Technical Specification for Concrete Structures

TMS1439

Reinforced Concrete Structures, Liquid Retaining Structures, Prestressed Concrete and Precast Concrete Structures, and Masonry Structures

Document Change History

Version History

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1.1	Raghbir Kalsi	Draft		
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Contents

1 General

1.1 Scope

This Technical Specification applies to the design and construction of reinforced concrete structures for water and wastewater infrastructure assets by Queensland Urban Utilities.

The purpose of this Technical Specification:

- Is to maintain consistent designs, construction and durability, and appearance requirements for all water and wastewater infrastructure.
- Shall be read in conjunction with all relevant Australian and International standards, and legislative requirements.
- It does not relieve the designers' responsibilities for the design and construction of infrastructure.

The design and construction of concrete structures involves design, construction planning, fabrication and erection, construction and maintenance. The work, at each stage, shall be carried out in a manner that all requirements specified in an upstream stage are satisfied. These tasks must be performed consistently.

This Specification provides the standard methods of verification for durability, safety, serviceability and restorability of structures in the design and construction stage of the structure.

1.2 Reference Documents

Reference	***Title***
AS 1012	Methods of testing concrete
AS 1012.13	Determination of drying shrinkage of concrete for samples prepared in the field or the laboratory
AS 1170.0	Structural Design Actions-General Principles
AS 1170.1	Structural Design Actions-Permanent, Imposed and Other Actions
AS 1170.2	Structural Design Actions- Wind Actions
AS 1170.4	Structural Design Actions – Earthquake Actions in Australia
AS 1214	Hot Dip Galvanised Coating on Threaded Fasteners
AS 1314	Prestressing anchors
AS 1379	Specification and supply of concrete
AS 1478	Chemical admixtures for concrete, mortar and grout
As 1554.3	Welding of reinforcing steel

AS 1726	Geotechnical site investigations
AS 2758.1	Aggregates and rock for engineering purposes – Concrete aggregates
AS 2841	Galvanised steel wire strand
AS 3582.1	Supplementary cementitious materials for use with portland and blended cement – Fly ash
AS 3582.2	Supplementary cementitious materials for use with portland and blended cement – Slag – Ground granulated iron blast-furnace
AS 3582.3	Silica fume
AS 3600	Concrete structures
AS 3610	Formwork for concrete
AS 3700	Masonry Structures
AS 3735	Concrete structures for retaining liquids
AS 3799	Liquid membrane-forming curing compounds for concrete
AS 3972	Portland and blended cements
AS 4020	Products in use with drinking water
AS 4671	Steel reinforcing materials
AS 4672	Steel prestressing materials
AS 4672.1	General requirements
AS 4672.2	Testing requirements
AS 4672	Steel prestressing materials
AS 4680	Hot Dip Galvanised (Zinc) Coatings on Fabricated Ferrous Articles
ASTM C42	Test methods for obtaining and testing drilled cores and sawed beams of concrete

1.3 Design Requirements

The concrete structures in this Specification shall be designed for ultimate strength and limit states in accordance with the general principles for design specified in the relevant Australian Standards, Codes and is also permissible to carry out design checks for strength and serviceability by testing a structure or component member.

Where the structures are to be used in extreme environments and the design is of a specialist's nature with specialist construction techniques, the Project Specification shall include the particular requirements where appropriate.

1.3.1 Basic Design Rules

- The design shall include the identification of performance requirements for a structure, structural performance and detailing to meet these

performance requirements, and the verification to confirm the performance requirements are met throughout the design service life of the structure.

- All performance requirements that need to be met in order to meet the intended purpose of the structure during construction and during the design service life of the structure shall be determined at the design stage.
- The structural planning stage shall take into consideration factors such as structural characteristics, materials, construction method, maintenance method, and economy so that the performance requirements can be met.
- The structural detailing stage shall take into consideration factors such as shapes, dimensions and reinforcement patterns. These structural details are critical for constructability. It is necessary to take these details into consideration in advance so that the designed structure does not fail to meet the constructability requirements.
- The performance verification requirements for the structure shall be verified in relation to durability, safety, serviceability, restorability, the impact on the environment and landscape throughout the design life. The performance verification refers to tasks of ascertaining, by an appropriate method, that the type of structure, structural cross section, materials to be used, structural specifications, social conditions, constructability and economy meet the specified performance requirements.

1.4 Construction Requirements

The construction requirements in this Specification are for use where structures have been designed to the relevant Australian Standards and Codes.

2 Performance Requirements

2.1 General

The design life of the structure shall be determined in consideration of the required service period of the structure, maintenance period, environmental conditions and economy.

All performance requirements of the structure during the construction and design life of the structure shall be specified for every element of the structure. The performance requirements related to durability, safety, serviceability, restorability, environment compatibility, landscape compatibility, etc. shall be specified as appropriate. Detailed requirements related to these performance requirements have to be identified. It is necessary to give careful consideration to the relationship with the performance of each individual element so that the performance required for the entire structure is met.

2.2 Durability

Durability is the resistance of a structure to performance degradation over time resulting from the materials degradation in the structure under expected

deterioration actions. The durability of a structure shall be specified for the purpose of maintaining the required performance of safety, serviceability and restorability throughout the design life of the structure. Durability is not independent of performance requirements.

2.3 Safety

Safety shall mean the performance of the structure to prevent risks to users and others in the vicinity under all expected conditions. Safety includes the structural safety and functional safety of the structure. Performance requirements for both, structural safety and functional safety, must be specified.

2.4 Serviceability

Serviceability of a structure shall mean the performance that enables users or others in the vicinity to use the structure comfortably and the functional performance required of the structure. Generally these requirements include:

- Traffic movement.
- Pedestrians' movement.
- Appearance.
- Noise.
- Vibrations.
- Water tightness.
- Water permeability.
- Sound insulation.
- Temperature insulation.
- Variable loads.
- Accidental loads.

2.5 Maintenance and Repairs

Maintenance and repairs shall mean the performance in restoring the performance of the structure that has degraded due to continued use or accidental loads. It shall be specified as the degree of difficulty in repairing the structure and all factors affected by the performance degradation.

Mechanical performance requirements related to repair ability of concrete structures are specified as restorability on condition that non-repairable related factors are separately taken into consideration. When considering the repair ability of concrete structures, it is necessary to determine the performance level according to the magnitude of accidental load involved, the state of the structure that can be used without doing repairs and the state of a structure that can be functionally restored in a short period of time.

2.6 Other Performance Requirements

Environmental compatibility and landscape compatibility performance requirements shall be specified on project specific basis. These performance requirements shall be carefully considered at the structural planning stage and confirmed with verifications.

3 Structural Requirements

3.1 General

The type of structure, materials to be used and main dimensions shall be specified so that the performance required of the structure can be met in the most rational way. It shall involve a comprehensive study that takes into consideration factors such as construction methods, maintenance methods, environment and landscape impacts and economy so that the performance required can be met. This shall include the necessary studies and surveys required according to the scope of the project.

3.2 Performance Requirements

The performance requirements shall include the design requirements for durability, safety, serviceability and restorability of the structure are attained and maintained throughout the design life of the structure.

3.2.1 Durability

The material deterioration and deformation in the structure shall be prevented to attain and maintain the required performance level of durability for the design life of the structure. Alternatively, the structure shall be designed to keep material deterioration at a minimum level. The concrete used in the structure shall have the required level of strength, durability and quality.

Every structure, its member and connections shall maintain the required performance throughout the design service life of the structure. Verification is required to confirm that the required performance of the structure will not be lost because of steel corrosion due to chloride attack, carbonation or concrete deterioration due to chemical attack. The durability verification shall include:

- Environmental factors.
- Steel corrosion.
- Concrete deterioration.

3.2.2 Safety

The safety of a structure shall be verified by confirming that no structural member reaches the limit of cross-sectional failure and the structure does not reach the limit state of stability under design loads. The structure should be designed so as to prevent the entire structure from collapsing even if some of the structural members reach the limit state of cross-sectional failure.

3.2.3 Serviceability

The structural members and the structure shall not reach the limit state of serviceability under the design loads. These include crack widths, displacement, deformation, stress, acceleration and vibration.

3.2.4 Restorability

It is necessary to select the type of structure that makes repairs and functional restoration as easy as possible in the event of structural damage or wear. The areas that can be damaged or worn should be located in easy to access areas where inspection and repair can easily be performed. Restorability is affected by the degree of difficulty in repairing a damaged structure and the state of implementation of structural measures such as preparation of materials for restoring a damaged structure and developing restoration technologies and establishing an organisational system for restoration.

3.3 Construction Performance

Restraints relating to construction shall be taken into consideration at design stage. Potential complications in fabrication and erection of formwork and reinforcement can result in lower construction accuracy in situations where structural members are made small for reasons of economy by using high strength materials such as high strength concrete. Careful design consideration is required in these conditions for concreting to comply with the structure's performance. This may require, at design stage, consideration of steel formwork and preassembled and prefabricated reinforcement.

The types of structural elements may need to be determined by the method of construction e.g. topographical constraints may require use of precast elements in place of cast in suit.

3.4 Maintenance Performance

A maintenance strategy and a preliminary maintenance plan for the structure shall be prepared at the design stage to rationalise the maintenance. This information can then be reflected in the maintenance plan. Inspections need to be conducted for every in service structure. These may include:

- Initial inspection at the start of the maintenance period.
- Daily inspections.
- Periodic regular inspections.
- Detailed inspections to evaluate various states in detail.
- Special inspections due to accidental damage.

The type of structure and materials to be used must be determined so that maintenance activities during service can be performed efficiently and cost minimised. E.g. it is desirable to design rigid frame structures in place of structures with movement joints, expansion joints, bearings, etc. where possible. Structures in aggressive environments such in treatment plants should also

consider durability enhancement measures such as surface treatment or liners for concrete, protective coating for reinforcement and protective coating at design stage to reduce the maintenance costs. Some preventative measures may need to be taken during the service life of the structure. These should be considered and allowed for at the design stage.

3.5 Environmental and Landscape Compatibility

The structural design shall consider the influence of concrete structures on the natural, social and other environments and landscape.

3.6 Economic Aspects

The design for a structure shall consider its economy from the view point of life cycle costs of the structure. Careful studies are required for the type of structure, structural member dimensions, materials, etc. with regard to economic aspects as the total cost of the project will be determined at the structural planning stage. It is necessary to evaluate economy not only for the initial cost but also for the life cycle, maintenance, repairs and reconstruction costs.

4 Verification

4.1 General

The performance verification shall verify that a structure and its members as designed and detailed do not reach the limit state specified during construction and during the design life of the structure. The limit state shall be specified for durability, safety and serviceability. The performance verification for the structure shall be verified by durability and initial cracking compliance.

The required verification requirements shall be specified at the structural planning stage and included in the Design Basis.

4.2 Verification Requirements

The performance verification prerequisite is that the structural detail requirements for performance verification, other structural detail requirements, construction method requirements and placement requirements in accordance with the Construction Section of this Specification, and the maintenance procedure requirements specified in the Maintenance Section of this Specification are met.

4.3 Verification Method

The verification of the limit state design shall be confirmed with the compliance requirements to:

- Durability.

- Structural safety.
- Serviceability.
- Seismic Design.
- Initial Cracking.

It is necessary to consider the state of the structure at the end of the design life in view of changes to performance over time.

4.4 Design Calculations

The detail design calculations shall clearly show the required performance and associated limit states of members or structures for verifying durability, safety, serviceability, seismic etc.

The calculations shall involve modelling the structure to be constructed according to:

- The shape of the structure.
- Support conditions.
- The state of loads.
- The limit states to be considered.

The structure shall be modelled appropriately according to the analysis method used for verification. Loads shall be modelled appropriately according to the load characteristics and the influence of different types of limit states to be taken into consideration.

Perform a structural analysis by using an analysis model of proven reliability, accuracy and calculating response values such as sectional forces, deflection, stress, strain, crack width, etc. according to verification indices.

The load shall be considered so that response values in the calculations are verified under the least favourable conditions. Sectional forces such as bending moment, shear force, axial force, torsional moment and deflection shall be calculated in accordance with an appropriate analytical theory according to each limit state.

4.5 Modelling

Modelling shall involve determining the extent of the region to be analysed and the dimensionality of analysis and modelling structural members according to the response characteristics of the structure under consideration. The extent of the region to be analysed consisting of the structure, ground and boundary elements, etc. shall be defined according to the extent of the region in which the response occurs. If the analysis region includes ground conditions, the model shall be performed so that the influence of such coverage can be evaluated properly.

The structure shall be modelled two or three dimensionally as an assembly of structural members in view of its shape.

4.6 Structural Analysis

A structural analysis method that meets the load and structural modelling need and makes verification indices available shall be used. An analysis of a structural member shall give consideration to the influence of nonlinearity according to response. A structural member may be regarded as a linear member if it is evident that the nonlinearity of the member does not affect verification indices such as sectional forces or that conservative and rational results are obtained.

The structural analysis shall include:

- Safety verification.
- Fatigue failure.
- Structural safety.
- Serviceability verification.
- Seismic verification.

4.7 Structural Details

Each member shall be provided with the necessary reinforcement, taking into consideration the shape and stiffness of the member, boundary conditions, load characteristics, the state of loadings, unexpected conditions e.g. steel corrosion, concrete cracks, initial defects, construction workability, etc.

The following minimum details shall be shown:

- Concrete cover shall be determined to confirm the bond strength performance, fire resistance, durability, importance of the structure and construction errors.
- The clear distance of the reinforcement shall be determined taking into account the type of member, maximum size of aggregate, diameter of reinforcement, construction errors, etc. to confirm the concrete surrounds the reinforcement appropriately.
- The reinforcement shall account for the minimum reinforcement, maximum reinforcement and additional reinforcement for crack control due to temperature gradient, shrinkage, etc.

Other structural details of reinforced concrete structures, prestressed concrete structures and precast concrete structures shall include the following additional details:

- Corners of reinforced members shall be bevelled.
- Additional reinforcement required near exposed surfaces to prevent cracks due to shrinkage and temperature changes.

- Additional reinforcement required under concentrated reactions and excessive stress concentrations.
- Additional reinforcement required around all openings in structural members.

4.8 Design Drawings

The design drawings shall include the following basic information on design, construction and maintenance in addition to the structural and reinforcement details.

- Design life.
- Environmental conditions.
- Characteristic values of loads and load combinations.
- Safety factors.
- Characteristic values of materials.
- Concrete cover to reinforcement and construction accuracy.
- Reinforcement joints and joint locations.
- Tension forces.
- Information necessary for construction and maintenance.
- Name of structure and place of use.
- Signatures of responsible engineer, design checker with dates.
- Scales and dimensions.
- Type of cement.
- Cement content.
- Maximum size of coarse aggregate.
- Concrete slump.
- Water/cementitious material ratio.
- Air content in concrete.

Design drawings shall be stored along with the construction record drawings throughout the functional and service life of the structure.

5 Design Requirements for Materials

5.1 General

The quality of concrete or steel shall consider the following additional material property requirements in addition to comprehensive or tensile stress.

- Strength.
- Modulus of elasticity.
- Deformation characteristics.
- Thermal characteristics.

- Durability.
- Water tightness.

The effect of loading rate on strength and deformation should also be considered if necessary.

Material properties are classified into mechanical and physical properties. Strength characteristics are expressed by strength under static and fatigue loading. Deformation characteristics are expressed by time independent quantities such as modulus of elasticity and Poisson's ration, and time dependent characteristics such as creep co-efficient and shrink strain.

Durability of concrete is time dependent deterioration resulting from various actions e.g. weather, intrusion of chemicals and erosion of chemicals. Quality of concrete is influenced by not only by materials used and their mix proportion, but also construction and environmental conditions at the site.

5.2 Concrete

Characteristic values of concrete strength shall be based on 28 tests in general. They may be based on tests of other appropriate ages depending on factors such as proposed function of the structure, time of main loading and construction schedule.

5.2.1 Thermal

Thermal characteristics of concrete are greatly influenced by the characteristics of the aggregate. The thermal characteristics can vary considerably depending on the level of saturation and temperature for the same concrete mix.

5.2.2 Shrinkage

The shrinkage of concrete which includes drying shrinkage, autogenous shrinkage and carbon shrinkage is effected by:

- Properties of the aggregate and cement.
- Compaction of concrete.
- Curing conditions.
- Temperature and humidity around the structure.
- Shape and dimensions of the cross section.
- Mix proportions of concrete.

Environmental humidity and member size strongly affect the magnitude and rate of shrinkage strain.

Shrinkage of concrete shall be determined considering the humidity around the structure, shape and dimensions of members, mix proportion of concrete, etc.

5.2.3 Creep

Creep coefficients of concrete shall be determined considering the effects of the following:

- Humidity around the structure.
- Shape and dimensions of the cross section of the member.
- Mix proportion of the concrete.
- Age of concrete when stress is applied.
- Properties of aggregate.
- Type of cement.
- Compaction and curing conditions of concrete.

5.2.4 Carbonation

The characteristic value of carbonation rate shall be determined on experimental data or past data. The carbon rate is a proportional constant when it is assumed that the depth of carbonation varies linearly with the square root of the exposed period.

6 Loads

6.1 General

Structures shall be designed for appropriate combinations of loads likely to act during the construction stage and design life of the structure with consideration of limit states for performance requirements being considered. Design loads shall be obtained by multiplying characteristic values of load by the appropriate load factor.

Combinations of design loads shall be determined according to the limit states for the required performance of the structure.

Combinations of Design Loads

Required Performance	Limit State	Combinations to be Considered
Durability	Every Limit State	Permanent Load + Variable Load
Safety	Cross-sectional Failure	Permanent Load + Primary Variable Load + Secondary Load
	Fatigue	Permanent Load + Variable Load
Serviceability	Every Limit State	Permanent Load + Variable Load
Seismic	Every Limit State	Permanent Load + Accidental Load + Secondary Variable Load

Although a combination of loads may be defined as a design load in some cases, design loads shall be determined for individual type of load in the specific design.

6.2 Load Factors

The characteristic values of load shall be determined respectively for each of limit states for which verification is required.

The characteristic values of permanent loads, primary variable loads and accidental loads used for verification shall be calculated from the maximum values of these loads during construction and the design life of the structure. In cases where the maximum value of the load governs the design, the expected minimum value of the load shall be adopted. The characteristic values of secondary variable loads shall be determined in accordance with the combination of primary variable loads and accidental loads. The characteristic values of loads used for verification of safety against fatigue shall be determined considering varieties in the loads expected to occur during the design life of the structure.

The characteristic values of loads to be used for verification of serviceability shall be calculated using loads that frequently occur during construction and the design life of the structure. The values shall be chosen appropriately depending on the limit state and the combination of loads being considered.

The characteristic values of loads to be used for the verification of seismic resistance shall be determined considering the predetermined level of seismic resistance provided that the value must not be greater than the maximum expected value during the design life of the structure.

The characteristic values of loads to be used for durability shall be calculated using the loads that frequently occur during construction and the design life of the structure.

6.3 Design Loads

The following loads shall be considered for performance verification as appropriate:

- Dead loads.
- Live loads.
- Earth pressure.
- Hydrostatic water pressure.
- Fluid dynamic force.
- Wave action.
- Prestress.
- Wind.
- Shrinkage and creep of concrete.
- Effect of temperature.

- Seismic loads.
- Loads during construction.
- Other specific load conditions.

6.4 Construction Loads

The following loads shall be considered to act on the structure or part of the structure during construction:

- Dead loads on account of the self-weight of the structure.
- Loads due to construction equipment.
- Wind loads.
- Seismic loads.

The actual values of the loads shall be chosen in consideration of the following:

- The method of construction.
- The structural system during construction.
- The length of the construction period.

6.5 Other Loads

It is necessary to consider other loads than those specified above. The characteristic values shall be determined in accordance with actual situation of the loads.

Impact load is one of the other loads in this clause. Examples of impact loads are vehicle impact, flying objects and ground settlement after completion of the structure.

7 Design - Liquid Retaining Structures

7.1 General

This section specifies additional requirements particular to structures which are part or wholly liquid retaining structures for water and waste water, and may also be in aggressive marine type environments in coastal zones.

7.2 Durability

It is the responsibility of the designer to assess the situation, the related economics and provide the most appropriate durability requirement for each individual situation.

The parameters governing the performance of the concrete have to be set on the basis of the durability requirements. The strength of concrete required for establishing the durability, by which the quality of concrete can be ascertained

has to be specified for each project.

The following information is provided to assist in achieving the objectives of durability:

- The drying shrinkage limits.
- Depending on the aggregate source, the total fines present in the mix and the mix design used, the contractor may have difficulties in meeting the limits imposed without the aid of suitable shrinkage reducers.
- Use of fly ash as a part replacement of Portland cement provides measurable benefits to long term concrete durability. The designer is encouraged to use fly ash concrete at a replacement rate of between 15% to 30%. Fly ash at the higher end of the replacement range provides extra benefits with regard to reduction in water demand of the mix and a lower shrinkage but it comes as an impediment to early strip of formwork because of a reduction in early strength.

The concrete mix designer should take these matters into consideration when submitting the proposed mix design for approval.

Concrete strengths may fluctuate in long duration projects due to seasonal factors such as changes in cement properties and at times a shortage of specified design mix materials supply. The concrete mix designer needs to be aware of this and to make changes and take corrective action as required. In these instances additional laboratory trial mixes may be required at regular intervals to reflect the changes.

The minimum concrete requirements for durability shall be as follows:

- Concrete grade S40.
- Compressive strength at 28 days 40 MPa
- Minimum cement content 380 kg/m3
- Maximum cementeous material 25%
- Water/cement ratio maximum 0.5
- Nominal slump 80 mm
- Drying shrinkage at 21 days 500 x 10-6
- Drying shrinkage at 56 days 600 x 10-6
- Total reactive alkali content not greater than 3.0 kg Na2Oper cubic meter.
- Heat of hydration to be controlled for thick and large pours to control temperature differential.

The parameters specified above apply to potable water containing concrete structures. The strength requirement specified is S40 grade concrete. For a greater severity exposure, typically those that exist in sewerage and marine environments, a S50 grade concrete may be required.

Prestressed Concrete

All prestressing tendons must be fully bonded and hand placed or mechanical placed mortar is not permitted.

Water Stops and Sealants

Water stops and sealants are critical to the durability of the structure although they may be considered minor parts. The durability and maintainability of these items must be carefully assessed and must be appropriately installed to enable them to be maintained if their durability is less that of the structure.

7.3 Serviceability

Excessive cracking leads to poor performance of the structure in terms of leakage, reinforcement corrosion and aesthetics of the structure. Cracking has to be controlled and is achieved for liquid retaining structures by limiting the crack widths implicitly in terms of steel stresses. Sufficient reinforcement is to be provided to confirm that the reinforcement does not yield and that the cracks formed are distributed and the width of the cracks formed must be controlled.

Other forms and equations to determine and design crack widths are not to be used.

The design of minimum reinforcement shall confirm cracks within acceptable limits and they shall be well distributed. The concrete designer shall confirm that when the first crack occurs, the subsequent shrinkage will result in further cracks and not an uncontrolled increase in the width of the first crack.

The angle of cracking has a significant effect on crack width. A change in the angle of cracking can lead to an increase in crack width by a factor of two. Inclined cracking examples are buttressed walls, two way slabs and deep beams. Orthogonal cracking examples are cracks in circular tanks about a third height from the wall base.

7.4 Construction

Concrete

Admixtures such as accelerators, retarders, plasticizers, form release and water proofing agents, curing compounds and others should be used only when there is proof that such admixtures will not have deleterious effect on the specified performance of concrete. Substantial evidence is to be provided for the use of admixtures.

Curing

The surface layer of the concrete shall remain moist for the full duration of the curing period to eliminate micro-cracking. Curing shall be undertaken by one of the following methods:

- Applying a curing compound with a curing efficiency greater than 75% while the concrete surface remains moist and maintaining the membrane for a duration equal to twice the curing period.
- Providing conditions to confirm the relative humidity will remain above 80% and wind speeds will remain below 6 m/s for a duration equal to twice the curing period.
- Other methods where it can be demonstrated that the curing conditions will remain as indicated above with full moisture curing at 100% relative humidity.

The curing efficiency of the membrane shall not be less than 75%.

8 Design - Prestressed Concrete

8.1 General

The designer of prestressed concrete structures must verify the requirements specific to prestressed concrete structures that the performance requirements related to safety, serviceability, etc. are met. It is necessary to perform modelling and taking into consideration factors such as anchoring locations of tendons and whether concrete members and tendons are bonded, so the prestressing induced in the concrete members can be allowed for appropriately.

The means of introducing permanent prestressing into concrete members is classified as follows:

- Pre-tensioning method.
- Post tensioning method.
  - Internal tendon method.
  - External tendon method.
  - Combination use of both methods.

8.2 Prestress Concrete Classification

Prestress concrete is classified into:

- Prestressed concrete structures. These structures do not permit cracking in serviceability related verification and are structurally designed to control the edge stress in concrete by introducing prestress.
- Prestress and reinforced concrete structures. These structures permit cracking in serviceability related verification and are structurally designed to control crack width by installing reinforcement and introducing prestress.

8.3 Durability

The verification of durability should take into account the influence of prestressing into consideration. Verification of steel corrosion is to be applied to reinforcing steel and prestressing steel. Prestressing steel is to be protected and not damaged with corrosion for the design service life. When prestressed reinforced concrete structures are constructed in chloride environments, plastic sheaths are to be used to protect the prestressing steel from corrosion. Verification of the steel corrosion is to be applied to the entire tendon system including anchors and deviators when external tendons and un-bonded prestressing tendons are used.

8.4 Safety

Verification of safety should take into consideration the influence of restressing into consideration. Safety verification is to include cross-sectional failure and fatigue failure.

8.5 Serviceability

Verification related to serviceability shall be done by classifying the structures either as prestressed concrete or as prestressed reinforced concrete. Verification related to appearance, vibration, displacement, deformation, watertightness, etc. must be completed.

8.6 Construction

Verification during construction shall include:

- The tensile stresses in tendons during and immediately after tensioning are not exceeded by the design values of tensile strength and yield strength of the tendons.
- The cracking of concrete is not permitted and the tensile stress in concrete does not exceed the design flexural strength.
- Tension reinforcement is provided in concrete in regions where tensile stresses exist.
- Diagonal tensile stress in concrete due to shear and torsional moment shall not be greater than the design tensile strength of concrete.
- The maximum value of flexural and axial comprehensive stress due to flexural moments, axial forces and prestressing forces immediately after prestressing shall be less than the design compressive strength of concrete.
- Verification of safety requirements completed.

9 Design - Precast Concrete and Tilt-up Concrete

9.1 General

Concrete members or products produced in advance at a factory or at a field production facility shall be considered as precast concrete.

The precast concrete shall be designed to confirm it meets the required criteria for performance, safety and economy when used as a single unit or as part of a structure. It is necessary for the single item and the whole assembly of precast concrete to have adequate safety during construction and the service period for the design life.

9.2 Loads

Precast concrete made by prestressing steel, the tensile forces initially applied to the prestressing steel and the methods of production and curing, shall be taken into consideration when determining the apparent relaxation ratio of prestressing steel for calculating the loss of prestressing.

The design loads shall include storage, transportation, fabrication, joining, and others in addition to the normal design loads.

9.3 Connections

The connections designs for the precast members used in part or whole of the structure shall confirm the load transfer capacity of the connections with consideration of the connection method. It shall be confirmed that the connection secure the required strength and durability based on the connection method.

10 Design - Masonry Structures

10.1 General

This section supplements AS 3700 Masonry Structures and the Building Code of Australia requirements.

Clay Masonry

Design and construction shall comply with the following additional requirements unless specified otherwise.

- Face fixed veneer ties to be screw fixed.
- Joints to be tooled.
- Control joints to be provided as detailed in the foundation design.
- Strength f'uc = 12 MPa.
- Salt resistance grade.

- Mortar Type = M3.
- Mortar nominal thickness = 10 mm.
- Core filling grout to brick piers = 20 MPa.
- Wall ties = Medium duty.
- Durability classification = R4 (stainless steel).
- Fixing = Embedment in mortar 50 mm minimum.

Blockwork

Design and construction shall comply with the following additional requirements unless specified otherwise.

- Blocks to AS 4455.
- Comprehensive strength 15 MPa.
- Grout comprehensive strength 20 MPa, aggregate 10 mm and slump 230 mm.
- Mortar admixtures to AS 3700 Clause 10.4.2.4.
- Lime to AS 1672.1.
- Portland cement to AS 3792 Type GP.
- Mortar mix M3 cement, lime and sand ratios (by volume) 1:0:4.
- Block construction to AS 3700 Table 11.1.
- Joints thickness 10 mm.
- Provide purpose made cleanout blocks at the base of each grouted core. Locate cleanout blocks on side of wall to be concealed. Clean cores to dislodge mortar fins protruding from the blocks and mortar droppings from reinforcement. Remove through cleanout blocks.
- Grouting not to commence until grout spaces have been cleaned out and the mortar joints have attained sufficient strength to resist blow-outs. Wet down the hollow cores before grouting. Limit the height of individual lifts in any pour so the grout can be thoroughly compacted to fill all voids and confirm bond between grout and masonry. Compact grout by vibration. Top up the grout after 10 minutes to 30 minutes on completion of the last lift and vibrate to mix with the previous pour.
- Backfill behind the retaining wall to be controlled fill Class II in accordance with AS 4678.
- Backfilling not to commence until the retaining wall has achieved its full design strength.
- Backfilling and compaction to be completed without damaging the drainage system and the retaining wall.
- Drainage system behind the wall to be installed and to the manufacturer's specification. Filter layer to be stopped 200 mm below the finished ground level.
- Clean all cores after each days laying.
- Control joints to be provided at a maximum of 6.0 m centres and as detailed.

Articulated Masonry

Design and construction shall comply with the following additional requirements unless specified otherwise.

- The design is based on masonry articulation joints being installed unless noted otherwise on the foundations and slabs.
- Articulation joints shall be located where new brickwork joins old brickwork.
- A slip joint around the lintel is required where an articulation joint is besides openings with brickwork above the openings.
- The articulation joint is to continue between the window/door frame and the brickwork to the full height of the wall. The frames are to be fixed with fasteners that allow movement of the joint.
- The maximum spacing of joints and articulation joints to AS 4773 unreinforced masonry unless noted otherwise. Refer AS 2870 for definitions. Use shorter spacing for HD sites.

Site Classification	Construction and Surface Finish	Joint Spacing For Walls Less Than 4 m High (m)	Joint Spacing For Walls Greater Than 4 m High (m)
A & S	Not required	-	-
	External face finish	6.0	4.2
	External rendered/painted	5.5	3.9
M, M-D	Internal face finish	6.0	4.2
	Internal rendered/painted	5.5	3.9
	External face finish	5.0 to 5.5	3.5 to 3.9
H1, H2	External rendered/painted	4.5 to 5.5	3.2 to 3.5
H1-D	Internal face finish	5.0 to 5.5	3.5 to 3.9
H2-D	Internal rendered/painted	4.5 to 5.0	3.2 to 3.5
P, E, E-D	Refer to Engineer	-	-

11 Products

All materials used in the structure shall comply with the project specification and the current Australian Standards. Specific samples may require testing. The constructor shall arrange for the samples to be supplied, identified, stored and tested, and the results issued.

Propriety products and materials shall be used in accordance with the manufacturer's written requirements and instructions.

Water Resisting Concrete

Details of materials used and their execution shall be in accordance with the Australian Standards with written confirmation from the supplier of the water resisting materials compliance by the supplier. The materials shall not affect the:

- Environment.
- Concrete.
- Curing.
- Release agents.
- Placing methods.
- Joints.
- Finishes.
- Reinforcement.
- Support details.
- Loads.
- Contents.

11.1 Formwork and False Work

The design, materials and construction shall be in accordance with AS 3610. Timber, wood and metal products certified for formwork and falsework shall be used. Permanent formwork may be used subject to the approval of the designer. The formwork shall be clear of all debris, oils, water and other contaminants.

Release agents shall be chosen to suit the method of construction and the finish required. They shall not be affected by the weather.

11.2 Reinforcement

All reinforcement shall comply with the requirements of the appropriate Australian Standard. All reinforcement suppliers shall hold a valid Certificate of Approval for manufacture and/or fabrication in compliance to the Australian Standards or equivalent. A supplier Certificate of Approval reference shall be stated on all documents.

Pre-assembled welded fabricated reinforcement delivered to site shall have approved certification for the manufacture of pre-assembled welded fabrication using welded semi-structural and/or structural joints or equivalent.

11.3 Reinforcement Accessories

Spacers

The materials and workmanship of spacers shall be in accordance with the relevant Australian Standard for spacers and chairs for steel reinforcement. The spacers shall have the required performance characteristics.

Continuity Strips

Propriety continuity strips manufactured to Australian Standards with approved certification or equivalent shall be used.

Couplers

All coupler manufacturers shall have a valid Technical Approval Certificate to Australian Standards or equivalent for the application of couplers. Reinforcing bars shall be adequately and appropriately prepared by the supplier to receive the agreed coupler.

Punching Shear Reinforcement Systems

All punching shear reinforcement systems manufacturers shall have a valid Technical Approval Certificate to Australian Standards or equivalent. Details of the source and suppliers shall be forwarded for approval.

Fibre Reinforcement

Fibre reinforcement is not to be used unless approved. Details of the proposed fibres, source and suppliers shall be forwarded if its application is approved.

11.4 Water Stops

Water stops in all construction joints and movement joints to be supplied and installed with the manufacturer's written instructions.

11.5 Curing Materials

Curing compounds must comply with AS 3799. Use only wax-based (AS 3799, Class A), resin based (AS 3799, Class B), and water-borne (AS 3799, Class Z) curing compounds. Do not use wax-based or chlorinated rubber-based curing compounds on surfaces forming substrates to concrete toppings, painted surfaces, cement-based render or similar. For each curing compound proposed, provide a current Certificate of Compliance from the supplier. For each batch delivered, provide a Certificate of Uniformity from the supplier.

11.6 Concrete Rehabilitation

11.6.1 Concrete Repair Materials

The concrete repair materials used shall be suitable for hand application. The concrete repair mortar shall have, as a minimum, an equivalent strength to the parent concrete. The concrete patch repair mortar shall be a single component polymer-modified cementitious repair mortar exhibiting the following characteristics:

- A minimum characteristic compressive strength of 40 MPa at 28 days.
- Drying shrinkage at 28 days age of less than 600 microstrain when tested in accordance with AS 2350: Part 13.
- The repair material shall not crack excessively due to thermal and/or shrinkage effects. Excessive cracking shall be defined as cracks with width in excess of 0.10 mm in the repair, crazing/cracking covering significant areas of the repair, or any cracking whatever at interfaces between old concrete and the repair material.
- The total chloride ion content of the repair material shall not exceed 0.1% by weight of cement.
- The total alkali content of the repair material (as Na2O equivalent) shall be limited to 3.0 kg/m3 of repair material.
- Seven day bond strength to substrate (by direct pull-off), no single result less than 1 MPa, mean result exceeding 1.2 MPa.

The preferred repair mortar is Renderoc HB40 or similar approved equivalent (compliant to AS 4020).

11.6.2 Epoxy Mortar Materials

The concrete surfaces that require a chemically resistant epoxy mortar lining shall comply with this section.

The concrete surfaces will be lined with a high build chemically resistant three component epoxy-based mortar. Nitomortar EL-HB is preferred or a suitably approved equivalent.

Concrete surfaces will be primed using an epoxy resin primer compatible with the repair material. Nitobond EP for Nitomortar EL-HB or a suitably approved equivalent.

11.6.3 Joint Sealant Materials

Joints will be sealed with an approved chemically resistant polyurethane sealant. Sikaflex Tank N is preferred or a suitably approved equivalent.

Primer shall be suitable for use with polyurethane sealants and concrete (Sika Primer - 3N is preferred or a suitably approved equivalent).

Backing rods shall be extruded closed cell polyethylene foam, with a diameter 25 % larger than the joint (Sika Closed Cell Backing Rod is preferred or a suitably approved equivalent).

Joint filler shall be non-absorbent, semi-rigid, polyethylene joint filler.

11.7 Precast Concrete

Grout

The preparation of grout, made with materials and plant proposed for use on site, shall be assessed for suitability for the intended purpose in advance of the grouting operation to enable adjustments to be made to the materials plant.

Grout shall consist of pre-bagged materials requiring only the addition of a measured amount of water and shall comply with the Australian Standards.

Strands

Strands shall comply with the Australian Standards. The grade and diameter shall be specified with the relaxation class. Strands shall be supplied by suppliers with valid Certificates of Approval for the supply of strands.

The coating material to un-bonded strands shall be 1 mm polypropylene unless otherwise specified.

Anchorage

Anchorages for post tensioning systems shall comply with the minimum performance requirements of Australian Standards. Documentary evidence of compliance shall be supplied with the anchors.

Ducts and Vents

Ducts, vents and connection material shall be sufficiently robust to resist damage during construction. They shall be smooth galvanised steel with a minimum wall thickness of 0.35 mm or corrugated galvanised steel with a minimum wall thickness or 0.3 mm. Where plastic ducts are used, they shall comply with the requirements Corrugated Plastic Ducts for Internal Bonded Post-tensioning.

Ducting shall prevent the entrance of paste from concrete and shall not cause harmful electrolytic action or deterioration of the tendons of tendon components. The internal cross sectional area shall be at least twice the net area of the tendons prestressing steel. The ducting shall be capable of transforming forces from the grout to the surround concrete.

12 Construction

12.1 Formwork

Any clashes between holes, cast in items and reinforcement shall be resolved with the engineer before concrete is placed. Methods of fixing the formwork that result in holes through the concrete section when formwork is removed shall not be used unless approved by the engineer. Through ties, to support vertical faces, are not to be used for liquid retaining structures. Formwork ties shall be of a type to maintain water resistance of the concrete. Ferrous metals shall not be used in the concrete cover zones.

12.1.1 Removing and Re-using Formwork

Formwork and false work shall be removed at a time determined by the contractor in compliance with the design. The formwork shall be removed in a procedure that shall not damage the concrete surface.

The sequence of propping, back propping and re-propping for the structure shall be specified in a method statement by the contractor and approved by the engineer. It shall not have any damaging effects on the permanent structure.

12.2 Reinforcement

Reinforcement shall be delivered to site in properly identifiable tagged bundles, mats or prefabricated assembly. It shall be stored on site so as not to become contaminated by deleterious materials or otherwise damaged. Fabric shall be stored flat.

Reinforcement shall not be dropped from height, mechanically damaged or shock loaded in any way.

Reinforcement shall be fixed in position in accordance with the reinforcement detail drawings and reinforcement schedules. Any alterations of reinforcement shall be carried out after written approval.

Tying

All tying of reinforcement shall be carried out with black annealed mild steel tying wire unless otherwise approved. All ends shall be bent away from the concrete surface and all loose ends removed prior to placing concrete.

Welding

The location of all welded joints shall be as detailed on the reinforcement drawings. Tack welding on site is not permitted unless approved in exceptional circumstances. Evidence of component welders and details of welding procedures will be required for approval. Welding shall comply with the Australian Standard for welding reinforcement.

Projecting Reinforcement

Reinforcement ends left projecting from the cast concrete shall be free of release agents and shall be protected against damage and corrosion. Light surface rusting will be acceptable unless detrimental to the finished structure or causing rust straining to adjacent exposed concrete or formwork.

Site Bending

A method statement must be submitted for approval for site bending. The following conditions apply to site bending:

- Bending of reinforcement, including straightening, is not permitted at temperatures below 5 degrees Celsius.
- The curvature shall be as constant as possible.
- Bending shall be in one operation at a constant rate.
- Reinforcement shall not be heated to more than 100 degrees Celsius.
- The bent radius shall not exceed the maximum permitted in the Australian Standards.
- Each bar bent shall be inspected for signs of fracture. Any fractured bars shall be non-conforming.

12.3 Water Stops

The method to maintain the water stops in the correct position and prevent movement or damage while concrete is placed, during or after removal of formwork is to be agreed with the engineer. Where centre section water stops are proposed, details of full compaction of concrete around the water stop are required.

12.4 Concrete Placement

Submit as appropriate, details of the proposed concrete in accordance with the project specification. Daily maximum and minimum atmospheric shade temperatures shall be recorded using a calibrated thermometer located close to the structure.

Suitable arrangements for premature cessation of a pour shall be agreed and in place before work starts and shall include the extend of, and timing of any remedial work before resumption of placing concrete.

Concrete shall not be placed in extreme weather conditions. Written approved arrangements to be prepared if the air temperature is below 5 degrees Celsius or above 30 degrees Celsius.

Water is not to be added on site to the concrete and if it is added to the concrete mixer drum, before discharge on site, the concrete shall be deemed non-confirming. The concrete producer shall carry out testing of the concrete in accordance with Australian Standards. When the producer identifies a non-

conformity that was not obvious at the time of delivery, this shall be reported to the engineer within 24 hours.

Concrete tests prepared by the constructor or their authorised agent, shall be manufactured, initially cured and transported to an approved NATA laboratory.

Concrete shall not be cast directly against existing construction or faces of excavations without prior approval from the engineer. The temporary or permanent support from the ground shall be firm enough for concreting operations where structural concrete is poured directly against the ground.

Placing and Compaction

Concrete shall be placed and fully compacted to avoid cold joints, honey combing and to minimise segregation, excessive blemishes or other defects in the hardened concrete. Compaction shall be carried out without causing damage or displacement of the formwork, reinforcement, tendon, ducts, anchors, inserts, etc.

The surface of the concrete shall be cured to avoid premature drying. Methods of curing shall be agreed with the design engineer. Curing membranes shall be compatible with the finishes to be applied subsequently.

Measures shall be adopted that minimise the risk of early age thermal cracking when concrete is placed in conditions or in an element where early age thermal cracking is likely.

Curing

Apply the curing compound to unformed surfaces immediately after completion of all finishing operations, and to formed surfaces within 30 minutes of removal of the formwork. Use a pressurised sprayer to give uniform cover. Incorporate a device for continuous agitation and mixing of the compound during spraying. Use a fine spray at the rate recommended by the supplier. Provide a continuous flexible coating without visible breaks or pinholes. Maintain an unbroken curing membrane for the specified curing period and repair any damage by re-spraying.

In hot weather, commence curing immediately after concrete placement, cover the concrete with an impervious membrane or continuously wet hessian. As an alternative to immediate covering, where the temperature exceeds 25° C or where not protected against drying winds, protect the concrete with a fog spray application of aliphatic alcohol evaporation retardant.

Post Concrete Inspection

The relevant work shall be inspected by the constructor and inspector at the end of the specified curing period.

Water Resisting Concrete

Inspections shall be carried out by the constructor and inspector for all water resisting construction before back filling or covering up of the structure to

identify defects that may lead to water penetration. Further inspections shall be jointly carried out after back filling.

12.5 Surface Finishes

A plain concrete finish is to be provided unless otherwise specified. It will require careful selection of the concrete, release agent and the use of good quality formwork. The concrete must be thoroughly compacted and all surfaces must be true with clean arises. Very minor inherent surface blemishes should occur, with no discoloration from the release agent or grout run off to adjutant pours. The struck surface should be of a consistent colour from the materials used. The arrangement of the formwork panels and tie holes should be in a regular pattern. Steps at joints between forms is to be a maximum of 1 mm. This surface finish should not require any further work to make them good.

Unformed Finish

The concrete shall be finished by trowelling, or a similar process, to produce a dense, smooth, level, uniform surface unless specified otherwise.

12.6 Precast Concrete

This section specifies additional requirements particular to structures which are part or wholly precast concrete. Records of the unit mark, unit component, date of casting and curing for each precast element shall be made by the manufacturer and issued with the precast element. All marks shall be made so that they are hidden when the unit is placed in position or may be removed without marking the concrete surface.

Connection details shall be compatible with the design and allow for the expected tolerances.

An erection specification and work programme shall be prepared and agreed with the design engineer.

Lifting

Precast elements shall not be lifted from the base on which they have been cast before the concrete has attained its design demounting strength and is strong enough to prevent the precast element from being damaged, overstressed or distorted giving regard to demounting equipment to be used.

Reinforcement and Fixings

The manufacturer shall determine the need for any additional reinforcement or fittings necessary for handling the precast element or other provisions required for temporary structural purposes until the precast elements are incorporated into the structure, including details for making good of any provision made for lifting etc.

Any inserts of fixings required to be cast in the concrete and permanently exposed either externally or within the building cavity envelope shall be stainless steel.

Handling and storage

Precast components shall be clearly marked before delivery in accordance with the erection specification to indicate their weight, location and orientation in the works in order to facilitate concrete erection. Where delivery cannot be timed for direct final positioning, arrangements shall be made for suitable storage to prevent deterioration or damage. Storage shall be on firm supports clear of the ground.

Precast component faces shall be protected from mechanical damage, dirt, staining, rust marks and other disfiguration.

Temporary Stability

Confirm that any precast concrete components to be incorporated into the structure shall be kept stable in its erected position until such time as the component can safely carry the construction loads without distress. The overall stability of the structure shall be maintained at all times during the erection process.

12.7 Joint Sealants

All expansion and contraction floor slab joints, and internal and external wall joints shall receive a joint sealant application.

Joint sealant works shall not commence until the concrete has had adequate time to cure in accordance with the manufacturer's recommendations (minimum 28 days).

Joints shall be sealed with an approved chemically resistant polyurethane sealant. Sikaflex Tank N is preferred or a suitably approved equivalent.

Primer shall be suitable for use with polyurethane sealants and concrete (Sika Primer -3 N is preferred or a suitably approved equivalent).

Backing rods shall be extruded closed cell polyethylene foam, with a diameter 25 % larger than the joint (Sika Closed Cell Backing Rod is preferred or a suitably approved equivalent).

Joint filler shall be non-absorbent, semi-rigid, polyethylene joint filler.

12.8 Prestress Concrete

Tendons

Tendons shall be fixed and supported at centres not exceeding 1 m and shall be securely fixed to prevent movement and floatation during the construction process. Tendons shall be cut to length using mechanical means. The actual position of the tendons shall indicate the location in both plan and elevation.

Un-bonded tendons may be deviated to avoid obstructions such as openings or columns with written approval from the engineer. The change of direction of the tendon should occur away from the opening and trimmer reinforcement shall be provided to avoid possible cracking at the corners.

Vents

Vents shall be fixed at injection and exit points. Where tendon drape exceeds 500 mm, intermediate vents shall be fixed at tendon high points. Intermediate vents shall also be provided on tendons which are over 20 m in length.

Stressing

The jacking force should not normally exceed 75% of the tendon characteristic strength but may be increased to 80% provided written approval is given considering safety and load extension characteristic of the tendon by the engineer. The initial prestress at transfer shall not normally exceed 70% of the tendons characteristic strength and in no case shall exceed 75%.

Measurement

Load and extensions shall be measured prior to commencement of stressing, after stressing and lock off to an accuracy of 2% or 2 mm whichever is more accurate. Measurements shall take into consideration the possible strand movement at the dead end anchor. Any resistance on the stressing sequence and increments shall be observed and recorded.

Commencement

Stressing shall not commence without prior agreement on theoretical extensions and the concrete has achieved the design transfer strength. The confirmation of the transfer strength shall be based on test sample taken from the last concrete delivery.

Stressing Equipment

Stressing jacks and their load measuring systems should have an appropriate and current calibration certificate to NATA compliance and not more than six months old at the time of stressing. The stressing equipment shall be capable of establishing a tendon load to an accuracy of +/- 2%.

Grouting

Personnel proposed for grouting shall be suitably experienced in such work and details shall be provided for review.

Full scale grouting trials shall be carried out using the same personnel, equipment, materials and procedures as approved. The trial shall demonstrate

that the proposed method, materials and equipment fills the ducts as specified. Trials shall be taken as early as possible to allow proper inspection and any necessary modifications or adjustments. A procedure shall be available for back up equipment or flushing out ducts for corrective action in the event of breakdown or blockage.

Cutting or Drilling

Where the tendon position is not accurately and authoritatively documented, reinforcement detection equipment must be used to locate the tendon positions prior to cutting or drilling.

13 Concrete Rehabilitation

13.1 Concrete Repairs

13.1.1 Breakout and Removal of Deteriorated Concrete

Breakout of existing failed concrete repairs is to be undertaken as follows:

- Saw cut the perimeter of each repair as a series of straight lines at right angles to the surface to a nominal depth of 20 mm to prevent feathering of edges. Reinforcement is not to be damaged during this process.
- Remove defective concrete within marked out areas through the use of a portable jack hammer or equivalent, to expose the sound concrete substrate.
- Where the breakout indicates that the surrounding concrete is not sound, inform the Superintendent. If necessary the repair area shall be enlarged, subject to approval from the Superintendent.
- Where reinforcement is exposed the breakout shall extend 25 mm beyond the depth of the reinforcement.
- The repair perimeter shall extend until a minimum 130 mm length of sound reinforcement (i.e. no section loss) is achieved.
- Featheredges will not be accepted and where necessary, fresh saw cuts are to be made to eliminate featheredges at the completion of the breakout.
- Record the exact locations and size of the breakout on relevant drawings and submit to the superintendent for approval. The drawings shall be used for the purposes of recording and measuring the work.

13.1.2 Treatment of Exposed Reinforcement

To inhibit further corrosion any exposed reinforcement is to be cleaned prior to the reinstatement of concrete.

- Reinforcement shall be cleaned to remove any loose scale and/or corrosion products to achieve a surface finish equivalent to Sa 2.5 AS 1627.4.
- Abrasive blasting or the use of power tools will be required to achieve this class of finish.
- Where a loss of section greater than 30 % is identified, an equivalent bar diameter in accordance with AS/NZS 4671 shall be welded to the existing sound bar. The weld shall be a double-lap splice (bars vertical) in accordance with Appendix F, Table F4 of AS/NZS 1554.3, Joint Type L-c. The minimum length of weld is 80 mm and weld consumable is W50X in accordance with AS/NZS 2717.1 (ISO 14341). Welding within 50 mm of bends in any bar is not permitted.
- The additional reinforcement shall be lapped in a manner such that the depth of cover is not reduced from the existing value.
- Welding of additional reinforcement shall be performed by experienced personnel with qualifications in accordance to AS 1554.

- Precautions shall be taken to prevent excessive heating and resultant damage to surrounding concrete during welding. The reinforcement welded joint configuration shall be double-lap splice as shown in Appendix F, Table F4 of AS/NZS 1554.3, Joint Type L-c.
- All reinforcement shall be primed with the preferred primer Nitoprime Zincrich (or a suitably approved equivalent). Application of the priming agent is to be in accordance with manufacturer's recommendations

13.1.3 Concrete Substrate Preparation

The concrete substrate is to be prepared prior to reinstatement of the concrete patch repair mortar as follows.

- The substrate shall be lightly scabbled with a hand held power tool such as a pneumatic hammer drill or jack hammer to ensure good adhesion (and mechanical key) with the repair mortar.
- Subsequent to scabbling, thoroughly wash the substrate surface to ensure that the substrate is free from dust, loose particles and other contaminants.
- Prepare the substrate prior to reinstatement of repair concrete by soaking with potable water for a minimum period of 2 hours.
- The substrate shall be primed with a compatible polymer emulsion-bonding agent (Nitobond HAR for Renderoc HB40). Application of the priming agent is to be in accordance with the manufacturer's recommendations.
- The Superintendent shall witness the concrete substrate preparation prior to concrete reinstatement.

13.1.4 Mixing

Mixing of the repair mortar shall be undertaken as follows.

- Mixing of the repair mortar shall be undertaken in accordance with the manufacturer's recommendations. Mixing shall be undertaken on site using power mixing tools. Hand mixing shall not be used.
- Whole bags of dry component material shall be used. Split bags shall not be used. Materials that have deteriorated in any way shall not be used.
- Potable water only is to be used during mixing.
- The volume of mix ingredients shall be measured and added in accordance with the mix proportions and procedures recommended by the manufacturer.

13.1.5 Reinstatement

Reinstatement of the repair mortar shall be undertaken as follows.

- The repair mortar shall be applied prior to the drying of the priming agent.
- Placement of material on the prepared substrate shall be either by gloved hand or trowel application.

- The repair mortar shall be thoroughly compacted onto the primed substrate and carefully packed around reinforcement to confirm there are no voids.
- Reinstate prepared area with proprietary high performance and low shrinkage repair mortar, compatible with existing concrete Renderoc HB40 preferred or similar approved equivalent in accordance with the manufacturer's requirements.
- If applying in layers, the manufacturers recommended minimum and maximum thickness of application shall be adhered to and each previous layer must be scratched to provide a mechanical key to subsequent layers.
- Confirm that fresh material does not contaminate the tank by providing adequate containment to the work area. Dispose of trapped materials off-site in accordance with statutory authority regulations.

13.1.6 Surface Finishing

Finishing of the repair surface shall be flush with the surrounding areas within a tolerance of 2 mm.

13.1.7 Curing

- Curing shall be undertaken immediately after reinstatement.
- The curing compound shall have a minimum curing efficiency of 90 %.
- A proprietary curing agent that is compatible with the repair mortar shall be used (Concure A99).
- Application of the curing compounds shall be in accordance with the manufacturer's requirements.

13.1.8 Repair of Surface Defects

Subsequent to the reinstatement and curing of the repair mortar, a visual inspection of the repairs shall be undertaken. Any surface defects identified shall be repaired as follows:

- Remove and dispose of all applied materials that lack uniformity, exhibit segregation, honeycombing, delamination, cracking, or which contain dry patches, voids or sand pockets.
- Repair such areas immediately after cleaning and surface preparation of the substrate and the interface with the existing repairs.

13.1.9 Inspection and Testing

Inspection and testing of the repair areas is to include compressive strength testing of repair mortar, visual inspection of all repairs and soundness survey of concrete repairs.

Where the manufacturers specify that additional testing is to be undertaken in order to adhere to their warranty schemes, then this additional testing must be

undertaken. If destructive testing is involved, then these test areas are to be repaired as indicated in this document.

13.1.10 Visual Inspection

Visual inspection is to be undertaken on the surface of all repair areas. Any defects identified in this visual inspection, such as voids, honeycombing, cracking, crazing, or any cracking at interfaces between old concrete and the repair, shall be deemed unacceptable and are to be satisfactorily repaired.

13.1.11 Soundness of Repair (Hammer sounding)

After 7 and 28 days curing, soundness surveys of all repair areas are to be undertaken. Any hollow sounding shall be deemed unacceptable and are to be removed and satisfactorily repaired, following the procedures outlined in this document.

13.1.12 Compressive Strength Testing

Compressive strength testing of the repair mortar is to be undertaken on the same batch of repair mortar to be used in the repair works as per AS 1012.9**.** The results of the compressive strength testing are to be submitted to the Superintendent for their approval.

13.1.13 Bond Testing

The bond strength of the applied materials shall be tested at a minimum of 3 locations after 7 days curing. The testing shall be undertaken by an adhesion testing of a 50 mm diameter core extending to 20 mm into the parent concrete. Aluminium dollies a minimum of 20 mm thick shall be bonded to ends of the cores. Tensile testing (in a calibrated test machine) shall be undertaken at a strain rate of 1 mm/minute. The load at calculated tensile stress failure and mode of failure shall be recorded. Areas of repair with bond strength below the performance criteria shall be deemed unacceptable and are to be removed and satisfactorily repaired, following the procedures outlined in this document.

13.2 Epoxy Mortar Lining

13.2.1 Contractor Experience

The applicators shall be manufacturer approved applicators of the lining material and shall have appropriate experience in the use of the material and application equipment. Experience in undertaking similar repairs shall be supplied to the Superintendent.

13.2.2 Trial Application

A trial application to confirm the material and application methodology is adequate shall be undertaken. The trial application shall occur at two sites for each structure to be repaired.

The full scale of epoxy mortar lining work shall not be undertaken prior to successful completion of the trial.

13.2.3 Concrete Substrate Preparation

The concrete substrate is to be prepared prior to application of the epoxy lining as follows:

- The area to be lined shall be demarcated using saw cuts 5 mm deep to prevent feathered edges at the extremities of the repair area.
- The substrate shall be lightly scabbled via grit or water blasting to ensure good adhesion (and mechanical key) with the epoxy mortar coating.
- Subsequent to scabbling, thoroughly wash the substrate surface to ensure that the substrate is free from dust, loose particles and other contaminants.
- The Superintendent shall witness the concrete substrate preparation prior to epoxy lining.

13.2.4 Mixing

Mixing of the epoxy mortar shall be undertaken as follows:

- Mixing of the epoxy mortar shall be undertaken in accordance with the manufacturer's recommendations. Mixing shall be undertaken on site using a slow speed electric drill with a suitable paddle. Hand mixing shall not be used.
- Whole bags of component material shall be used. Split bags shall not be used. Materials that have deteriorated in any way shall not be used.
- The use of thinners is not permitted.
- The volume of mix ingredients shall be measured and added in accordance with the mix proportions and procedures recommended by the manufacturer.

13.2.5 Application

Application of the epoxy lining shall be undertaken as follows:

- The surface shall be primed using an epoxy resin primer Nitobond EP. Application of the primer shall be by brush or spray.
- The epoxy mortar lining material shall be applied within 90 minutes of priming, while the primer is still tacky. If the primer is allowed to dry, a second application is required.
- Application of the epoxy mortar shall be by gloved hand to allow the material to be thoroughly worked into the prepared surface. The epoxy mortar lining shall not be applied over the vertical wall joints.
- The lining shall be built up as required to thickness such that the outmost aggregate is covered by a minimum of 5 mm of epoxy mortar in accordance with the manufacturers recommended application rates.
- The repair surface shall be finished with a steel trowel.

- Confirm that fresh material does not contaminate the tank by providing adequate containment to the work area. Dispose of trapped materials off-site in accordance with statutory authority regulations.
- Should the contractor wish to use Nitomortar ELS (spray applied), work methods statement and evidence of experience in the application method must be submitted and accepted by the Superintendent prior to application.

13.2.6 Curing

The epoxy mortar shall be allowed to cure for a minimum of 7 days. The finished surfaces shall be adequately protected whilst curing.

13.2.7 Limitations

Limitations for the works are as follows:

- The repair material shall not be applied when the substrate or ambient temperatures are below 5° C
- Do not mix part bags.
- Do not use thinners.

13.2.8 Inspection and Testing

Inspection and testing of the coated areas is to include visual inspection of all surfaces, soundness survey and bond testing.

Where the manufacturers specify that additional testing is to be undertaken in order to adhere to their warranty schemes, then this additional testing is to be undertaken. If destructive testing is involved, then these test areas are to be repaired as indicated in this document.

13.2.9 Visual Inspection

Visual inspection is to be undertaken on the surface of all coated areas. Any defects identified in this visual inspection, such as voids, honeycombing, cracking, crazing, or any cracking at interfaces between old concrete and the coated area, shall be deemed unacceptable and are to be satisfactorily repaired.

13.2.10 Soundness of Repair (Hammer Sounding)

After 7 and 28 days curing, soundness surveys of all coated areas are to be undertaken. Any hollow sounding shall be deemed unacceptable and are to be removed and satisfactorily repaired, following the procedures outlined in this document.

13.2.11 Bond Testing

The bond strength of the applied materials shall be tested at a minimum of 3 locations after 7 days curing. The testing shall be undertaken by adhesion

testing of a 50 mm diameter core extending to 20 mm into the parent concrete. Aluminium dollies a, minimum of 20 mm thick, shall be bonded to ends of the cores. Tensile testing (in calibrated test machine) shall be undertaken at a strain rate of 1 mm/minute. The load at calculated tensile stress failure and mode of failure shall be recorded. Areas of repair with bond strength below the performance criteria shall be deemed unacceptable and are to be removed and satisfactorily repaired, following the procedures outlined in this document.

13.3 Joint Sealant

All expansion and contraction floor slab joints and internal wall joints shall receive joint sealant application.

Joint sealant works shall not commence until the concrete repair mortar and epoxy mortar lining have had adequate time to cure in accordance with the manufacturer's recommendations (minimum 14 days).

13.3.1 Contractor Experience

The applicators shall be manufacturer approved applicators of the sealant material and shall have appropriate experience in the use of the material and application equipment. Experience in undertaking similar repairs shall be supplied to the superintendent.

13.3.2 Trial Application

A trial application to confirm the material and application methodology is adequate in sealing the joints shall be undertaken to the satisfaction of the Superintendent. The trial application shall occur at four sites.

Trial Site 1
Floor slab contraction joint, 5 m total trial length (include concrete repair, intersection and saw cut length).

Trial Site 2
Floor slab expansion joint, 5 m total joint length (include concrete repair, intersection and saw cut length).

Trial Site 3
Internal wall contraction joint 5 m total joint length.

Trial Site 4
Internal wall expansion joint 5 m total joint length.

The full scale of joint sealing work shall not be undertaken prior to successful completion of the trial.

13.3.3 Joint Saw Cutting

The following joint saw cutting will be undertaken prior to joint preparation:

- The joint edges shall be saw cut and broken out to the nominal depth and width in order to achieve the specified dimensions (maintaining a width to depth ratio of 2:1).
- Concrete within the saw cut area shall be mechanically broken out to form the prescribed joint detail as detailed in the Project Drawings.
- Joints which do not require saw cutting shall have their surfaces ground to the depth of sealant application.
- A 3 to 5 mm chamfer shall be ground on all joint edges.

13.3.4 Joint Preparation

The following joint preparation will be undertaken prior to the application of the joint sealant:

- Joint surfaces to receive replacement sealant shall be cleaned using mechanical grinding followed by water blasting to remove all traces of foreign material, moisture, or other contaminants.
- All traces of the existing sealant and other contaminants shall also be removed on the concrete surfaces adjacent to joint areas.
- The joint shall be cleaned of all loose material by vacuuming to its full depth.
- A sound, clean and dry (moisture content below the maximum allowed by the sealant manufacturer at time of sealant application) surface shall be achieved ready for the replacement joint sealant.
- Prior to application of sealant, a backing rod shall be installed. The backing rod shall be fitted at the depth of the joint as shown on the Project Drawings to maintain a width to depth ratio of 2:1. The diameter of the backing rod shall be approximately 25% larger than the joint width.
- Prior to application of the replacement sealant, the prepared concrete joint surfaces shall be primed using Sika Primer -3N in accordance with the manufacturer's recommendations unless otherwise approved by the engineer in writing.
- The surface either side of the joint shall be temporarily masked to prevent contamination with excess sealant and facilitate compaction of the sealant thus confirming full contact with the joint sides. The tape shall be removed after sealant application and prior to the manufacturer's specified skinning time.

13.3.5 Application

Joint sealant application shall be undertaken as follows:

- Sikaflex Tank N shall be applied to the primed surfaces in accordance with the approved Contractors Method Statement and sealant manufacturer's recommendations.
- The sealant shall have a minimum depth of 15 mm and a maximum depth no greater than 20 mm and also meet the required width to depth ratio of 2:1.

- Immediately after the sealant application, the sealant must be tooled and compacted into a regular cross section to the specified profile, using a small spatula or other suitable tool.
- The Contractor must ensure that the completed sealant is adequately protected during curing to prevent damage being caused to it by its or others operations.
- The sealant shall be allowed a minimum of 6 days curing time for 15 mm depth, with an additional 24 hours per additional 2.5 mm depth. The sealant manufacturer shall confirm the curing period and any other curing requirements deemed relevant for this project.

13.3.6 Inspection and Testing

The following inspection and testing shall be undertaken:

The sealant manufacturer shall recommend quality control testing on site and acceptance criteria appropriate to confirm the acceptable application of the product, which shall be included in the Contractor's Method Statement, for the Superintendent's approval.

As a minimum at one location per 100 m of sealant installed a "tongue" of sealant shall be cut using a sharp knife along either side of the joint so that the "tongue" can be lifted to project by approximately 150 mm. The tongue shall then be pulled at an approximate angle of 45 to 90 degrees to the joint surface to tear the sealant out of the joint. The sealant shall fail in cohesion, i.e. tear within itself, rather than pull away from the concrete substrate. In the event that his is not achieved, the Superintendent shall instruct additional testing in the 100 m of sealant represented by the test and any areas failing to meet the requirement shall be replaced at the Contractors expense.

The Contractor shall inform the Superintendent of all completed sealant replacement one day after final application for the Superintendent inspection and approval.

Areas where the replaced sealant does not comply with the quality control testing and/or is not properly bonded as demonstrated by hand probing, sagging, has voids, etc. or where the sealant is in the Superintendents opinion defective in other ways, it shall be replaced by the Contractor to the Superintendents satisfaction at the Contractors own cost. Additional quality control testing may be carried out to non-compliant designated areas at the Contractors cost.

All destructive tests required to the applied replaced sealant for quality control testing shall be made good and reinstated to the profile of the surrounding surfaces using the approved sealant materials and workmanship.

Upon acceptance that all sealant has been applied in accordance with this Specification the Contractor shall submit two original "As Repaired" documents in digital and hard copy to the Superintendent for the purpose of recording the repair works inclusive of:

a) Tabulated listing of all applied replacement sealant.

b) Position marked on drawing plan of all applied sealant.

c) All quality control tests completed and results obtained.

d) Position marked on drawing plan of quality control tests.