrete.

## (g) Testing and Acceptance of Concrete on the Basis of 28 Day Compressive Strength

## (i) Test Cylinders

A minimum of two cylinders per sample shall be tested at 28 days after casting. The specification will be satisfied if the compressive strength of each sample, as determined from the average value of the test cylinders, is not less than the specified minimum 28 day compressive strength and provided that the compressive strength of any cylinder in each sample is not less than 90% of the specified minimum 28 day compressive strength.

**Should the strength of any one sample representing the concrete fall short of the specified minimum 28 day compressive strength as shown in Table 610.051, the concrete represented by that sample may be rejected or the Contractor may elect to test concrete cores subject to approval by the Superintendent Council.**

**Non-destructive tests may be used to determine the in situ strength of suspect concrete subject to approval by the Superintendent Council.**

## (ii) Test Cores

Where required by the Superintendent Council, test cores shall be cut from the completed structural member, portion of member or group of members represented by the test cylinder sample(s). A minimum of three cores per sample shall be tested. All cores shall be clearly labelled to identify them with the structural member and location they represent.

The dimensions and testing of the concrete cores shall be in accordance with AS 1012.14.

The coring procedure shall comply with the requirements of clause 610.46.

Testing shall be undertaken in accordance with the requirements of clause 610.46 to ensure that the core locations are remote from existing steel reinforcement. Where cores are cut from concrete decks and slabs, core locations shall be remote from wheel paths. Cores containing steel reinforcement shall not be tested.

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**The coring procedure and core locations shall be submitted for approval by the Superintendent Council.**

Cores shall not be cut from prestressed concrete after the prestressing force has been applied or transferred to the concrete, unless the proposed coring is certified by the proof engineer. The certification shall state that the proposed coring will not be detrimental to the prestressed concrete member.

The core holes shall be cleaned and repaired with a shrinkage compensating polymer modified cementitious repair material in accordance with the requirements of Section 689. The exposed surface of the repaired hole shall be similar in texture and colour to the surrounding concrete.

The specification will be satisfied if the compressive strength of each sample, as determined from the average value of the test cores, is not less than the specified minimum 28 day compressive strength and provided that the compressive strength of any core in each sample is not less than 90% of the specified minimum 28 day compressive strength.

Should the strength of any one sample representing the concrete fall short of the specified minimum 28 day compressive strength as shown in Table 610.051, the concrete represented by that sample may be rejected.

## (h) Testing and Acceptance of Sprayed Concrete on the Basis of 28 Day VPV Value

A minimum of two cores per sample shall be cut from the sprayed concrete test panels and permanent sprayed concrete and tested at 28 days at the minimum specified sampling frequency. Each core shall be 75 mm diameter and a minimum of 150 mm long, cut transversely into two equal slices and tested for VPV at 28 days in accordance with test method AS 1012.21. The VPV value for each core shall be determined from the average value of the test slices. The specification will be satisfied if the VPV value for each sample, as determined from the average value of the test cores, is not larger than the specified maximum VPV values at 28 days as shown in Table 610.061.

(i) Testing and Acceptance of Concrete Mix Design on the Basis of 3, 7 and 28 Day Compressive Strengths

A minimum of two cylinders per sample per trial mix shall be tested. The specification will be satisfied if the compressive strength of each sample, as determined from the average value of the test cylinders, is not less than the specified minimum 3, 7 and 28 day compressive strengths and provided that the compressive strength of any cylinder in each sample is not less than 90% of the specified minimum 3, 7 and 28 day compressive strengths.

Should the strength of any one sample representing the concrete fall short of the specified minimum 3, 7 and 28 day compressive strengths as shown in Table 610.051, the Contractor shall take steps to modify the concrete mix design and re-test to ensure that the specified minimum compressive strengths have been achieved.

(j) Testing and Acceptance of Non-Conforming Concrete

In the event that any of the specified requirements of this section can not be clearly demonstrated to have been satisfied, the Contractor shall undertake appropriate measures to resolve the non-conformance(s) to the satisfaction of ~~the Superintendent~~ Council.

~~The Superintendent~~ Council may at his discretion require additional VPV testing and compressive strength testing to be undertaken from the remainder of the fresh concrete supply or the in situ hardened concrete or both, as described below.

(i) Fresh Concrete

In addition to the compressive strength requirements as specified in this section, additional samples of concrete as detailed in clause 610.16(b) and Table 610.161 of at least two cylinders shall be tested for VPV at 28 days, in accordance with test method AS 1012.21. The specification will be satisfied if the VPV value for each sample, as determined from the average value of the additional test cylinders, does not exceed the specified maximum 28 day VPV value in Table 610.061.

Should the VPV value of any one sample representing the concrete exceed the specified maximum 28 day VPV value as shown in Table 610.061, the Contractor shall modify the concrete mix design and undertake other measures as required at its own expense, to satisfy the specification requirements for subsequent concrete supply by further sampling and testing. The hardened concrete represented by the samples shall be subject to rejection, rectification by the Contractor, the requirements as described below, or as determined by ~~the Superintendent~~ Council.

(ii) Hardened Concrete

In addition to the requirements of clause 610.16(g)(ii) for compressive strength of test cores, a minimum of two cores per sample shall be cut from the relevant completed structural member, portion of member or group of members represented by a set of test cylinder sample(s) and tested at 28 days. Each core shall be 75 mm diameter x 150 mm long, cut transversely into two equal slices and tested for VPV at 28 days in accordance with test method AS 1012.21. The VPV value for each core shall be determined from the average value of the test slices.

For members where the thickness is less than 150 mm the core length shall be the full thickness of the member. The specification will be satisfied if the VPV value for each sample, as determined from the average value of the test cores, does not exceed the specified maximum VPV value at 28 days as shown in Table 610.061.

All cores shall be clearly labelled to identify them with the structural member and location they represent. Testing shall be undertaken to ensure that the core locations are remote from the existing steel reinforcement. Where cores are cut from concrete decks and slabs, core locations shall be remote from wheel paths. Cores containing steel reinforcement shall not be tested.

**Core locations shall be submitted for approval by ~~the Superintendent~~ Council.**

For coring from prestressed concrete the requirements of clause 610.16 shall be satisfied.

Where the VPV value of any one sample representing the concrete exceeds the specified maximum 28 day VPV value as shown in Table 610.061, the Contractor shall carry out rectification works. These works shall achieve the specified level of durability, otherwise the concrete represented by that sample may be rejected.

**Non-destructive tests may be used to investigate non-conforming concrete of observed or suspect quality subject to approval by the Superintendent Council.**

(k) Testing and Acceptance of Concrete on the Basis of 28 Day VPV Value

Notwithstanding the requirements of clause 610.16(j), where a concrete pour exceeds 50 m<sup>3</sup> a sample consisting of at least two cylinders shall be sampled at the point of discharge and tested for VPV at 28 days, in accordance with test method AS 1012.21.

For concrete structures located in marine and other saline environments or which are subject to sulphate and chemical attack at least two cylinders per sample shall be tested for VPV at 28 days as detailed in clause 610.16(b) and Table 610.161.

Should the VPV value of any one sample representing the concrete exceed the specified maximum 28 day VPV value as shown in Table 610.061, the concrete represented by that sample and subsequent concrete supply shall be subject to the requirements of clause 610.16(j) for testing and acceptance of non-conforming concrete.

(l) Determination of early age compressive strength

Where early application of loading or early removal of formwork is proposed, or where concrete is to be placed over or adjacent to and connected with a previous section prior to achieving the minimum 7 day compressive strength, additional test cylinder(s) per sample shall be taken for the assessment of early age compressive strength.

The Contractor shall nominate the total number of cylinder(s) per sample in excess of the minimum number of cylinders specified in clause 610.16(d).

Further to the requirements of clause 610.16(e), when additional test cylinder(s) per sample above the specified minimum number are taken to vary a requirement of this specification, such as early application of loading or early removal of formwork, the test cylinder(s) shall be cured with the concrete member under conditions no more favourable than the most unfavourable conditions for the portion of the concrete which the test cylinders represent. Test cylinders shall not be moved or transported to the laboratory for testing prior to 18 hours from moulding in accordance with the requirements of clause 9.2.2 of AS 1012.8.1.

In addition to the early age compressive strength requirements of this sub-clause 610.16(l), the Contractor shall also comply with the curing requirements of clause 610.23 and the minimum curing period requirements as stated in Table 610.231.

(m) Maturity Testing and Temperature Matched Curing (TMC) for Estimating the In Situ Strength of Concrete

**Further to the requirements of clause 610.16(d) and clause 610.16(e) various types of maturity testing and TMC may be used to determine the early age in situ strength development of concrete over a required time period for the purpose of facilitating early formwork removal, lifting precast units out of moulds or early application of loading, subject to the approval of the Superintendent Council.**

**Based on the specific application, a proposed maturity method or TMC of assessing early in situ strength shall be submitted for review by the Superintendent Council.** Each proposal shall be supported with a documented detailed methodology and documented evidence of previous performance including accuracy in determining the in situ strength development of concrete.

The proposed method of maturity testing or TMC shall include:

- (i) the type of equipment to be used to monitor the in situ temperatures, or the control temperatures for TMC for the specific concrete mix and prevailing curing conditions:
  - (1) for maturity testing - to develop a maturity curve (correlation between compressive strength and maturity)
  - (2) for TMC – to monitor the heat development in the in situ concrete which heats the water in the TMC system and matches the temperature of the in situ concrete with the temperature of the cylinders in the TMC system to facilitate strength development
- (ii) method of recording the time/temperature relationship including the type of data loggers
- (iii) the period of monitoring
- (iv) the proposed number and location of temperature sensors to be used which shall include as a minimum the interior and near surface of the concrete member.

The maturity curve shall be updated as a minimum on a 3 monthly basis or earlier to allow for any changes in materials, in concrete mix proportioning, the performance of mixing equipment and construction conditions to ensure the ongoing validity of the maturity curve.

The maturity curve shall also be verified at the commencement of maturity testing and subsequently on a 3 monthly basis as follows:

- (i) compare the early age strengths of test cylinders sampled and tested in accordance with clause 610.16 during construction, with the maturity curve;
- (ii) monitor the maturity of an additional early age strength test cylinder per sample, sampled in accordance with clause 610.16, during construction and compare the strength with the maturity curve.

The Contractor shall maintain records of all maturity testing to demonstrate compliance with the specified requirements of this section. **The Contractor shall ensure that the records are available for review by the Superintendent Council.**

In addition to the maturity testing requirements of this sub-clause 610.16(m), the Contractor shall also comply with the curing requirements of clause 610.23 and the minimum curing period requirements as stated in Table 610.231.

(n) Sampling and Testing for Self Compacting Concrete (SCC)

Sampling and testing for SCC to demonstrate compliance with the requirements of Table 610.131 shall be in accordance with clause 610.16, except that the slump flow,  $T_{500}$  (measure of viscosity) and passing ability of SCC shall be sampled and tested at the same frequency as superplasticised concrete, as stated in clause 610.16(c).

When making test cylinders for SCC 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 SCC.

## 610.17 TEMPERATURE, EVAPORATION LIMITS AND CONCRETING OPERATIONS

(a) General

All freshly finished concrete surfaces shall be protected where required from the sun, wind or rain, until curing is implemented.

Where extreme conditions of temperature, humidity, wind and/or rain are expected during and after placing the concrete, the Contractor shall implement special precautions to protect the concrete.

The temperature of concrete, measured immediately prior to placing, shall not be less than 10°C or greater than 32°C.

The Contractor shall minimise evaporative moisture losses from the freshly placed and unprotected concrete in accordance with the requirements of clauses 610.17(e) and 610.17(f).

**The Contractor shall submit to the Superintendent Council for review, full details of the proposed hot or cold weather concreting procedure, not less than two weeks prior to placement of concrete. The Contractor shall not proceed with the placement of concrete until the hot or cold weather concreting procedure has been reviewed and approved by the Superintendent Council.**

(b) Hot Weather Concreting

Concrete shall not be placed when the air temperature measured at the point of placement is above 35°C, unless special precautions as detailed in this clause are implemented to reduce the concrete temperature and facilitate hot weather concreting works.

Steel formwork, reinforcing steel and any other steel surfaces that will come in contact with the concrete shall be cooled by shading, by providing covers or wetting down with water before the concrete is placed, to prevent flash setting of the concrete.

Concrete temperature reducing precautions shall include the following measures to ensure compliance with the requirements of this section:

- (i) shading the aggregate stockpiles
- (ii) sprinkling aggregates with cold water ahead of time for evaporative cooling, provided the moisture content of aggregates complies with the requirements of clause 610.13(d) prior to batching of concrete
- (iii) using refrigerated water in the concrete mix
- (iv) injecting liquid nitrogen into the mixer
- (v) water mist spraying to cool the air provided that the water does not collect or pond on the exposed concrete surfaces.

For decks and slabs, the concrete surfaces shall be protected immediately after screeding and finishing operations are progressively completed in order to minimise evaporative moisture losses, until curing by one or a combination of the methods specified in clause 610.23 is implemented.

(c) Cold Weather Concreting

Concrete shall not be placed in the works when the air temperature measured at the point of placement is below 5°C, unless special precautions as detailed in this clause are implemented to facilitate cold weather concreting works.

Concrete which has been damaged by frost as a result of failing to maintain the temperature of the concrete surface above 5°C will be rejected.

Special precautions shall include the following measures to ensure compliance with the requirements of this section:

- (i) heating and blending mixing water to a maximum of 70°C and keeping concrete temperature to below 32°C
- (ii) heating the aggregates
- (iii) use winter grade admixtures
- (iv) use higher concrete grade
- (v) control sequence of batching ingredients when some are heated to avoid flush setting and balling within the agitator
- (vi) avoid delays in delivery to avoid heat loss during transit
- (vii) improve thermal effects by utilising insulating materials and thermal blankets as part of formwork and curing and maintain uniform temperature conditions within the curing chamber until required strengths are achieved.

(d) Wet Weather Concreting

Concrete shall not be placed during rain or when rain appears imminent.

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

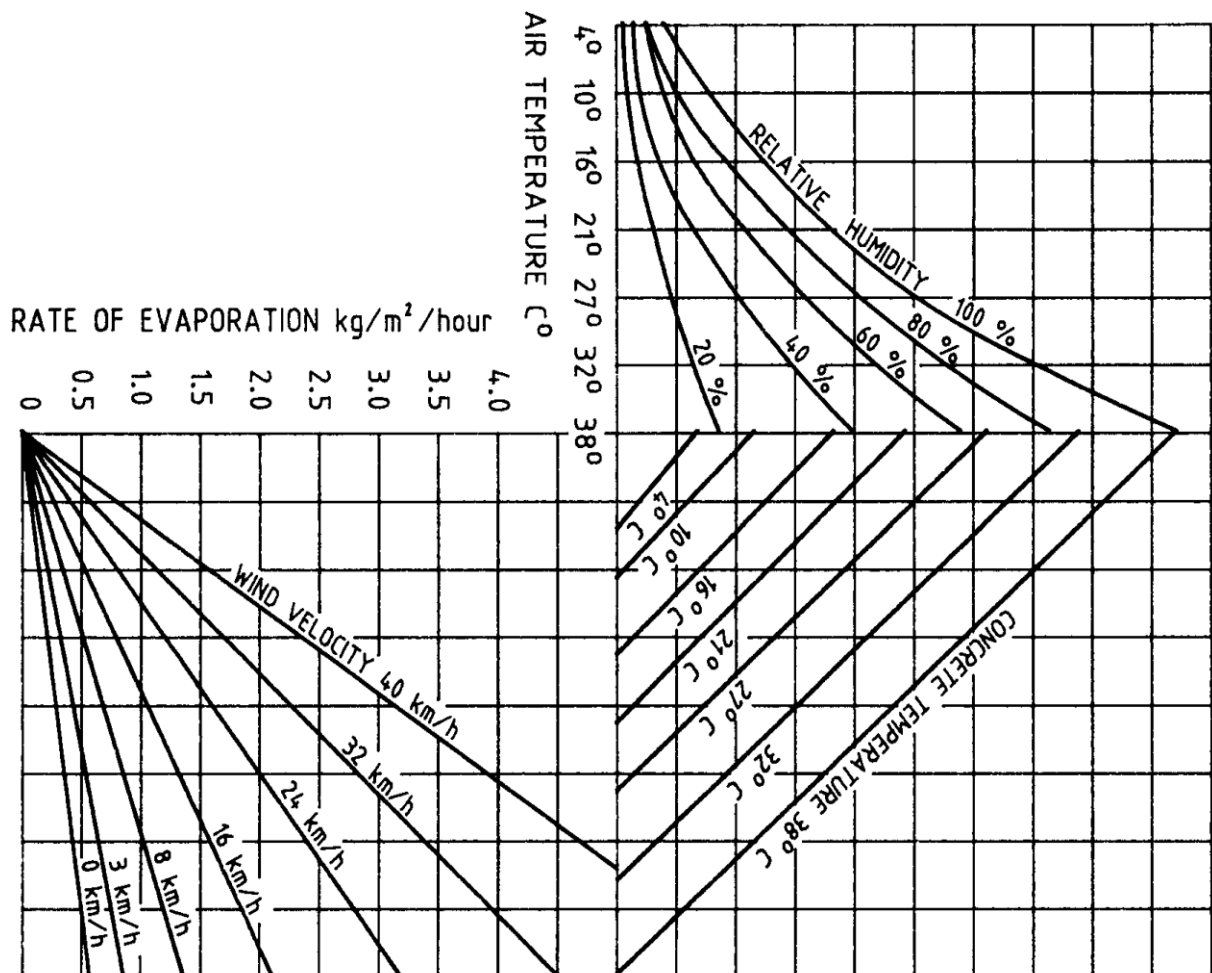
Any concrete which is exposed to rain or other precipitation within the period from placement to curing will be nonconforming.

(e) Evaporation Limits for Concreting Operations

The Contractor shall be responsible for measuring and recording the air temperature, relative humidity, concrete temperature and wind velocity (measured one metre above the as placed concrete) at the point of concrete placement from commencement of placing the concrete and continue until curing has commenced. This information shall be used in conjunction with Figure 610.171 to determine the rate of evaporation of water from the freshly placed and unprotected surface of the concrete. The rate of evaporation shall be monitored by the Contractor until such time as curing commences.

When the value of the rate of evaporation as determined from Figure 610.171 exceeds 0.50 kg/m<sup>2</sup> per hour the Contractor shall take precautions to minimise evaporative moisture losses such as the application of an aliphatic-alcohol based evaporative retarding compound or controlled fog spray.

Figure 610.171- Evaporation of Water from Freshly Placed Concrete





## (f) Application of Evaporative Retarding Compound

The evaporative retarding compound, when required, is to be applied immediately after initial screeding. The remaining finishing operations can be carried out after application of the compound.

An evaporative retarding compound shall be used for concrete decks and slabs.

Application of the evaporative retarding compound shall be implemented in accordance with the manufacturer's instructions. It shall be applied in a uniform manner to produce a continuous film to protect freshly placed concrete and minimise the evaporative water loss during finishing operations.

The evaporative retarding compound shall contain a fugitive dye to ensure uniform application and enable clear differentiation between covered and non-covered areas.

**Details of the proposed evaporative retarding compound and its application procedure including minimum application rates, shall be submitted to the Superintendent Council for review not less than four weeks prior to the commencement of concreting works.**

**610.18 PLACING AND COMPACTING CONCRETE**

## (a) Placing – General

**The Contractor shall submit a detailed work method statement(s) (WMSs), inspection and test plan(s) (ITPs) and quality control checklist(s) for all concrete construction works which explicitly reference the acceptance criteria and all performance requirements of Sections 610, 611, 613 and 614, for review by the Superintendent Council not less than 4 weeks prior to the placement of concrete. Generic or incomplete WMSs and ITPs will not be accepted.**

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Concrete shall not be placed until:

- (i) **the Contractor's has a quality system in place documenting WMS, ITPs and quality control checklist(s) ~~have been reviewed by the Superintendent~~**
- (ii) **the evidence that the forms, reinforcement, any stressing materials and embedments conforming to the requirements of this specification and the drawings, has been reviewed by the Superintendent Council**
- (iii) **all foreign material has been completely removed from the forms**
- (iv) **the Contractor has implemented a documented process ~~submits documented evidence of~~ conducting tool box meetings of all concrete construction personnel on all aspects of the WMS, the ITPs, quality control checklist(s) and all specification requirements**
- (v) **the Contractor ~~submits~~ has implemented a site sampling and testing procedure in accordance with the minimum frequency of testing requirements of this section for assurance of concrete quality, and as stated in clause 610.16(b), clause 610.16(c) and clause 610.16(n), including superplasticised concrete and SCC.**

Concrete shall be transported, handled and placed so as to prevent segregation, loss or leakage of materials.

Concrete shall not be dropped freely from a height exceeding two metres. Where placing concrete would otherwise necessitate a drop exceeding two metres, suitable tremie pipes, chutes or other concreting devices shall be used to place the concrete to prevent segregation. Concrete shall not be moved horizontally by the use of vibrators.

Concrete shall be supplied at an adequate rate in a continuous operation to ensure that all the concrete in the forms can be kept plastic until placed in its final position and compacted, and all temporarily exposed surfaces covered by and knit in with fresh concrete so that no cold joints are formed. Equipment and personnel shall be adequate to maintain the rate of concrete placement adopted.

**In continuous concrete pours the maximum time lag between truck loads on site shall not exceed 25 minutes.**

No strain shall be placed on any projecting reinforcing steel or embedment for a period of at least 12 hours following completion of concreting.

For construction of deck slabs the fixed screed supports shall be placed parallel to the longitudinal centreline of the bridge.

Concrete above deck shall not be placed until the deck formwork or the falsework for the span has been released and/or any post-tensioning and grouting operations are completed.

Prior to placing concrete any absorbent surfaces including blinding concrete and construction joints shall be thoroughly moistened and excess free water shall be removed.

(b) Pumping of Concrete

Pumping of concrete may only be used when the concrete mix is designed for such placement method.

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

Pumping equipment shall be positioned such that freshly placed concrete is not affected by vibration in accordance with the requirements of clause 610.38.

(c) Placing Concrete in Bored Piles, Under Water and in Dry Bores

**The Contractor shall submit the procedure for placing concrete in bored piles, under water and in dry bores, for review by the Superintendent Council at least four weeks prior to concreting.**

**Concrete shall not be placed in bored piles, under water or in a dry bore until the proposed method of placement of concrete has been approved by the Superintendent Council.** The minimum concrete grade for concrete placed in bored piles, under water or in dry bores shall be VR400/40, in accordance with the requirements of this section. The proposed mix shall be either a self compacting concrete (SCC) or a highly workable concrete as specified in clauses 610.13(b) and 610.13(c) respectively.

Highly workable concrete shall be compacted in accordance with the requirements of this section.

Placing of concrete in bored piles, underwater or in a dry bore shall be carried out in one continuous operation by tremie methods in accordance with Section 606. Concrete shall not be placed in water which has a temperature of less than 5°C.

Unsound or contaminated areas of exposed concrete shall be removed and the surface thoroughly prepared in accordance with clause 610.20 prior to subsequent placement of concrete.

Where cofferdams or cylinders have been sealed by underwater placement of concrete, dewatering shall not proceed until at least 48 hours after completion of concrete placement.

(d) Compaction, Screeding and Finishing of Concrete

(i) Compaction

Care shall be taken during compaction to fill every part of the forms or excavations, to force the concrete under and around the reinforcement and any other embedded fixtures without displacing them, to work coarse aggregate back from the face, and to remove air bubbles and voids.

Concrete shall be deposited in horizontal layers not more than 350 mm thick except in the manufacture of prestressed concrete members. For prestressed members the concrete shall be built up to the full depth of the section and the concrete face moved forward progressively. For prestressed concrete members over 600 mm deep this may occur in two or three passes.

During and immediately after placing, the concrete shall be effectively compacted by internal vibrators of adequate size, number and frequency and supplemented as required by external form vibrators. A minimum of two internal vibrators shall be provided at any time.

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 to avoid leaving a defect. Concrete shall not be vibrated to the point where segregation of the ingredients occurs.

Internal vibrators shall be inserted vertically at successive locations at spacings not exceeding the manufacturer's stated zone of influence, and shall not be allowed to rest on the steel reinforcement, embedded fixtures or formwork.

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

Concrete decks or slabs shall be compacted by internal vibrators and vibrating screeds such that uniform consolidation is achieved throughout the deck and slab area.

**Where approved by the Superintendent Council proprietary power vibrating screeds of suitable widths may be used in narrow or constricted areas or where required by the deck and slab layout, with each new vibrating run overlapping the previous one by a minimum of 300 mm, such that uniform consolidation is achieved throughout the deck and slab area.**

Where intense compaction is specified both external form vibrators and internal vibrators shall be used.

Where rigid formwork is specified on the drawings only steel forms shall be used.

Internal vibrators shall always be used when external form vibrators are used.

(ii) Screeding of Exposed Surfaces

Immediately after placing and compaction, exposed surfaces other than decks and slabs shall be screeded off to the specified levels and finished with a wooden float to an even uniform surface. Construction joints shall be left rough in accordance with clause 610.20.

During screeding surplus concrete shall be maintained ahead of the screed to ensure full and uniform compaction to exposed concrete surfaces.

Concrete deck and slab surfaces shall be screeded on a longitudinal direction using vibrating screeds on screeding guides. The screeding guides shall be accurately set and rigidly fixed in position. Guides shall be capable of sustaining construction loading without undue or permanent deflection.

**The Contractor shall submit its proposed method of compaction adjacent to screed guides, and its proposed method and timing of repairs at screed guide supports for review by the Superintendent Council.**

(iii) Finishing of Exposed Surfaces

Final finishing of exposed concrete surfaces shall be carried out after all bleed water has been removed and the concrete has become sufficiently hard to support the finishing operation. Driers (i.e. dry sand, cement or stone dust) shall not be used to absorb free water.

Finishing of concrete decks or slabs shall be effected with a power trowel fitted with rotating steel floats.

Any drying cracks which appear prior to initial set and before or during finishing operations shall be immediately closed as required with either a wooden or steel float.

Curing shall commence immediately following the progressive completion at any location of final finishing operations.

(iv) Protection of Self Compacting Concrete (SCC) from Vibration and Disturbance

Notwithstanding the requirements of this clause, SCC shall not be vibrated or be subjected to any physical disturbance after deposition. The Contractor shall undertake adequate precautions and manage the effects of external sources of vibration from nearby activities and construction equipment, in accordance with the requirements of clause 610.38, to ensure that the freshly placed SCC remains undisturbed and does not segregate.

### 610.19 CONCRETE CASTING SEQUENCE

The casting sequence shall be as shown on the drawings or as specified in this specification.

(a) Deck Casting Sequence

The deck casting sequence shall be as shown on the drawings or as specified in this specification. At least seven days shall elapse between the casting of adjacent sections. The maximum deck casting length shall be 25 metres.

(b) Box Girder or Voided Slab Casting Sequence

**The Contractor shall submit details of the proposed casting sequence and falsework design, including the proof engineering certificate of compliance for review by the Superintendent Council. All falsework shall comply with the requirements of Section 613.**

Casting sequence details shall include the length of segments, the order of casting and whether segments are to be cast monolithically or in stages. Box girders or voided slabs shall be cast in longitudinal segments with a maximum segment length of 25 metres. At least seven days shall elapse between the casting of adjacent segments.

Segments incorporating a transverse diaphragm shall be cast monolithically with the full cross section of the webs, floor and deck slab extending a distance of at least five metres from the face of the diaphragm.

Segments which do not incorporate transverse diaphragms shall be cast monolithically with the full cross section of webs, floor and deck slab, or alternatively may be cast in two stages with a construction joint provided between the webs and the deck slab. If the latter method is adopted, the deck slab shall be cast not later than 14 calendar days after the casting of the webs and floor slab.

### 610.20 CONSTRUCTION JOINTS AND BONDING OF NEW CONCRETE

The location and details of construction joints shall be as shown on the drawings.

**Construction joints whose location and details are not as shown on the drawings shall be subject to approval by the Superintendent Council.**

The placing of concrete shall proceed continuously from joint to joint.

Any point at which the placing of concrete has stopped and the concrete has taken its initial set shall be treated as a construction joint.

Construction joints shall be perpendicular to the principal lines of stress, and in general shall not be located in regions of maximum bending or maximum shear.

At the base of columns or walls construction joints shall be located at least 100 mm above the tops of the footings or pilecaps.

Where applicable, concrete in the existing structure shall be broken back as shown on the drawings. Any cracked or damaged concrete remaining after breaking back shall be removed and replaced with new concrete.

Before placing new concrete against concrete which has set, the forms shall be re-tightened.

Construction joints shall be prepared to produce a well-bonded interface between hardened concrete and freshly placed concrete.

Concrete against which new concrete is to be placed shall be roughened by removing all laitance and sufficient mortar to expose the coarse aggregate to a depth of 3 mm, with the coarse aggregate still firmly embedded in the concrete. The roughened surface shall be cleaned of foreign matter, laitance and loose or porous material. Any projecting steel reinforcement shall also be cleaned. The surface shall be thoroughly moistened with water and any excess surface water removed immediately prior to placing of concrete.

**610.21 INSERTIONS AND GREASED JOINTS**

Abutting surfaces of concrete shall be separated by grease or other surface coatings or insertions of bituminous impregnated felt or fibreboard as shown on the drawings, so as to prevent the surfaces from bonding or binding together.

Dowels shall be placed as shown on the drawings and prior to placing the surrounding concrete.

**610.22 CONTROL OF EARLY AGE THERMAL CRACKING OF LARGE AND RESTRAINED MEMBERS**

Measures shall be taken to control early age thermal cracking of concrete for large and restrained members including but not be limited to crossheads, diaphragms, columns, abutments, footings and pile caps where:

- (a) the least dimension of a member exceeds 500 mm; or
- (b) one or more faces of a concrete member is restrained by previously placed hardened concrete or by other external restraints.

Except where justified by analysis and testing, the temperature differential across the concrete member being constructed shall not exceed 20°C during the period of curing. The Contractor shall implement special precautions to reduce differential temperature build-up prior to the temperature differential between the concrete core and that of the exposed concrete surface exceeds 20°C. As a minimum the special precautions shall consist of 2 layers of 8 mm thick closed cell foam or inner double core aluminium foil based thermal blankets.

Thermocouples shall be placed at a range of positions within the large and restrained concrete member to determine the maximum temperature and differential temperature across the section of concrete.

Thermocouples with an accuracy of  $\pm 1^\circ\text{C}$  shall be cast into each large or constrained concrete member, located in the centre of the core and 25 mm below the exposed surface, and monitored at continuously regular intervals by data loggers until the temperature difference falls such that control measures are no longer required.

**The temperature data acquired and proposed control measures to reduce differential temperature within the specified limits shall be submitted for review by the ~~Superintendent~~ Council.**

Temperature differential monitoring shall be undertaken on at least one representative member from each type of large and restrained members, provided that any required control measures to reduce the differential temperature within the specified limits is adopted for the subsequent construction of members of the same type.

The maximum internal temperature of all concrete members following concrete placement shall not exceed 75°C.

**610.23 CURING**

- (a) General

Curing of concrete shall be carried out using one or a combination of the methods as specified in clauses 610.23(c), 610.23(d), 610.23(e), 610.23(f), 610.23(g) and 610.23(h).

The curing of exposed concrete surfaces shall commence immediately after finishing operations are progressively completed at any location and shall continue uninterrupted for not less than the periods specified in Table 610.231.

**HP**

**The Contractor shall submit to the ~~Superintendent~~ Council for review, full details of the proposed methods of curing, as part of the concrete mix design submission, not less than four weeks prior to placement of concrete. The Contractor shall not proceed with the placement of concrete until the curing method(s) has been reviewed and approved by the ~~Superintendent~~ Council.**

Details submitted shall include the following information for the proposed methods of curing:

- (i) Water Curing - materials, method and timing of curing
- (ii) Curing Compound - technical specification of the proposed curing compound including the timing, rate of application, procedure for the determination of the application rate and method of removal (where required)
- (iii) Polyethylene Sheet - material and method of application, sealing and control
- (iv) Maintaining Formwork in Place - timing, method of sealing the formwork and curing exposed surfaces
- (v) Steam or Radiant Heat Curing - full details of control methods and proposed curing cycle.

(b) Period of Curing

The period of curing shall be not less than the number of days given in Table 610.231.

The Contractor shall implement a quality procedure in accordance with the minimum requirements of Table 610.231 to ensure that for concrete decks and slabs, the periods of curing are extended by 2 days and when the average air temperature during the specified periods of curing falls below 10°C, the periods of curing are extended by 2 days. **The Contractor shall ensure that records of temperature monitoring during the curing period are available for review by the Superintendent Council.**

**Table 610.231**

Periods of Curing (excluding steam and radiant heat curing)				
Concrete Grade	Exposure Classification	Type of Cement	Periods of Curing (days)	
			Average Air Temperature During Curing	
			10°C to 17°C	Above 17°C
VR330/32	A, B1	GP	7	6
		GB	9	8
VR400/40	B2	GP	6	5
		GB	8	7
VR450/50 VR470/55	C1, C2	GP	5	5
		GB	7	7
For concrete decks and slabs, the periods of curing shall be extended by 2 days.				
Notes: 1. Type of cement: GP - General purpose portland cement GB - General purpose blended cement				
2. When the average air temperature during the specified periods of curing falls below 10°C, the periods of curing shall be extended by 2 days.				
3. Where a higher concrete grade is adopted than that shown for a particular exposure classification, the periods of curing for the higher concrete grade may be adopted.				

The curing periods for concrete grades higher than VR470/55 shall be the same as those for concrete grade VR470/55.

(c) Water Curing

All surfaces of the concrete shall be kept continually moist for the specified periods of curing by continuous spraying, ponding, wet hessian, felt matting or sand blankets and the concrete maintained at a temperature above 5°C. Wet curing materials used on vertical surfaces shall be securely wrapped during the whole curing period to ensure that all surfaces are evenly and effectively cured. The water used shall conform to the requirements of clause 610.09.

(d) Curing Compounds

(i) General

Curing compounds shall comply with the requirements of AS 3799. The concrete shall be maintained at a temperature above 5°C.

Prior to the use of curing compounds, full details of the proposed curing method shall be submitted to the Superintendent Council, including the time and rate of application, documented evidence of the effectiveness of the compound as a curing agent supported by test certificates endorsed in accordance with the AS ISO/IEC 17025 accreditation for the testing laboratory and method of removal where required. The test certificates 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 present the results of uniformity testing of the curing compounds for both non-volatile content and density in accordance with AS 3799 clause 3.2, and for viscosity in accordance with AS 3799 clause 3.1.5.

(ii) Specific Requirements

Curing compounds shall not be used on concrete decks or slabs, unless an aliphatic-alcohol based evaporative retarding compound is also applied after initial screeding in accordance with clause 610.17(f).

PVA based curing compounds shall not be used.

The curing compounds shall be pigmented sufficiently to allow visual inspection to ensure full application on the surface. The pigment shall not be visible fourteen days after application. Curing compounds shall not have a deleterious effect on the concrete or stain the surface of the concrete.

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<sup>2</sup> per coat, whichever is the greater.

Two coats shall be applied at the full rate.

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

Curing compounds shall not be applied to construction joints unless the joint is to be roughened or sandblasted at a later date.

Curing compounds shall not be applied to surfaces which are to be subsequently coated unless they are compatible with the coating, waterproofing or surfacing system or provision is made for removal of the compound from these surfaces prior to the application of the coating, waterproofing or surfacing system.

The curing membranes shall be maintained intact for not less than the specified period of curing. Any damage to the curing membranes during the period of curing shall be repaired immediately at the original rate of application.

(iii) Determination of Application Rate of Curing Compound

The application rate shall be checked by calculating the amount of curing compound falling on felt mats, each approximately 0.25 m<sup>2</sup> in area, placed on the concrete surface during the application of the curing compound.

The application rate shall be determined as follows:

- (1) pre-weighed absorbent felt mats placed at different places on the area to be sprayed
- (2) after the applicator has covered the area concerned, the felt mats are immediately folded with their wet sides together, placed in plastic bags to prevent evaporative losses and weighed
- (3) the application rate (r) shall be determined as follows:

$$r = m/A \times \rho$$

where r = application rate, (litres/m<sup>2</sup>)

A = area of felt mat, (m<sup>2</sup>)

ρ = density of curing compound (kg/litre), which may be available from the material manufacturer's data sheet or the test report

m = net mass (weight of felt mat with curing compound minus pre-weighed felt mat) (kg)

(e) Polyethylene Sheet

Polyethylene sheet shall be of sufficient strength to withstand wind and any imposed foot traffic or physical loading. Torn or punctured sheeting shall not be used. Laps shall be 300 mm minimum and edges and laps shall be sealed by tape or held down by boards or other means. All edges and laps shall be sealed against evaporative moisture losses for the duration of curing. Water shall be sprayed under the sheeting at the edges and at laps on the day after placing concrete and at regular intervals to maintain moist conditions.

Polyethylene sheet shall not be used on concrete decks or slabs unless used in conjunction with water curing.

(f) Curing by Maintaining Formwork in Place

Where formwork is left in place to satisfy the formwork removal times as specified in clause 610.25, or where formwork is left in place for the specified period of curing or part thereof, the exposed surfaces of the concrete shall be cured and the formwork shall be sealed against evaporative moisture losses for the duration of curing.

Where formwork is removed prior to the completion of the curing period, curing shall recommence within half an hour and continue until the total curing time is not less than the periods of curing specified in Table 610.231.

(g) Steam Curing

(i) General

Method of control and the proposed curing cycle to achieve the specified concrete compressive strength shall be submitted to the Superintendent Council. After the initial 'maturity' period, units shall be cured in an atmosphere saturated with water vapour at a pressure not exceeding atmospheric pressure.

The Contractor shall take measures to allow for the potential lower 28 day compressive strength obtained from test cylinders cured initially under in situ conditions, as compared to those cured in accordance with the requirements of AS 1012.

(ii) Steam Covers

To prevent drying out, steam covers shall be placed over the units immediately following the casting and screeding operations in such a manner as to ensure free circulation of the steam around the concrete mass.



(iii) Curing Cycle

After an initial 'maturity' of 40°C hours, but not less than two hours after batching the last batch of concrete for the units, steam shall be admitted to the steam covers at such a controlled rate that the maximum average temperature rise shall not exceed 24°C per hour. (Note: The initial 'maturity' period is calculated by dividing 40°C hours by the concrete temperature of the last batch of concrete placed in the unit. The concrete temperature is as measured on an indicating thermometer.) In addition, the temperature rise in any one fifteen minute period shall not exceed 6°C.

If the admission of steam to the steam covers is delayed by more than the initial specified 'maturity' of 40°C hours after the completion of placing of concrete, water curing, as specified in clause 610.23(c) shall be applied until steaming commences.

Steaming shall continue at a rate such that the temperature rise shall not exceed 24°C per hour, until a temperature under the steam covers of not greater than 70°C has been reached. The corresponding maximum temperature of the concrete shall not exceed 75°C.

After the elapse of sufficient time at the maximum temperature for the required concrete properties to have been reached, steam shall be completely shut down. Steam covers shall not be removed nor any part of the concrete units and test cylinders disturbed or operated upon in any way until the temperature under the steam covers has fallen to within 30°C of the ambient temperature. Also the rate of loss of temperature under the steam covers after shutting off steam shall not exceed 30°C per hour.

(iv) Temperature Controls

Temperature shall be recorded by means of recording thermometers supplied and installed by the Contractor. These thermometers shall be maintained in good condition and calibration. The temperature sensitive parts of the thermometers shall be so positioned under the steam covers as to cause the thermometers to record the minimum temperature under the covers. One recording thermometer shall be used for each unit or group of units in line up to a total length of 25 m. For greater lengths, additional recording thermometers shall be used and the distance between the temperature sensitive parts of the thermometers shall not exceed 25 m.

The recording thermometers shall be set in operation immediately upon completion of the casting and screeding, the temperature sensitive part of each thermometer being installed in position at the same time.

Charts shall not be removed from any recording thermometers, nor the recording thermometers disturbed or moved in any way until after the removal of the steam covers.

Charts from temperature recording thermometers shall be retained.

The following information shall be recorded on the chart:

- (1) date on which steaming commenced
- (2) unique identification and description of concrete unit
- (3) temperature correction, if any
- (4) time correction, if any
- (5) batching of concrete
- (6) temperature of concrete when placed
- (7) ambient temperature at time of removal of steam covers
- (8) name of Contractor or manufacturer.

(v) Steam Delivery

Under no circumstances shall steam jets be allowed to impinge upon any part of the concrete units or of a test specimen, or of their formwork or moulds. Neither shall any steam delivery pipe be attached directly to any formwork or moulds in such a manner as may cause localised overheating of the concrete.

Sufficient steam jets or steam entry points shall be provided to ensure that a substantially uniform temperature is maintained under the steam covers such that the difference in temperature between any two points adjacent to the concrete units is not more than 10°C.

(vi) Extent of Steam Curing

Unless otherwise specified, steam curing shall be continuously applied until at least the 7 day compressive strength for the specified concrete grade is obtained.

(vii) Partial Steam Curing

Where steam curing is used only to obtain sufficient compressive strength for removal of forms or for lifting, curing shall be continued by one or a combination of the methods specified in clauses 610.23(c), (d) and (e) for a minimum period of seven days from the time of finishing the concrete.

Where partial steam curing is employed as above, curing shall recommence within half an hour of the cessation of steam curing.

The minimum requirements of clause 610.23(g)(iii) shall be complied with.

(viii) Curing of Test Cylinders

Concrete compression test cylinders shall be placed near the concrete units, and shall be so positioned under the steam covers as to be midway between two adjacent points of steam entry, subject always to their being no closer to any points of steam entry than half the width of the concrete units. Test cylinders shall be positioned in a group at the lower face of the concrete unit and shall in no case be placed on top of the concrete unit or its formwork. Test cylinders shall remain in position under the steam covers until the steam curing cycle is complete. Test cylinders shall be suitably covered in such a way as to minimise moisture and temperature losses between the time of removal from the steam covers and the time of forwarding to an accredited laboratory for testing. Cylinders shall be transported in moisture proof containers.

(h) Radiant Heat Curing

(i) General

The application of heat shall be effected by the circulation of hot water which is fed through a series of conduits attached externally to the steel form. A heating box used for the curing of concrete test cylinders shall be connected to the hot water heating system.

(ii) Curing Cycle

The curing cycle of the radiant heat curing method shall be in accordance with clause 610.23(g)(iii) except that reference to steam curing shall be replaced by the application of hot water. The top surface of the finished concrete shall be kept moist throughout the curing cycle.

(iii) Temperature Controls

The water temperature shall be controlled by a thermostat and shall not exceed 70°C. The corresponding maximum temperature of the concrete shall not exceed 75°C. The temperature difference between ingoing and outgoing water shall be maintained at less than 10°C.

Temperature controls shall be in accordance with clause 610.23(g)(iv), except that reference to steam covers shall be replaced by curing covers. In addition to the specified requirements of clause 610.23(g)(iv), the Contractor shall also monitor the temperature of the test cylinder heating box by means of a recording thermometer. The difference in temperature between the test cylinder heating box and any point along the hot water heating system shall not exceed 10°C.

(iv) Curing Covers

To prevent drying out, curing covers shall be placed over the units after the top surface of the concrete has taken its initial set and the watering hose has been placed on the concrete.

(v) Extent of Radiant Heat Curing

Radiant heat curing shall be continuously applied until at least the 7 day compressive strength for the specified concrete grade is obtained.

(vi) Curing of Test Cylinders

Concrete test cylinders shall be placed in the heating box which is connected into the mould heating system as soon as the curing starts and shall remain in position until the curing cycle is complete. Test cylinders shall be suitably covered to minimise moisture and temperature losses between the time of removal from the heating box and the time of forwarding to an accredited laboratory for testing. Cylinders shall be transported in moisture proof containers.

(i) Delayed Ettringite Formation

To control the risk of delayed ettringite formation at later ages, the maximum concrete temperature during the curing period shall not exceed 75°C except where analysis has been performed that justifies a particular maximum temperature limit for concrete.

(j) Loading of concrete and vibration effects during the curing period

Concrete shall remain undisturbed and not be subjected to any loading or vibration effects for the minimum period of curing as stated in Table 610.231.

**610.24 CRACKING OF CONCRETE**

(a) General

The Contractor shall plan the various construction activities and control the supply and delivery of concrete, placing, compacting, finishing, curing and protection of freshly cast concrete such that cracking in concrete members is prevented.

(b) Maximum Acceptable Crack Widths

The concrete shall have no cracks at any stage after construction measured at the concrete surface of width greater than the relevant value given in Table 610.241 for the corresponding exposure classification. Where such cracks exist, they shall be identified as a non-conformance.

Notwithstanding the requirements of this clause the acceptable crack width at the concrete surface of pre-cast pre-stressed concrete members shall not exceed 0.1 mm.

**Table 610.241**

<b>Exposure Classification</b>	<b>Maximum Acceptable Crack Widths (mm)</b>
A	0.20
B1	0.20
B2	0.15
C, U	0.10

The Contractor shall undertake an assessment of the cracked concrete structure to evaluate the influence of cracks on the load bearing capacity, serviceability and durability.

The widths of cracks at the concrete surface may be measured using a plastic strip gauge with fixed width lines or a hand-held optical comparator fitted with a microscope and suitable measuring scale. Live/active cracks may be measured with the use of overlapping upper and lower plastic plates bonded across the crack or steel studs bonded across the crack and movement measured with a Demec gauge or similar device.

**HP The assessment of the cracked concrete structure shall be undertaken by a technical specialist with a minimum of 5 years practical experience in the diagnostic assessment and investigation of concrete structures.**

The assessment shall ensure that the cracking of concrete does not compromise the durability, strength, serviceability and appearance of the concrete structure.

The Contractor shall establish the cause(s) of the cracks, crack width, the moisture condition of the crack and whether a crack is active or inactive.

**HP The Contractor shall submit a crack repair procedure for the Superintendent Council's review, prior to any repair works being undertaken.**

The repair of concrete cracks shall be in accordance with Section 687.

(c) Repair of Inactive Cracks

Repair of inactive cracks shall be as follows:

- (i) Cracks up to 1 mm wide shall be repaired by pressure injection of low viscosity epoxy resin.
- (ii) Vertical cracks 1–2 mm wide shall be repaired by pressure injection of low viscosity epoxy resin. Horizontal cracks 1–2 mm wide shall be repaired either by pressure injection of epoxy resin or other repair methods which comply with the requirements of Section 687, provided a supporting assessment and evaluation by an appropriately experienced consultant has been submitted to the Superintendent Council for review.
- (iii) Cracks over 2 mm shall be repaired with filling materials and methods in accordance with the requirements of Section 687. Where the repair of such cracks is likely to result in the complete detachment of fractured pieces of concrete away from the main concrete member, such fractures shall be treated as patch repairs and repaired with polymer modified cementitious repair materials in accordance with the requirements of Section 689.
- (iv) Where cracks run through the entire cross section and are accessible from both sides of a concrete member the larger crack width measurement shall be the controlling width for the purposes of crack repair, thus requiring the full depth of the crack to be pressure injected with low viscosity epoxy resin and if necessary injected from both ends. Such concrete members shall include but not be limited to concrete decks slabs, all types of walls, slabs, columns, crossheads, diaphragms and abutments.

(d) Repair of Active Cracks

Live/active cracks shall be repaired using flexible filler materials and methods in accordance with the requirements of Section 687.

(e) Water Leakage through to Deck Slab Soffit

Following inspection, where crack repairs with pressure injected low viscosity epoxy resin fail to stop water leakage through the cross section to the concrete deck slab soffit, the whole of the top surface of the deck slab shall be waterproofed with the installation of a waterproofing membrane prior to the placement of asphalt in accordance with the requirements of Section 691.

## 610.25 REMOVAL OF FORMWORK

(a) General

Formwork shall be removed carefully and in such a manner as to avoid damage to the member or the concrete surfaces and maintain safety at all stages of removal.

(b) Formwork Removal Times

Formwork and formwork supports shall not be disturbed or adjusted during the concreting operation and shall remain in position and undisturbed until the minimum removal times given in Table 610.251 have elapsed, after completion of the placing of concrete.

(c) Vibration Effects Due to Construction Activities

Construction activities shall be planned and managed such that the formwork and concrete are not affected by vibration in accordance with the requirements of clause 610.38.

**Table 610.251**

<b>Concrete Members</b>	<b>Minimum Period before Removal of Formwork and Formwork Supports</b>
Soffits of beams, soffits of decks, soffits of slabs, soffits of cantilevers, soffits of diaphragms, soffits of pier and abutment crossheads and soffits of other structural members.	7 days or until such time as the concrete has reached the specified 7 day compressive strength, whichever is the greater.
(a) Vertical faces of members when height of each day's cast is: (i) Columns - greater than 7 metres (ii) Walls - greater than 4 metres (b) Load supporting sides of sloping walls of box girders.	5 days
(a) Vertical faces of members when height of each day's cast is: (i) Columns - 4 to 7 metres (ii) Walls - 2 to 4 metres (b) Vertical faces of beams and pier and abutment crossheads (c) Vertical faces of pad footings.	3 days
Vertical faces of members when height of each day's cast is: (i) Columns - less than 4 metres (ii) Walls - less than 2 metres	2 days
Sides of slabs and piles.	1 day
Where Type GB cement is used, the times for removal of formwork and formwork supports shall be increased by 1 day. This requirement shall not apply to vertical faces of beams and crossheads, columns and walls when the height of each day's cast is less than 4 metres or 2 metres respectively, or the sides of slabs and piles.	

Where the timing for the removal of formwork and formwork supports is based on compressive strength as given in Table 610.251, test cylinder(s) shall be prepared, cured and tested as specified in clause 610.16. In addition, the curing requirements of clause 610.23 shall apply to the newly exposed surfaces.

**610.26 REINFORCEMENT BAR CHAIRS AND SPACERS**

(a) Steel reinforcement supports

All steel reinforcement shall be securely held during placing and compacting of the concrete. Steel reinforcement supports shall comply with AS/NZS 2425. The supports shall be made of durable materials strong enough to withstand the imposed loads without movement of the steel reinforcement as specified in this section, shall be positively attached to the steel reinforcement, and of such size as to maintain the specified cover.

Concrete bar chairs and spacers shall be manufactured from machine mixed concrete and shall have a minimum 28 day concrete compressive strength of 60 MPa when tested in accordance with AS 1012.9. Notwithstanding the requirements of AS/NZS 2425, concrete bar chairs and spacers shall have a maximum VPV value at 28 days of 12% when tested in accordance with AS 1012.21. A sample consisting of two specimens shall be tested for each of compressive strength and VPV, in accordance with the sampling frequency as stated in clause 6.2 of AS/NZS 2425.

Each concrete bar chair and spacer mix design shall be tested for soluble salts (chloride ion and sulphate ion content) in accordance with AS 1012.20.1 on a 12 monthly basis or earlier if the mix design changes to demonstrate compliance with the requirements of clause 610.07(k) for soluble salts.

Reinforcement bar chairs and spacers for structures constructed in marine and other saline environments or subject to sulphate and chemical attack shall comply with the requirements of clause 610.29(f) in addition to the requirements of this clause.

Continuous bar chairs shall not be more than 350 mm in length and shall not be placed on a continuous straight line.

Bar chairs and spacers made of wood, metal, plastic coated metal and site made concrete shall not be used. Pieces of coarse aggregate or broken bricks or the like shall not be used to support steel reinforcement.

The Contractor shall submit for review by ~~the Superintendent~~ Council not less than 14 days prior to the proposed use of the steel reinforcement bar chairs and spacers, a signed statement including relevant test reports demonstrating compliance of the bar chairs and spacers with the specification.

Bar chairs and spacers which do not comply with the requirements of this section shall not be used in the Works.

(b) Placing

All steel reinforcement shall be securely held with the correct tie wire during placing and compacting of the concrete. The supports shall be positively attached to the steel reinforcement, and of such size as to maintain the specified cover. Bar chairs and spacers shall be placed sufficiently close together to ensure that the specified cover is maintained before and during concrete placement, compaction and finishing operations, and to prevent any potential deformation, displacement or crushing of the bar chairs and spacers such that deformation or displacement of the steel reinforcement is also prevented.

The specified minimum concrete cover shall be maintained at tie wire positions. Excess tie wire shall be cut off and the twisted ends of wire ties shall project away from the cover zone.

Placing bars on layers of fresh concrete as the work progresses and adjusting bars during the placing of concrete will not be permitted.

## 610.27 ERECTION OF BEAMS AND OTHER CONCRETE MEMBERS

Prestressed and reinforced concrete beams and other concrete members shall not be erected and landed until the specified 28 day concrete compressive strength for piers or pier and abutment crossheads has been achieved, and not before 14 days after casting. Beams shall not be placed until at least seven days after pedestals have been cast. Where fixed bearings are specified beams shall not be placed until at least four days after fixing the dowels. Beams shall be placed so that anchor dowels at fixed bearings are engaged in the holes provided in the sole plates of beams.

Beams shall be braced to prevent overturning at all stages of construction.

**Should a Contractor desire to place slabs using construction equipment operating from a previously placed span of slabs, the written approval of ~~the Superintendent~~ Council shall be obtained.**

## 610.28 CONSTRUCTION OF PEDESTALS

Pedestals with a depth of less than 200 mm shall be constructed using a proprietary single component, self consolidating, and dual compensating (plastic and hardened state) non-shrink cementitious grout or a single component low shrinkage mortar specifically formulated for the construction of pedestals, complying with the minimum compressive strength requirements as specified on the drawings and in this specification. Only whole bags of material shall be used. Test certificates, material data sheets and health and safety data sheets shall be available for all materials. Pedestals shall be cured in accordance with the requirements of clause 610.23.

Proprietary cementitious materials which are specifically formulated and marketed as lightweight concrete repair materials shall not be used for the construction of pedestals.

Three (3) 75 mm test cubes shall be taken from the first batch of material mixed, then three (3) 75 mm cubes for every 100 kg of material used thereafter to test for compressive strength. The cubes shall be cured for seven days under laboratory-controlled conditions. Two (2) cubes shall be tested at seven days and the third cube at 28 days to confirm compliance with the minimum compressive strength requirements as specified on the drawings and in this specification and the material manufacturer's technical data sheet. Test cubes shall be made in rigid steel moulds, cured and tested in accordance with AS 1478.2.

The contact face of the concrete shall be flat and have a surface roughness between an amplitude of 0.5 mm to 1.5 mm, with a surface presenting similar to Grade 40-grit sandpaper.

## 610.29 PROTECTIVE MEASURES FOR THE CONSTRUCTION OF STRUCTURES IN MARINE AND OTHER SALINE ENVIRONMENTS

Further to the requirements of clause 610.07(g) the following protective measures shall be implemented during the construction period to prevent the ingress of chlorides in the concrete in its early maturing and strength developing period.

### (a) Protection Against Ingress of Chlorides

- (i) All reinforcement and embedded metallic fixtures shall be protected against chloride contamination.
- (ii) All reinforcement and construction joints shall be cleaned with water complying with the specification prior to casting the concrete to ensure that salt deposits are removed.

### (b) Curing

Further to the requirements of clause 610.23, the period of continuous curing for all cast-in-place concrete shall be not less than 14 days.

Combinations of water adding techniques such as ponding or continuous sprinkling, or by continuous application of mist spray, retention of formwork in place and polyethylene plastic (in combination with wet hessian) shall be used to provide effective curing to the exposed surfaces of concrete of the various cast-in-place members.

Curing compounds shall not be used for the construction of structures in marine, brackish and other saline environments.

### (c) Extended Protection of Concrete During the Curing Period

Formwork shall be kept in place for the minimum period in accordance with the requirements of clause 610.25 prior to removal. Immediately following the removal of formwork, and for the remainder of the curing period, polyethylene sheet in combination with wet hessian shall be used to protect the surfaces of concrete being cured against ingress of chlorides from salt water or sea spray.

### (d) Electrical Continuity of the Steel Reinforcement

Steel reinforcement shall be made electrically continuous in all substructure concrete members, including piles, to allow for future application of a cathodic protection system if required.

(e) Application of Protective Coatings

The following protective coatings shall be applied in accordance with Section 686.

- (i) Concrete surfaces extending between 0.5 m below the low water level and 0.5 m above the high water level

An epoxy protective coating shall be applied to all exposed surfaces of concrete extending between 0.5 m below the low water level and 0.5 m above high water level. The epoxy protective coating shall be grey in colour and shall be a solvent free, high build epoxy system, providing good chemical, abrasion and corrosion resistance, for horizontal and vertical surfaces of concrete or steel. The epoxy coating shall be applied in a minimum of two coats to a dry film thickness of 300 microns.

The epoxy coating shall be a two pack, solvent free epoxy coating with a volume solids content of 100%, and shall exhibit the following chemical resistance characteristics to a range of aggressive chemicals including:

- (1) Sodium hydroxide, Sulphuric acid, Nitric acid and Hydrochloric acid @ 25%;
- (2) Tartaric acid and Acetic acid @ 15%;
- (3) Lactic acid @ 10%; and
- (4) Resistance to saturated salt, saturated citric acid, petrol and kerosene.

The appearance of the finished product has a high priority and the application of the coating system must ensure a uniformity of colour.

- (ii) Concrete surfaces 0.5 m above the high water level

A dual protective coating system consisting of a pore-lining penetrant (i.e. silane, solid silane or silane cream) and two coats of a film-forming decorative/anticarbonation top coat shall be applied to all exposed surfaces of concrete extending from 0.5 m above the high water level including columns, pier and abutment crossheads, all exposed beam surfaces, sides and exposed soffits of deck slabs, parapet units, end posts, fender walls, keeper walls and wingwalls in accordance with the requirements of Section 686.

In addition to the general requirements of clause 686.05(a) and clause 686.05(c)(i) the dual protective coating system shall satisfy the following requirements:

- (1) Silane pore-lining penetrants shall consist of at least 95% active ingredients and shall be applied in two applications and the application rate shall be a minimum 0.30 litres/m<sup>2</sup> per application. Solid silane or silane cream pore-lining penetrants shall consist of at least 80% active ingredients and shall be applied in one thick application and the application rate shall be a minimum 0.40 litres/m<sup>2</sup>.
- (2) The film-forming topcoat shall satisfy the requirements of clause 686.05(b) for decorative / anti-carbonation coatings, except that its dry film thickness shall be at least 200 micron.

(f) Reinforcement Bar Chairs and Spacers for Structures Constructed in Marine and Other Saline Environments

Further to the requirements of clause 610.26 steel reinforcement for structures constructed in marine and other saline environments shall be supported by premium grade extruded fibre concrete bar chairs and spacers manufactured under factory controlled conditions, using non-metallic synthetic fibres.

The premium grade extruded fibre concrete bar chairs and spacers shall comply with the sampling and testing requirements of clause 610.26.

Supports and spacers made of plastic, wood, metal, plastic coated metal and site made concrete or factory produced non extruded fibre concrete shall not be used for structures constructed in marine and other saline environments. Bar chairs and spacers shall be placed sufficiently close together to ensure that the specified cover is maintained before and during concrete placement, compaction and finishing operations, and to prevent any potential deformation, displacement or crushing of the bar chairs and spacers such that deformation of the steel reinforcement is also prevented



## (g) Construction Joints in Sea or Brackish Water

Further to the requirements of clause 610.20, unless shown otherwise on the drawings, construction joints in sea or brackish water shall not be located from 1.0 m below minimum low water to 1.5 m above maximum high water tide levels.

## (h) Other Concrete Durability Enhancing Measures

Other concrete durability enhancing measures such as controlled permeability formwork (CPF), stainless steel reinforcement, and corrosion inhibiting admixtures, cathodic prevention and glass reinforced concrete permanent formwork shall be as specified in the drawings and specification.

**610.30 PROTECTIVE MEASURES FOR CONCRETE STRUCTURES SUBJECT TO SULPHATE AND CHEMICAL ATTACK**

Concrete structures subject to sulphate and chemical attack with a pH lower than 5.0, or where highly mobile ground water conditions exist or high exchangeable soil acid conditions prevail the environment shall be assessed as exposure classification U and be subject to special consideration. As a minimum when conditions as stated in this clause prevail, additional protective measures in addition to the requirements of clause 610.07(h) shall include the application of suitable protective coatings in accordance with Section 686 and/or other physical protection subject to approval by the Superintendent Council. Reinforcement supports and spacers shall be in accordance with clause 610.29(f).

**610.31 SURFACE FINISH**

## (a) General

For any particular class of concrete surface finish, the method of construction and the materials used in the concrete and formwork shall remain consistent and shall be such as to comply with the requirements of this specification.

The Contractor shall undertake the works such that the standard of surface finish is not adversely affected by the quality of formwork, the formwork release oil used, the compaction of the concrete, and the manner in which the formwork is removed. The higher the standard of surface finish required the greater care shall be taken to satisfactorily address these factors.

Formwork release oils or lubricants used to prevent adhesion of the freshly placed concrete onto the formwork shall be of the non-staining type and shall not discolour the surface of the concrete. The release oil or lubricant shall be applied uniformly in a thin film and any surplus removed prior to the concrete placement.

The concrete shall be effectively placed and compacted in accordance with the requirements of clause 610.18 to avoid the entrapment of bubbles and formation of blowholes, surface imperfections and other defects in the surface of formed concrete. The surface finish of formed concrete shall be of a uniform colour and texture.

Formwork shall not be removed until the concrete has the required strength to resist any formwork suction forces in accordance with the requirements of clause 610.25.

The use of mortar topping will not be permitted.

## (b) Types of Surface Finishes

The following surface finishes are specified:

- \* Class 1
- \* Class 2
- \* Class 3
- \* sandblast
- \* rope
- \* tooled and bush hammered
- \* exposed aggregate
- \* scabbled
- \* broomed
- \* off-form.

(c) Cast In Situ Concrete Surfaces

Except where other surface finishes are specified on the drawings, surface finishes Class 1, Class 2 and Class 3 shall be used as follows:

(i) Substructure

The back of abutments, culverts and wingwalls shall have a Class 1 surface finish. All exposed surfaces of abutments, wingwalls and piers from 300 mm below ground level shall have a Class 2 surface finish, except that in cellular structures the faces of wingwalls and ends of piers or walls only shall have a Class 2 surface finish.

Upper surfaces of concrete bearing pedestals shall have a Class 2 surface finish.

(ii) Superstructure

The underside of deck between beams shall have a Class 1 surface finish. The faces and undersides of the beams, the edges and the underside of the cantilevered deck slab shall have a Class 2 surface finish. The interior and exterior faces of kerbs and the upper surfaces of the kerbs shall have a Class 3 surface finish.

For box girder bridges, the inside surface of box girder webs, floor and deck shall have a Class 1 surface finish. All external surfaces of the box girder and voided slab shall have a Class 2 surface finish.

(iii) Above Deck Surface

All surfaces above the tops of kerbs shall have a Class 3 surface finish. End posts shall have a Class 3 surface finish. Precast parapet units and associated cast-in-place concrete shall have a Class 3 surface finish.

(d) Top Surface of Decks and Approach Slabs

All deck and approach slab surfaces shall have a broomed finish in accordance with clause 610.31(n).

(e) Precast Concrete

Except where other surface finishes are specified on the drawings, surface finishes for precast members shall be as follows:

(i) precast crown units shall have a Class 2 surface finish

(ii) precast parapet units shall have a Class 3 surface finish

(iii) precast piles shall have a Class 1 surface finish

(iv) precast members other than crown units and parapet units shall have a Class 2 surface finish.

(v) the top surface of precast beams shall be finished as for construction joints in accordance with clause 610.20.

(f) Rejection of Surfaces Finishes

Any concrete surface that does not comply with the requirements of this specification shall be subject to the following alternatives:

(i) rejection of the concrete, in which case the concrete shall be demolished and replaced

(ii) acceptance of the defective concrete surface will be withheld subject to remedial measures being carried out in accordance with clause 610.32.

(g) Class 1 Surface Finish

A Class 1 surface finish shall be of a uniform colour and texture and no defects which structurally affect the concrete or reduce the cover to the steel reinforcement will be permitted. All mortar fins shall be tooled away to expose a surface of dense sound concrete. Bolts, wires and other embedments shall be set back to the minimum clear cover specified and the ends filled with shrinkage compensating mortar. Concrete bar chairs and spacers shall comply with the requirements of clauses 610.26 and 610.29(f).

(h) Class 2 Surface Finish

A Class 2 surface finish shall achieve a concrete surface of uniform colour and texture and be free from any major surface defects. The design of the formwork shall be such as to give a deflection under the loads imposed on it of not more than 3 mm between studs or frame supports. The formwork shall be constructed so as to prevent water runoff carrying stains on to previously cast concrete surfaces. The finished concrete surface shall be protected from mortar slurry, physical damage, spillage and water borne staining. Steel shall be protected to prevent rust staining of the concrete surface. No defect which structurally affects the concrete or reduces the cover to the steel reinforcement or other embedded components will be permitted.

(i) Class 3 Surface Finish

A Class 3 surface finish shall achieve a concrete surface of uniform colour and texture and free from surface defects. The design of the formwork shall be such as to give a deflection under the loads imposed on it of not more than the following:

- (i) 1.5 mm between adjacent framing members
- (ii) 3 mm over the vertical face for the full depth of a panel, or height of a lift, whichever is the lesser
- (iii) 3 mm over a 3 m length horizontally.

(j) Sandblast Finish

The following grade of sandblasting shall be applied as shown on the drawings:

- (i) Brush Finish - sandblasting shall remove the surface laitance and expose only the cement matrix. There shall be no projection of the coarse aggregate from the concrete surface.
- (ii) Light Finish - sandblasting shall expose the fine aggregate with occasional exposure of coarse aggregate. Projection of the coarse aggregate shall not exceed 2 mm above the finished concrete surface.
- (iii) Medium Finish - sandblasting shall be such as to expose the coarse aggregate which shall project no more than 4 mm above the finished concrete surface.
- (iv) Heavy Finish - sandblasting shall expose the coarse aggregate so as to provide a rough and uneven finished surface. The maximum projection of the large aggregate shall be 6 mm above the finished concrete surface.

(k) Tooled and Bush Hammered Surface Finish

The types of tooled and/or bush hammered surface finishes are as follows:

- (i) Light Bush Hammering - sufficient only to break the concrete surface to remove surface mortar without fracturing the coarse aggregate. Usually achieved by the use of a combed head roller chisel, or disc bush hammer.
- (ii) Medium Bush Hammering - sufficient to expose the coarse aggregate pattern but without any pitting or spalling of concrete.
- (iii) Heavy Jack Picking - a coarse texture achieved through jack picking the concrete surface. Substantial lumps of concrete are spalled from the concrete surface.

The Contractor shall manufacture suitable test panels for each type of finish to be used prior to placing concrete.

(l) Exposed Aggregate Finish for Unformed Surfaces

The prepared surface shall have an exposed coarse aggregate finish free from loose aggregate and laitance.

(m) Scabbled Finish

Scabbling shall remove all laitance and loose or porous material without leaving excessive depressions. Exposed aggregate shall be firmly embedded in the concrete.

(n) Broomed Finish

The concrete surface shall be broomed in a direction at right angles to the bridge centre line with a stiff-bristled broom not less than 400 mm wide or using a suitable mechanical grooving device to produce a uniformly roughened surface texture with an average depth of not less than 0.9 mm. After texturing the concrete surface shall be cured in accordance with clause 610.23

### 610.32 REPAIRS TO FORMED SURFACES AND OTHER DEFECTS

The method of repair of minor surface imperfections including porous spots, shallow honeycombing, rough areas and blow holes not conforming to the class of surface finish as specified in clause 610.31, and the method of cementitious patch repair of other concrete defects shall be in accordance with Section 689.

Epoxy materials shall not be used for the patch repair of concrete.

The exposed surface of the repaired area shall have a texture and colour which is uniform with the colour and texture of the surrounding concrete.

### 610.33 MORTARS AND GROUTS FOR GENERAL APPLICATIONS

Where required for general applications other than those specified elsewhere in this specification, cementitious mortars and grouts shall be shrinkage compensating proprietary products with a consistency appropriate for the required use, and able to be placed and compacted to achieve full encapsulation. Cementitious mortars and grouts shall have a minimum 28 day compressive strength of not less than 40 MPa.

Cementitious grouts shall be as a minimum Type C Class dual shrinkage compensating.

Only whole bags of material shall be used. Test certificates, material data sheets and health and safety data sheets shall be available for all materials. The mortar and grout applications shall be cured in accordance with the requirements of clause 610.23.

Mortars and grouts shall be sampled and tested in accordance with the requirements of clause 610.28.

### 610.34 MEASUREMENT OF CONCRETE COVER TO REINFORCEMENT

A concrete cover measurement survey of reinforced and precast concrete members shall be undertaken after construction on a representative and randomly selected number of exterior surface areas using a commercially available concrete cover meter in at least one 3 m<sup>2</sup> test area for every 25 m<sup>2</sup> or part thereof. A minimum of 10 cover meter measurements shall be undertaken within the test area and the least distance from the reinforcement to the concrete surface recorded to the nearest millimetre.

The Contractor shall maintain records of all cover meter measurements to demonstrate that completed concrete members comply with the specified minimum concrete cover as shown on the drawings and the allowable dimensional tolerances as stated in clause 610.41. **The Contractor shall ensure that the records are available for review by the Superintendent Council.**

Any concrete members which exhibit cover less than the specified minimum shall be identified as a non-conformance and the affected locations marked and mapped.

**The Contractor shall undertake an assessment of the low cover concrete to evaluate the influence of the low cover on the durability of the structure and submit a proposed corrective action to rectify the non-conformity for review by the Superintendent Council.**

As a minimum, acceptable rectification shall include but not be limited to the application of approved protective treatment(s) in accordance with the requirements of Section 686.

The cover meter shall be supported with a current calibration certificate and shall be capable of detecting the presence of reinforcement and indicating the depth from the concrete surface to the nearest point on the surface of the reinforcement with an accuracy of  $\pm 1$  mm at a depth of 25 mm.

### **610.35 PLACEMENT OF FILL MATERIAL AGAINST CONCRETE**

Fill material shall not be placed against concrete within 14 days of casting in accordance with the requirements of clause 204.11 of Section 204.

Proposed placement of fill material against concrete prior to 14 days from casting shall comply with the early application of loading requirements of clause 610.16(l) or maturity testing requirements of clause 610.16(m).

### **610.36 EARLY LOADING AND TRAFFICKING OF BRIDGE DECKS, DECK OVERLAYS AND APPROACH SLABS**

Further to the requirements of clause 610.16 and clause 610.23, bridge decks, deck overlays and approach slabs shall not be loaded or opened to traffic until the concrete is at least 4 days (96 hours) old and not before a minimum compressive strength of 32 MPa after casting has been achieved.

Light plant and equipment operated in a strictly controlled manner may access the bridge deck, concrete deck overlay or approach slab, at least 3 1/2 days (84 hours) after casting, provided the minimum strength of 32 MPa has also been achieved.

Light plant and equipment shall be as follows:

- (a) equipment not exceeding 0.5 tonnes in weight
- (b) maximum axle loads: 5.0 tonnes single, 8.0 tonnes tandem, 9.0 tonnes triaxle
- (c) tracked vehicles: maximum 15 tonnes/m<sup>2</sup> pressure over the track area, providing the concrete is protected from surface damage.

The early age in situ compressive strength development of concrete shall be determined in accordance with the maturity testing requirements of clause 610.16(m).

The Contractor shall undertake temperature differential monitoring and maximum temperature measurements of concrete and control early age thermal cracking to demonstrate compliance with the requirements of clause 610.22.

Curing shall remain intact and completed in accordance with the requirements of clause 610.23 unless asphalt placement is completed immediately after the minimum 4 day period. Curing shall be supplemented with 2 layers of 8 mm thick closed cell foam or inner double core aluminium foil based thermal blankets.

Additional test cylinders shall be sampled and tested as required in order to demonstrate when the required strength has been achieved.

**HP Early loading and trafficking of bridge decks, concrete deck overlays and approach slabs shall not proceed until:**

- (i) the Contractor's early loading and trafficking quality procedure and inspection and test plan(s) have been reviewed by the Superintendent Council**
- (ii) the evidence that the minimum periods stated in this clause have been satisfied and maturity testing, temperature monitoring and compressive strength test results have been reviewed by the Superintendent Council.**

### 610.37 CONSTRUCTION OF DECK WIDENING, LONGITUDINAL STITCH POURS, IN-FILL STRIPS AND STAGED CONSTRUCTION OF DECK OVERLAYS UNDER LIVE TRAFFIC

Deck widening may necessitate the use of connecting longitudinal stitch pours or in-fill strips, between the main body of the new deck and the existing deck to provide a monolithic structural connection.

The Contractor shall implement quality procedures and undertake the works in a manner which minimises the effects of traffic induced vibrations, differential deflections and stresses on the new deck widening and in the vicinity of the stitch pour and staged deck overlay, including:

- (a) adverse effects on the bond between the steel reinforcement and the fresh concrete
- (b) development of any voids between the steel reinforcement and fresh concrete
- (c) adverse effects on the mechanical bond at the joint interface
- (d) adverse effects on bonded anchors if they are used in accordance with Section 680
- (e) cracking during the early hardening and strength developing period.

Construction of deck widening, longitudinal stitch pours and in-fill strips and staged construction of deck overlays under live traffic shall be subject to the following conditions:

- (i) Use a high early strength concrete of minimum 50 MPa (VR450/50) to facilitate early strength development.
- (ii) Close adjacent traffic lane to the deck widening, stitch pour or deck overlay and ensure a minimum clearance of 4.5 metres from the edge of the deck widening or stitch to the nearest wheel path. **For narrow roads the minimum clearance and overall configuration details including traffic detours if required shall be subject to approval by the Superintendent Council.**
- (iii) Limit traffic speed to 40 km/h until the concrete in the deck widening or stitch reaches 20 MPa.
- (iv) When 20 MPa is reached the speed limit can be increased to 60 km/hour until the concrete reaches a minimum strength of 32 MPa at which point the lane closure ends and the speed limit can increase to 80km/h.
- (v) Undertake peak particle velocity (PPV) measurements at edge of the deck widening or stitch. The average PPV shall be less than 5 mm/sec and the maximum instantaneous PPV of less than 55 mm/sec for the concrete for the deck widening and stitch pours. PPV measurements shall be made during the period between commencement of concrete placement and when the minimum compressive strength of 32 MPa has been achieved.
- (vi) The early age in situ compressive strength development of concrete shall be determined in accordance with the maturity testing requirements of clause 610.16(m).
- (vii) The Contractor shall undertake temperature differential monitoring and maximum temperature measurements of concrete and control early age thermal cracking to demonstrate compliance with the requirements of clause 610.22.
- (viii) Curing shall remain intact and completed in accordance with the requirements of clause 610.23 unless early trafficking is required in accordance with the requirements of clause 610.36. Curing shall be supplemented with 2 layers of 8 mm thick closed cell foam or inner double core aluminium foil based thermal blankets.
- (ix) Steel reinforcement from the existing deck to only extend into the in-fill strip for overlap with the new steel reinforcement
- (x) Steel reinforcement within the in-fill strip to be effectively tied such that rigid continuity is provided between old and new.
- (xi) If bonded anchors are used to comply with the requirements of Section 680.
- (xii) Sample and test additional test cylinders to demonstrate when the required strength has been achieved.

**HP Construction of deck widening, longitudinal stitch pours and in-fill strips and staged construction of deck overlays under live traffic shall not proceed until the Contractor's quality procedure and inspection and test plan(s) have been reviewed by the Superintendent Council.**

**HP Lane closures and speed restrictions shall not be removed until PPV measurements, maturity testing, temperature monitoring and compressive strength test results have been reviewed by the Superintendent Council.**

A 1 metre wide waterproofing membrane strip shall be installed over the construction joint formed at the interface with the new deck widening, longitudinal stitch pours and in-fill strips and staged construction of deck overlays in accordance with the requirements of Section 691, prior to the placement of asphalt.

#### **610.38 EFFECTS DUE TO CONSTRUCTION ACTIVITIES AND GROUND VIBRATION ON FRESHLY PLACED CONCRETE**

The Contractor shall implement adequate precautions and manage construction activities to prevent the disturbance of formwork or transmit vibrations through to recently cast concrete or projecting steel reinforcement. The Contractor's construction quality procedure and inspection and test plan(s) shall address as a minimum the distance from the source of vibration, the intensity and duration of vibration, and the nature of the medium or underlying soil type through which the vibration is travelling.

#### **610.39 PLACING OUTSIDE DAYLIGHT HOURS**

When concrete is placed and finished outside daylight hours or in any other conditions where natural light may be inadequate, the Contractor shall provide adequate lighting for the works including placement, compaction, finishing, curing, sampling and testing, monitoring and inspection.

#### **610.40 SLIPFORMED CONCRETE BARRIERS**

**Construction of concrete barriers by slipforming shall be subject to approval by the Superintendent Council.**

#### **610.41 MINIMUM CONCRETE COVER TO REINFORCEMENT**

The minimum concrete cover to steel reinforcement and other steel embedments shall be as shown on the drawings and in accordance with the requirements of clause 4.14.3 of AS 5100.5. The dimensional tolerance of concrete cover shall be 0 to +5 mm as stated in Table 610.471.

The curing of concrete shall be continuous and uninterrupted in accordance with clause 610.23 to ensure the effectiveness of the minimum concrete cover.

The minimum concrete cover for concrete members cast in standard formwork and compacted with standard compaction as defined in clause 610.03 shall be in accordance with the requirements of Table 4.14.3.2 of AS 5100.5.

Where lower minimum concrete cover is specified for concrete members cast in rigid steel formwork with intense compaction in accordance with Table 4.14.3.3 of AS 5100.5, the intense compaction shall consist of both external form vibrators and internal vibrators as defined in clause 610.03. A high level of supervision shall be employed to ensure that the required level of intense compaction is achieved and the rigidity of formwork is maintained during concrete placement.

Where curing compounds are used, the concrete cover shall be increased by 5 mm for classifications A and B1 and by 10 mm for other classifications in accordance with the requirements of Table 4.14.3.2 and Table 4.14.3.3 of AS 5100.5.

#### **610.42 COVER AND SPACING REQUIRED FOR CONCRETE PLACEMENT**

The minimum cover required for concrete placement and the minimum allowable steel reinforcement spacing within a concrete member shall not be less than 1.5 times the maximum size of aggregate in the concrete mix or the reinforcement bar diameter, whichever is the larger, unless greater concrete placement requirements apply as per AS 5100.5, to ensure that the concrete can be satisfactorily placed, flow and compacted around the steel reinforcement.

Continuous bar chairs shall provide a minimum gap between the formwork and the underside of the bar chair voids of 1.5 times the maximum nominal size aggregate in the concrete mix.

The maximum aggregate size shall ensure that effective consolidation and aggregate interlock is achieved within a dense concrete microstructure without voids and honeycombs which can adversely affect the durability and the in situ strength of concrete.

Steel reinforcement shall be placed such that adequate gaps exist for the insertion of poker vibrators and concrete can flow around the steel reinforcement. Congestion created by a large number of closely placed parallel bars with little or no separation shall not be allowed. Where bundled bars are used as part of design to overcome steel reinforcement congestion, they shall be limited to four in any one bundle with no more than two bars in one plane and shall be tied together in contact and be enclosed within stirrups or ties. Bundles of bars may consist in groups of two, three or four longitudinal bars to act as a unit.

#### **610.43 PROVISIONS FOR STRAY CURRENT CORROSION**

The effects of possible stray current corrosion shall be considered as required where bridges and concrete structures are adjacent to or carry electrified rail and tramways, especially where they are powered by direct current, concrete structures located in the vicinity of high voltage power lines and where impressed current cathodic protection is installed.

#### **610.44 STEEL FIBRE REINFORCED CONCRETE**

Where required steel fibre reinforced concrete shall be as specified in the drawings and specification and shall comply with the requirements of AS 5100.5.

Fibre reinforced sprayed concrete shall comply with the requirements of Section 684.

#### **610.45 FIRE RESISTANCE OF CONCRETE**

Where required fire resistance of concrete shall be as specified in the drawings and specification and shall comply with the requirements of AS 5100.5.

#### **610.46 DRILLING OF HOLES IN CONCRETE MEMBERS**

**Holes shall not be drilled in concrete members unless approved by the Superintendent Council.**

**Drilling of holes in concrete members shall be located as shown on the drawings, as specified in this specification or as approved by the Superintendent Council.** Holes may be drilled with carbide-tipped rotary hammer or diamond-tipped core drill.

Holes shall be drilled to the required length and diameter and be positioned to avoid damage to steel reinforcement and pre-stressing tendons or to services.

Prior to drilling of holes, reinforcing bars, pre-stressing tendons and cables and services that lie within the depth of the drill hole shall be accurately located by reference to as-constructed drawings.

The actual position of bars and tendons shall then be located by use of a recently calibrated concrete cover meter or ground penetrating radar (GPR), operated by a competent person. If reinforcement is encountered during drilling, drilling shall cease immediately and hole location shall be adjusted locally to avoid reinforcement.

Where drilling of holes is undertaken by coring the required depth shall be controlled by use of a positive stop device fitted to the coring machine or a depth measurement mark placed on the core barrel.

Drilling of holes into concrete members shall be undertaken under the direction of a qualified Contractor's representative and for the purposes of surveillance, the Contractor shall give the Superintendent Council a minimum of two (2) days written notice of its intention to drill holes into concrete members.



Drilling of holes shall not cause spalling, cracking, or other damage to the existing concrete, the steel reinforcement or other steel embedments. Any damage to the concrete member including the steel reinforcement shall be repaired to the satisfaction of ~~the Superintendent~~ Council.

Where existing steel reinforcement is encountered during the drilling operation, and holes have been relocated, the uncompleted holes shall be cleaned and repaired with a shrinkage compensating polymer modified cementitious repair material in accordance with the requirements of Section 689. The exposed surface of the repaired hole shall be similar in texture and colour to the surrounding concrete.

**HP The drilling procedure and drill locations shall be submitted for approval by the Superintendent Council.**

The Contractor shall maintain records of all hole drilling activities and immediately notify ~~the Superintendent~~ Council where the concrete member or steel reinforcement has been damaged. **Contractor shall ensure that all records are available for review by the Superintendent Council.**

**610.47 DIMENSIONAL TOLERANCES**

(a) General

The dimensional tolerances listed in Tables 610.471, 610.472, 610.473 and 610.474 are the allowable deviations of the completed concrete member from the dimensions shown on the drawings. These dimensional tolerances will be a basis for acceptance of the work.

The Contractor shall maintain records of dimensional measurements to demonstrate that all completed concrete members comply with the allowable dimensional tolerances as stated in this clause. **The Contractor shall ensure that the records are available for review by the Superintendent Council.**

Fitments and embedments shall be located with sufficient accuracy to prevent any misfit or misalignment between mating components.

(b) Soffits

The soffits of arches, box girders, beams and deck edges shall be continuous curves or straight lines as shown on the drawings, free from all visible irregularities.

(c) Slipformed Concrete Kerbs and Barriers

Cast in situ slipformed concrete kerbs and barriers and cast in situ off-structure concrete barriers shall comply with the tolerance requirements for precast concrete units as stated in Table 610.474. In addition, the vertical and horizontal alignment between adjacent segments shall not exceed 5 mm.

**Table 610.471 General Tolerances**

Item	Tolerance (mm)
Placing of reinforcement	5
Placing of post-tensioning sheathing	5
Concrete cover	0 to +5

Table 610.472 Cast In Situ Concrete

Item	Tolerance (mm unless shown otherwise)
<b>(i) Footings</b> * Plan dimensions - Formed footings and pile caps - Unformed footings (when approved by the Superintendent Council) * Thickness                - < 300 mm - > 300 mm * Top of footing or pile cap reduced level * Departure from the plan position in any direction	-15 to +50 0 to +150 -5 to +25 -10 to +50 -25 to +25 50
<b>(ii) Cylinders</b> * Variation from the vertical * Departure from the plan position in any direction	25 mm in 3 m 75
<b>(iii) Variation in Cross Section of Columns, Piers, Pier and Abutment Crossheads, Slabs, Walls, Beams and Similar Parts</b> (excluding deck slabs and end posts) * < 3 m * > 3 m	-5 to +15 -10 to +25
<b>(iv) Variation of Cross Section of End Posts</b>	-5 to +5
<b>(v) Deck</b> Thickness of Deck Slabs (excluding allowance for correction of camber or hog) Deck surface reduced level	0 to +10 -10 to +10
<b>(vi) Deck Joints</b> * Width of slot	-3 to +3
<b>(vii) Variation from Vertical or Specified Batter of Columns, Piers, Walls, Handrail Posts and Arises</b> * Unexposed concrete * Exposed concrete	10 mm in 2.5 m (1/250) 5 mm in 2.5 m (1/500)
<b>(viii) Variation from Grades Indicated on Drawings for Railings, Kerbs and Arises</b>	2.5 mm in 2.5 m (1/1000)
<b>(ix) Reduced Level of Tops of Pier and Abutment Crossheads and Piers</b> * With pedestals * Without pedestals * Difference in Level across width of crosshead	-10 to +10 -5 to +5 5
<b>(x) Bearing Pedestals</b> * Reduced level * Variation from grade across the width of individual pedestals shall not exceed * Deviation from flat surface	-2.5 to +2.5 1 in 200 +1.0 to -1.0
<b>(xi) Departure from Plan Position at any level</b> * Columns, Piers, Walls, Pier and Abutment Crossheads, Beams, Slabs, Kerbs, Railing and other similar parts * Relative displacement of adjoining members shall not exceed	25 10
<b>(xii) Departure from Alignment</b> * Rows of columns, faces of piers or walls * Handrails, Faces of hand rail posts, Kerbs	10 5
<b>(xiii) Maximum Allowance for Irregularities in Exposed Concrete Surfaces</b> * Sections less than 1 m in dimension when measured with a straightedge across the dimension of the section * Sections greater than 1 m in dimension when measured with a straightedge across the dimension of the section, except that when sections are greater than 2.5 m in dimension, a 2.5 m straightedge shall be used	2.5 5
<b>(xiv) Irregularities in Railings</b>	2.5 mm in 2.5 m
<b>(xv) Slab Surface Finish</b>	5 mm in 2.5 m

**Table 610.473 Pre-tensioned Concrete**

Item	Tolerance (mm unless shown otherwise)
<p><b>(i) Cross Section</b></p> <ul style="list-style-type: none"> <li>* Dimension - &lt; 2 m</li> <li>- &gt; 2 m</li> <li>* Out of square - &gt; 2 m</li> </ul>	<p style="text-align: center;">-3 to +3 -6 to +6 0.5 in 250, or Desirable 3, Maximum 5</p>
<p><b>(ii) Strand and Reinforcement</b></p> <ul style="list-style-type: none"> <li>* Placing of reinforcement</li> <li>* Placing of prestressing strand</li> <li>* Concrete cover</li> </ul>	<p style="text-align: center;">5 3 0 to +5</p>
<p><b>(iii) Squareness of Ends</b></p> <ul style="list-style-type: none"> <li>* Dimension - &lt; 500 mm</li> <li>* - &gt; 500 mm</li> </ul>	<p>Deviation from a plane perpendicular to the longitudinal axis of a member, or from the specified end plane:</p> <p style="text-align: center;">3 mm 6 mm per metre (10 mm maximum)</p>
<p><b>(iv) Length</b></p> <ul style="list-style-type: none"> <li>* Diagonal length for precast unit</li> <li>* Overall length or length centre to centre of bearings (for beams and slabs)</li> <li>* Centre to centre spacing of holes for transverse rods or both</li> </ul>	<p style="text-align: center;">5 0.06% x specified length (max 20) 5</p>
<p><b>(v) Profile in a Vertical Plane (Hog)</b></p>	<p>The deviation in hog of any unit from the mean hog of all units shall not vary by more than 0.07% of the length of the units. The absolute value for hog for any unit shall not be less than zero. Hog measurements shall be made at transfer of prestress.</p>
<p><b>(vi) Profile in a Horizontal Plane (Bow)</b></p>	<p>The deviation of a unit from the required profile shall not exceed 0.06% of the length of the unit or a maximum of 15 mm.</p>
<p><b>(vii) Twist</b></p>	<p>The angular rotation of any cross section relative to an end cross section shall not exceed 1 in 200.</p>
<p><b>(viii) Sole Plates</b></p>	<p>The plane of the sole plate or bearing surface shall not vary from that shown on the drawings by more than 1 in 200 in any direction.</p>
<p><b>(ix) Deviation</b></p> <ul style="list-style-type: none"> <li>* The distance of any point from a flat plane held against that surface.</li> </ul>	<p style="text-align: center;">3 mm in 2 m</p>

Table 610.474 Precast Concrete Units

Item	Tolerance (mm)
<b>(i) General</b> * Placing of reinforcement * Placing of sheathings for post-tensioned segmental members * Concrete cover	5 5 0 to +5
<b>(ii) Cross Section</b> * Dimension - < 2 m - > 2 m * Out of square	0 to +3 0 to +6 Maximum 5
<b>(iii) Squareness of Ends</b>  * Dimension - < 500 mm *               - > 500 mm	Deviation from a plane perpendicular to the longitudinal axis of a member, or from the specified end plane:  3 mm 6 mm per metre (10 mm maximum) For parapet units and new jersey barriers, the deviation from a plane perpendicular to the longitudinal axis shall not exceed 3 mm.
<b>(iv) Length</b> * Diagonal length for precast unit * Overall length or length centre to centre of bearings (for beams and slabs) * Centre to centre spacing of holes for transverse rods or bolts * Overall length for parapets and new jersey barriers	5  0.06% x specified length (max 20)  5  3
<b>(v) Profile in a Vertical Plane (Camber)</b>	The deviation of a unit from the design camber, after allowance has been made for the deflection due to the mass of the member, shall not exceed 0.10% of the length of the unit with a maximum of 6 mm. Measurement of camber shall be made at the mid-point of the member which shall be supported at the bearing positions.
<b>(vi) Profile in a Horizontal Plane (Bow)</b>	The deviation of a unit from the required profile shall not exceed 6 mm or 0.10% of the length of the unit, whichever is the greater. Bow in precast parapet units and new jersey barriers shall not exceed 3 mm.