



Engineering

Technical Standard

TS 0711.1- Concrete Remedial Works: Concrete Repair

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

Significant/Major Changes Incorporated in This Edition

This is the first issue of this Technical Standard. However, it supersedes the following SA Water documents:

- SAW-ENG-STR-TEM-TSB-001 Technical Specification - Concrete Repair Works: Patch Repairs
- TS137 – Rehabilitation of Concrete Wastewater Manholes

Document Controls

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1 Introduction

1.1 Purpose

The purpose of this section of the Concrete Remedial Works Technical Standard is to detail SA Water's minimum technical requirements for the supply of materials, surface preparation, material application, inspection and testing for structural and non-structural concrete repairs to reinforced concrete water and wastewater assets.

It is intended that repairs completed in accordance with this Technical Standard are of consistent high quality and attain the specified durability and service life.

1.2 Concrete Remedial Works Technical Standard Suite

This Technical Standard is one part of the SAWS-ENG-0711 Concrete Remedial Works Technical Standard suite, that comprises:

- TS 0711.0: General requirements
- **TS 0711.1: Concrete repair (This Document)**
- TS 0711.2: Joint sealant replacement
- TS 0711.3: Concrete crack repair
- TS 0711.4: Structural bonding and strengthening
- TS 0711.5: Surface protection and lining of concrete.

Read TS 0711.1 in conjunction with TS 0711.0: General Requirements.

1.3 General Requirements

TS 0711.0 General Requirements apply to all aspects of the work:

1. Introduction: Purpose, references
2. Scope: Type of structures and repair methods, exclusions and technical dispensation
3. Using the technical standard
4. General project requirements
5. Quality requirements
6. Health and safety requirements
7. Environmental requirements
8. Construction requirements

Appendix A : Schedules of hold points, witness points and identified records.

1.4 Concrete Repair Requirements

Carry out all remediation of concrete in accordance with the requirements as specified in TS 0711.0, the project contract documents, the requirements specified in this Technical Standard and the repair material manufacturer's instructions.

Request written advice from SA Water's Representative to resolve any conflict between this Technical Standard and any manufacturer's instructions.

Make no deviation from this Technical Standard without written approval from SA Water's Representative.

The technical requirements of this Technical Standard include:

1. Type of repair and materials
2. Pre-work survey to identify, mark out and record the location of concrete defects
3. Installation of temporary propping
4. Trial repair to verify materials and workmanship
5. Removal of defective concrete to provide a sound substrate
6. Supplement and prepare reinforcement
7. If required install additional repair system components, such as galvanic anodes, dowel bars, etc.
8. Preparation and priming of the concrete substrate
9. Reinstatement of concrete using cementitious or epoxy resin repair materials
10. Curing of the repair material
11. Quality control testing to verify compliant repair works
12. Submission of an As-Repaired report.

Undertake additional remedial works if required (crack injection, joint sealant, surface protection, structural bonding or strengthening) in accordance with TS 0711.2 to TS 0711.5.

This Technical Standard does not cover speciality repairs for areas protected by impressed current cathodic protection systems, sacrificial anode jacket systems, chloride extraction or re-alkalisation electrochemical treatments. Use project specific specifications for such works.

If required, undertake demolition of complete structural components in accordance with TS 0711.0 Clause 6.4.5.

1.5 Abbreviations

Abbreviations used in this document are defined in TS 0711.0 Clause 1.2.

1.6 References

Australian and International Standards, SA Water Standards, Industry Technical Guidelines and other documents referenced in this Technical Standard are defined in TS 0711.0 Clause 1.3.

1.7 Definitions

The terminology and technical definitions applicable to this Technical Standard are defined in TS 0711.0 Clause 1.4.

A selection of key technical terms relevant to this Technical Standard are defined in Table 1.

Table 1: Definitions of Terms Used in this Technical Standard

Term	Definition
Blowholes	Small regular or irregular cavities, usually not exceeding 15 mm in diameter or 5 mm in depth, resulting from entrapment of air bubbles in the surface of formed concrete during placement and consolidation.
Bond	The adherence between the repair material and the existing concrete substrate.
Bond strength (or pull-off strength)	The resistance to separation of a repair material from the existing concrete substrate via the application of a tensile stress.
Breakout	Removal of a limited area of concrete. Typically, from or adjacent to a damaged area, but may also occur for testing purposes.
Cathodic protection	The prevention or reduction of corrosion of steel in concrete by the distribution of sufficient direct current to the steel to make it the cathode in a galvanic or electrolytic cell.
Corrosion deteriorated concrete	Concrete with deterioration, delamination, cracking or spalling due to contamination by deleterious substances such as chlorides and carbon dioxide associated with the overall mechanism of corrosion of steel reinforcement.
Curing	Application of water, or retention of water using sheet or liquid applied membranes to control the rate and extent of moisture loss from a newly formed concrete surface exposed to air during the initial setting and hardening cement hydration phase.
Delamination	The separation of a section of concrete from solid concrete usually along steel reinforcement which is identified by a drummy or hollow sound instead of a clear ringing sound when metal hits the concrete.
Dry surface	Concrete residual moisture after surface preparation does not exceed the limits for successful coating application, bonding and curing in ASTM D4263, ASTM F1869 or ASTM F2170.
Electrochemical chloride extraction	A temporary treatment to permanently draw chloride ions out chloride contaminated concrete using an external anode system in an electrolyte medium, electrically connected to the reinforcement with a direct current DC operated for a fixed time period.
Electrochemical re-alkalisation	A temporary treatment to permanently create high alkalinity conditions in carbonated concrete in the vicinity of reinforcement using an external anode system in an electrolyte medium, electrically connected to the reinforcement with a direct current DC operated for a fixed time period.
Fairing coat	A thin layer of cementitious material used to render large surface areas and cover, fill or smooth blowholes and surface imperfections flush with the finished concrete surface.
Featheredging	Cementitious repair material applied to the edge of the repair in a very thin layer instead of a thicker layer which is contained at the edge with a square cut.
Galvanic cathodic protection	A permanent treatment to provide direct current using a sacrificial anode system embedded within or external to reinforced concrete that acts as an electrolyte medium, and is electrically connected to the steel reinforcement, that reduces the rate or halts corrosion of the steel.
Hydrophilic crystalline cementitious material	A proprietary material used as an additive in slurry coating and mortar materials that reacts with water and chemicals within hardened concrete or diffuses into concrete to form a non-soluble crystalline compound within the concrete pores, capillary tracts and cracks as part of a hydrophilic waterproofing system.
Impressed current cathodic protection (ICCP)	A permanent treatment to provide direct current using an external power system via an anode system in an electrolyte medium, electrically connected to the steel reinforcement, that reduces the rate or halts corrosion of the steel.
Moist surface	Concrete surface has a matt moist appearance with no shiny water film, the pores are not water saturated, indicated by a drop of water being readily

Term	Definition
	absorbed, restoring the surface to a matt appearance.
Non-corrosion deteriorated or defective concrete	Concrete with deterioration, damage or defects due to accidental or physical loadings, temporary overloading, impact and other mechanical or uncontaminated damage, excessive early shrinkage or thermal stresses and low quality honeycombed or off form voided concrete.
Principal (in AS/NZS 1554.3 and 1554.6)	The term "Principal" shall mean SA Water's Representative.
Sacrificial anode	A cast piece of metal lower in the galvanic series than steel, that forms the main component of a galvanic cathodic protection system.
Saturated surface dry (SSD)	The concrete substrate pores are saturated with water to a depth of several millimetres, the concrete surface may have a wet sheen, but there is no dripping/ponded/free water on the surface, as if it had been dried with a cloth.
Spall	A fragment of concrete broken off or detached from the edge of solid concrete due to the corrosion of steel reinforcement or due to accidental, physical or mechanical damage.
Surface imperfections	Surface voids or cavities not exceeding 5 mm in depth left on the concrete surface (in the form of surface honeycomb), due to failure of the mortar to effectively fill the spaces among coarse aggregate particles during placement and consolidation.
Wet surface	The concrete surface has dripping or standing water.

2 Concrete Repair System Selection

This Technical Standard provides requirements for concrete repairs, which might include one or more combinations of repair type as listed in Table 2.

Select the most onerous set of conditions to determine the required repair method.

Classify all concrete repairs in the format shown in Table 3, using the reference numbers in Table 2, and state n/a if a repair feature is not applicable.

Submit Table 3 in the Pre-Repair Survey Report (Clause 4.8) in addition to Defect Map(s) identifying type, location and quantity of defects.

Table 2: Concrete Repair Type Definitions

Repair Feature	Ref. #	Detail	Standard Clauses
Type of Repair	1A	Structural	
	1B	Non-Structural	
Asset Type	2A	Potable/Treated Water	
	2B	Raw/Untreated Water	
	2C	Wastewater - Treated/Fresh/Stale	
Application Method	3A	Hand applied patch repair	9
	3B	Spray applied repair	10
	3C	Flowable micro-concrete repair	11
	3D	Underwater repair	12
	3E	Leakage sealing repair	13
	3F	Rapid set horizontal repair	14
	3G	Grouting	15
	3H	Fairing coat	16
	3I	Epoxy resin mortar repair	17
Reinforcement Corrosion	4A	Chloride/Salt induced reinforcement corrosion	
	4B	Atmospheric carbonation induced reinforcement corrosion	
	4C	Submerged (Leaking water/Soft-water/Low oxygen induced reinforcement corrosion)	
	4D	H ₂ S biogenic (sewer) acid attack induced reinforcement corrosion or direct acidic chemical attack	
Concrete Degradation Mechanism	5A	Moderate/shallow surface degradation via chemical/acid attack, sulfate attack, biological attack, freeze thaw attack, soft water exposure, salt crystallisation	
	5B	Severe/deep surface degradation via H ₂ S biogenic (sewer) acid attack, or chemical/acid attack,	
	5C	Mechanical damage (delamination or spall)	
	5D	Physical (surface degradation via fire, erosion, abrasion, cavitation, wear)	
	5E	Internal expansion via AAR, DEF or Sulfide aggregate reactions	

Table 3: Example Concrete Repair Classification Schedule

Structure Components Reference	Repair Type Reference #	Asset Type	Application Method	Reinforcement Corrosion	Concrete Degradation Mechanism

3 Materials

3.1 General Requirements

Appendix A provide general guidance of the typical performance characteristics, application methods and ability for high/low build and high early age strength for Class R1 to Class R4 cement based repair products and acid resistant cement type repair products. Requirements for epoxy mortar products are set out in Clause 3.9.

Comply with general materials requirements detailed in TS 0711.0 Clause 8.4 and Clause 8.5:

1. General
2. Repair systems
3. Proprietary items
4. Manufacturer's recommendations
5. Product Supplier
6. Compliance with AS/NZS 4020
7. Materials submissions
8. Storage of materials
9. Trials.

3.2 Approved Concrete Repair Materials

Products not having prior documented SA Water approval shall not be used until approval has been obtained from SA Water's Representative.

HOLD POINT

3.3 Materials Testing

Undertake materials testing in accordance with TS 0711.0 Clause 5.9.

List all tests proposed to be undertaken to demonstrate compliance with the Technical Standard in the ITP.

Provide manufacturer's documented evidence including copies of original test certificates that demonstrate that as a minimum the product exceeds each of the minimum performance requirements.

HOLD POINT

3.4 Cementitious Repair Materials

3.4.1 Performance Requirements

Cementitious concrete repair materials shall achieve the following performance requirements, unless noted otherwise:

1. Be a sag resistant one or two component pre-bagged polymer modified cementitious material based on Portland cement to which clean potable water or the pre-blended polymer emulsion for a multi-part material shall be the only permitted site addition
2. Be certified to BS EN 1504-3 Class 1 to Class 4: and/or
3. Be compatible with the properties of the parent concrete material and meet the key minimum performance requirements for structural and non-structural concrete repair materials in EN 1504-3 Table 3, as listed in Table 4, and/or
4. Comply with

5. Table 5 to align the repair material class to the substrate strength, with testing to AS 1012 methods, and/or
6. Comply with Table 6 for additional material performance requirements by repair type
7. Provide the required vapour permeability
8. Maximum drying shrinkage strain <700 microstrain at 56 days to AS 1012.13
9. Minimum wet density 1600 kg/m³
10. Maximum water/powder ratio to the manufacturer's specification
11. The total chloride ion content of the repair material shall not exceed 0.05% by weight of cement
12. The total sulfate ion content (SO₃ equivalent) shall be less than 4% of the total cementitious material
13. The maximum aggregate size shall be 7 mm
14. Do not extend the cementitious repair material through on-site mixing of additional aggregates unless the additional aggregates are part of a proprietary repair system and are supplied in the manufacturers pre-bagged packaging for addition as whole bags without the requirement for site portioning
15. The completed 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
16. The workability shall be appropriate to the method of placing.

Table 4: BS EN 1504-3 Minimum Concrete Repair Materials Performance Requirements

Characteristic	Test Method	Unit	Class R4	Class R3	Class R2	Class R1
Compressive strength	EN 12190	MPa	≥45	≥25	≥15	≥10
Adhesive bond	EN 1542	MPa	≥2.0	≥1.5	≥0.8 ¹	≥0.8 ¹
Elastic Modulus Ec	EN 13412	GPa	≥20	≥15	No Req ¹	No Req ¹

Note 1: Minimum 0.5 MPa if cohesive failure within substrate

Note 2: Refer BS EN 1504.3 for full list of performance requirements.

Table 5: Cementitious Repair Material Properties to AS 5100.8 Table 3.5.3.3.2

	Unit	Class R4	Class R3	Class R2	Class R1
Substrate Compressive Strength	MPa	>50	30 to 50	15 to 30	n/a
Min. Compressive Strength at 1 day	MPa	15	10	5	n/a
Min. Compressive Strength at 7 days	MPa	40	25	19	n/a
Min. Compressive Strength at 28 days	MPa	60	35	23	n/a
Min. Flexural Strength at 28 days	MPa	10	6	4	n/a
Min. Tensile Strength at 28 days	MPa	3.8	2.8	1.8	n/a
Min. Pull Off Bond Strength to Concrete Substrate at 7 days¹	MPa	2.5	1.5	0.8	0.8
Calculated Minimum Ec (based on min. Substrate Strength, to ACI 318.08, +/- 25%)²	GPa	27	20	15	n/a

Note 1: AS 5100.8 value modified to match EN 1504 requirement.

Note 2: SA Water requirement

Table 6: Additional Materials Performance Requirements

Repair Type Ref. Table 2	Detail	Additional Material Performance Requirements
1A	Structural	a. Approximately match (within 20%) the original concrete substrate's elastic modulus, thermal expansion coefficient and tensile strength and exceed (not greater than by 20%) the compressive strength.
1B	Non-Structural	a. Have a lower elastic modulus than the original concrete substrate
2A	Water - Potable/ Treated	a. All components of repair materials in contact with potable water shall meet the requirements of AS/NZS 4020.
2B	Water - Untreated Raw	a. None.
2C	Wastewater - Treated/Untreated	a. Normally submerged: None b. H ₂ S – as per Type 5B
3A	Hand applied patch repair	a. None
3B	Spray applied repair	a. None
3C	Castable/flowable repair	a. Flow characteristic, 600 mm (flow trough) to AS 1478.2 b. Maximum drying shrinkage strain <600 microstrain at 56 days to AS 1012.13.
3D	Underwater repair	a. Plug of water seepage: <ul style="list-style-type: none"> • Formulate to seal active water leaks • Set within 30 to 180 seconds of mixing • Waterproof, anti-wash out property b. Underwater mortar: <ul style="list-style-type: none"> • Set within 5 to 10 minutes of mixing • Waterproof, anti-wash out admixture

Repair Type Ref. Table 2	Detail	Additional Material Performance Requirements
3E	Leakage sealing repair	a. Cementitious fibre reinforced mortar or slurry coating containing a hydrophilic crystalline waterproofing admixture that achieves minimum 90% reduction of depth of water penetration under pressure compared to control (to EN 12390-8) b. Meet the requirements of AS/NZS 4020.
3F	Rapid set repair	a. Compressive strength >20 MPa at 6 hours using standard cylinders to AS 1012, at a flowable consistency
3I	Epoxy resin mortar	a. Comply with Clause 3.9
4A	Chloride/Salt induced reinforcement corrosion	a. Maximum repair mortar chloride ion diffusion coefficient $1 \times 10^{-12} \text{ m}^2/\text{s}$, according to Nordtest NT Build 443 at 56 days. b. Maximum repair mortar 28-day resistivity 15 kohm cm as measured by a calibrated handheld instrument using the Wenner four probe method if SACP used. c. Maximum repair mortar 28-day resistivity 30 kohm cm as measured by a calibrated handheld instrument using the Wenner four probe method if ICCP used. d. Polymer-modified Cementitious bar coating For patch repair system (not SACP or ICCP), the bar coating can also be zinc rich epoxy. For ICCP repair systems, bar coating is not required. e. Provide SACP system such as discrete sacrificial anodes around edge of the repair. f. Provide protective coating as per TS 0711.5, primer include an organic migratory corrosion inhibitor.
4B	Atmospheric carbonation induced reinforcement corrosion	a. Polymer-modified Cementitious bar coating and repair mortar shall include corrosion inhibitor b. Provide anti-carbonation protective coating as per TS 0711.5
4C	Leaking water/Soft-water/Low oxygen induced reinforcement corrosion	a. Polymer-modified Cementitious bar coating and repair mortar shall include corrosion inhibitor
4D	H ₂ S biogenic (sewer) acid attack induced reinforcement corrosion	a. Provide minimum grade 316L stainless steel replacement reinforcement and dowels
5A	Moderate surface degradation via chemical/acid attack, sulfate attack, biological attack, freeze thaw attack, soft water exposure, salt crystallisation	a. Acid resistance: Achieve negligible mass loss (<0.5%) at 84 days acid exposure to ASTM C 267. b. Sulfate resistance: maximum expansion 0.05% at 12 months to ASTM C1012. c. Softwater: Waterproof mortar, as per Type 3E

Repair Type Ref. Table 2	Detail	Additional Material Performance Requirements
5B	Severe surface degradation via H ₂ S biogenic (sewer) acid attack or chemical/acid attack	a. CAC mortar : <ul style="list-style-type: none"> • Minimum CaAl cement content 400 kg/m³ maximum w/b ratio 0.4. • Maximum 7 mm manufactured CAC clinker aggregate • Compressive strength >20 MPa at 6 hours using standard cylinders to AS 1012, at a flowable consistency • Nil Portland cement • May contain glass fibres • CAC comply with BSEN 14647 b. Waterproof slurry or mortar, as per Type 3E, incorporating an anti-microbial admixture that has documented 10 year track record in sewers. c. Geopolymer or inorganic polymer based mortar with acid resistance as per Type 5A (a)
5C	Mechanical damage (delamination or spall)	a. Provide bonded dowels and mesh to suit size of the repair.
5D	Physical (surface degradation via fire, erosion, abrasion, cavitation, wear)	a. Minimum Class R3, containing polymer or steel fibres b. Have sufficient hydraulic abrasion resistance where subject to running water.
5E	Internal expansion via AAR, DEF or Sulfide aggregate reactions	a. The total alkali content (Na ₂ O equivalent) of the repair material shall be limited to 2.8 kg/m ³ of repair material. b. Mortar containing a waterproofing admixture based on hydrophilic crystalline sealing technology that achieves minimum 90% reduction of water penetration under pressure compared to control (to EN 12390-8)

3.5 Reinforced Concrete

Use SA Water Standard TS 710 Concrete for full replacement of components using ready mix concrete and precast concrete.

Ready mixed repair concrete used for form and pour shall be a highly-workable concrete. Highly-workable concrete shall include a superplasticiser with a nominated slump of between 160 mm and 220 mm.

Highly-workable concrete placed under water shall contain an anti-washout admixture.

3.5.1 Fibre Reinforced Concrete

Use steel fibres in ready mixed concrete in accordance with TS 0710 Clause 31.1.

Use synthetic fibres in ready mixed concrete in accordance with TS 0710 Clause 31.2.

3.6 Reinforcement

3.6.1 General

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

If requested, supply to SA Water's Representative copies of the manufacturer's test certificates identifiable with the reinforcement supplied or provide documentary evidence that all products meet the requirements of AS/NZS 4671 (steel) or BS 6744 (stainless steel) and that the supplier has a system in place to prevent non-conforming material from being supplied.

Where such certificates cannot be supplied, arrange testing of reinforcement for tension, bending and ductility to demonstrate compliance to the relevant standard. If required, SA Water's Representative may require submission of technical data including: tensile strength, yield stress, mass, percentage elongation, cold bend radii, mill certificates, delivery dockets and test reports, to confirm compliance with this Standard.

3.6.2 Mild Steel

Provide high yield deformed bars Grade 500 or hot rolled plain bars Grade 250 reinforcing steel that conforms with AS/NZS 4671.

3.6.3 Stainless Steel

Provide stainless steel reinforcement that conforms with the requirements of BS 6744 or ASTM A955M and is manufactured, processed, fabricated and supplied only by an Australian Stainless Steel Development Association accredited supplier.

Design stainless steel reinforcement taking into account its physical and mechanical properties.

Use Grade 316 or Grade 316L stainless steel reinforcement or dowel bars as a minimum or a higher corrosion resistant grade.

3.6.4 Galvanising

Where required by the Project, provide steel reinforcement hot dip galvanised to at least Grade HDG600 in accordance with AS/NZS 4680.

The hot-dip galvanized coating shall have a minimum average weight of 600 g/m² and a minimum average coating thickness of 85 µm.

3.6.5 Tie Wire

Provide annealed steel tie wire having a diameter of not less than 1.2 mm to tie mild steel reinforcement.

Provide hot dip galvanised steel tie wire having a diameter of not less than 1.2 mm to tie hot dip galvanised mild steel reinforcement.

Provide stainless steel tie wire of diameter not less than 1.2 mm of the same grade to tie stainless steel reinforcement.

3.6.6 Fibre Reinforced Polymer (FRP) bars

This Technical Standard does not allow for the use of Fibre Reinforced Polymer (FRP) bars as a partial substitute or to supplement the existing steel reinforcement in a concrete repair.

Design replacement components that wholly comprise FRP bar reinforcement in accordance with ACI 440.1R or equivalent and construct FRP reinforced components in accordance with TS 0710.

3.6.7 Bar Chairs or Spacers

General

Provide bar chairs and spacers that comply with AS/NZS 2425 and this Technical Standard and are manufactured in an AS/NZ ISO 9001 approved production facility, subject to approval by SA Water's Representative.

Do not use plastic ties or clips. Continuous spacers shall not be more than 350 mm in length and shall not be placed in a continuous straight line.

Use stainless steel chairs or spacers of the same stainless steel grade as stainless steel reinforcement.

Water Retaining or Water Excluding Structures

Provide high durability proprietary fibre-cement moulded or extruded bar chairs and spacers that comply with the requirements of AS/NZS 2425 and have not lesser durability characteristics than the concrete to be placed around them.

3.7 Water

Use potable quality water, drawn from the metropolitan reticulated supply, conforming to AS 1379 for mixing with concrete repair materials, curing, cleaning and surface preparation.

3.8 Additional Concrete Repair System Materials

3.8.1 Reinforcement Protective Coating

Provide an active reinforcement protective coating material that meets BS EN 1504-7 and is able to passivate the reinforcement, in accordance with

Table 7.

The concrete repair material manufacturer shall provide written confirmation that the reinforcement primer coating is fully compatible with its concrete repair material.

Reinforcement primer cementitious coatings shall be single or multi-component pre-packaged polymer modified cementitious material based on Portland cement to which clean potable water or a pre-blended polymer emulsion is added.

Corrosion inhibitors shall be amino alcohol organic migrating corrosion inhibitor (MCI).

Table 7: Reinforcement Protective Coating Types

Repair Type	Exposure Environment	Reinforcement Protective Coating Type
4B	Atmospheric carbonation	Polymer-modified Cementitious, min 2 x 1 mm DFT, or Epoxy zinc, min 2 x 40 µm DFT
4C	Submerged/Splash	Cementitious, min 2 x 1 mm DFT
4A	Chlorides	Cementitious incorporating MCI, min 2 x 1 mm DFT
4D	Biogenic/ gaseous H ₂ S	Cementitious incorporating as 4B with MCI, top coated with an epoxy resin coating, or Cementitious/epoxy coating incorporating MCI min 2 x 1 mm DFT
2A	Potable Water	Cementitious, min 2 x 1 mm DFT, AS/NZS 4020 compliant, or Top coat with an AS/NZS 4020 compliant epoxy bar coating

3.8.2 Bonding Agent

General

Provide a bonding agent material that is recommended by the repair material manufacturer's recommended product and/or the approved Work Method Statement.

Bonding agent options include:

1. None (substrate is clean and roughened concrete, pre-soaked with water for 2 hours to be saturated surface dry {SSD})
2. Slurry form of the concrete repair material (material is typically mixed 2 parts powder to 1 part water), applied to SSD substrate
3. Proprietary single or multi-component polymer resin bonding material
4. Proprietary single or multi-component polymer bonding material modified cementitious material based on Portland cement to which clean potable water or a pre-blended polymer emulsion is added (in some cases may be the same material as the reinforcement primer coating material in Clause 3.8.1).

Type 2A Water Contact Repairs

Provide a TS0800 compliant bonding agent.

Type 3B Sprayed Concrete and Type 3C Flowable Micro-concrete

Do not use bonding agents

Substrate shall be SSD.

3.8.3 Curing Material

Provide curing material for all cementitious based repair materials in accordance with the repair material manufacturer's recommended product and/or the approved Work Method Statement.

Curing options include:

1. Polythene sheeting securely fastened and taped at all edges (repair mortar manufacturer may recommend for hot weather conditions), and/or
2. Degradable spray applied curing compounds such as solvent-based hydrocarbon resin type (AS 3799, Class B), or water based emulsion type (AS 3799, Class Z) that comply with AS 3799, greater than (or equal to) 90% efficiency
3. Wet curing by misty fog spray within an impermeable enclosure
4. Wet burlap or polyester geofabric scrim with soaker hoses under polythene sheeting
5. Manufacturer's proprietary curing agent that is part of its repair system.

Do not use wax based film-forming (AS 3799, Class A) curing compound that may remain on the surface for more than 28 days following application.

All curing methods shall not damage the finished surface and shall be compatible with subsequent coating application to the concrete surface (e.g., repair material or protective coating system).

Where doubt exists, use non-contaminating curing systems (e.g., polythene wrap).

Type 2A Water Contact Repairs

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

3.8.4 Evaporation Retarder

Provide a proprietary evaporation retarder as part of early age crack risk mitigation during hot weather casting of horizontal surfaces.

3.8.5 Type 4A Repairs: Galvanic Anodes

Materials

Where required as part of chloride induced reinforcement corrosion concrete repairs, provide sacrificial galvanic anodes that form part of a complete corrosion mitigation system:

1. Discrete anodes, based on a zinc metal alloy either:
 - a. Pre-encased in a precast highly alkaline cementitious material designed to be embedded within the concrete repair material; or
 - b. Metal alloy anode designed to be placed in a cored hole and encased in alkaline mortar insitu.
2. Anodes may be cylinders, blocks, rods, mesh or other type
3. Encapsulating mortar shall be a proprietary mortar manufactured by or approved for use by the anode manufacturer
4. Electrical connections and cabling system to complete connections between the anodes and reinforcement and any monitoring hardware.

Design Requirements

Match the design life of the SACP anode to the design life of the repair nominated in TS 0109.

The concrete SACP system shall be designed by a corrosion engineer minimum certified to NACE CP2 or equivalent with greater than 5 years' experience in concrete remedial works using anode design information provided by the anode system manufacturer, including anode output and maximum permitted spacing.

Submit drawings, calculations, work method statements and ITPs for SA Water's Representative approval prior to installation of the anodes showing:

1. Design report that details the reinforcement surface area to be protected, anode type, current output and design life
2. Anode connection and installation details
3. Electrical continuity and reinforcement connection details
4. The maximum permitted spacing for the nominated anode system
5. Number of anodes required by size of concrete repair area, to cover the range of expected concrete repair types.

3.8.6 Type 4A Repairs: Liquid Applied Corrosion Inhibitor

Provide a proprietary liquid applied MCI that meets the following criteria:

1. Organic amino alcohol based surface applied corrosion inhibitor applied in 2 to 5 applications to achieve a total consumption of 0.5 kg/m² or 5.5 m²/l, with a certified minimum penetration of concrete to a depth of 25 mm in 28 days
2. Do not dilute the inhibitor.

3.8.7 Cementitious Fairing Coats

Provide cementitious fairing coat repair material required to fill blowholes and imperfections on concrete structures that complies with the following requirements:

1. A single component polymer modified material
2. Capable of application at 0 – 3 mm thick and fill blowholes and imperfections flush with the finished concrete surface
3. Capable of application over a large area without being subject to shrinkage cracking.

Type 2A Water Contact Repairs

Provide an AS/NZS 4020 compliant cementitious fairing coat.

3.8.8 Cementitious Grout

Provide a proprietary pre- packaged, cement-based grout to fill voids.

Only use fresh packaged grout mixes less than one month old.

Grout mixes may be pre-packaged when only water and admixtures are added to the dry grout mix on Site, or may be designed to meet specific project requirements where different grout mix ingredients are batched on Site.

Grout shall have the following properties and comply with the performance requirements in Table 8:

1. High bleed resistance, low shrinkage and high fluidity
2. Maximum nominal fine aggregate size of 1.0 mm
3. Water / cement ratio not greater than 0.33 by mass
4. Cement's chloride content $\leq 0.06\%$ by weight cement
5. Maintain workability for minimum 1 hour
6. Expansive admixtures shall:
 - a. Be of the pre-hardening type
 - b. Not contain iron or aluminium powder
 - c. Not generate gases from chemical reaction between grout mix constituents or other materials in contact with the grout.

Table 8: Grout Performance Requirements

Property	Test Method	Criteria	Comments
Bleeding	ASTM C940	Final Bleeding < 0.5%.	Measured when two successive readings show no further expansion or bleeding.
Early Expansion	ASTM C940	< 2% at 3 hours.	Temperature tolerances are at 20°C \pm 5°C.
Fluidity	ASTM C939 / AS 1478.2 App C	Immediately after mixing: Efflux time < 20 s. 45 minutes after mixing: Change in efflux time < \pm 3 s	Constructor's target efflux time for the Site conditions shall not vary from nominated value by more than \pm 2 s.
Compressive Strength	AS 1478.2 App A	≥ 50 MPa at 7 days	-

3.9 Epoxy Resin Mortar

Provide two-component solvent-free thixotropic epoxy resin mortar systems supplied in pre-weighed quantities ready for on-site mixing and use for the purpose of resin patching mortar, adhesive and fairing coats, that comply with the requirements in Table 9 and as follows.

1. Fairing material: Capable of application at 0 – 5 mm thick and fill blowholes and imperfections flush with the finished concrete surface
2. Patching mortar: Structural adhesive and patching mortar up to 25 mm deep, >25 mm with added kiln dried sand at the mixing ratio 2 parts sand to 1 part epoxy resin
3. Compatible with/capable of being applied damp surfaces
4. Cure quickly to form a completely impermeable surface ready for over-coating
5. Potable water certified to AS/NZS 4020.

Table 9: Epoxy Resin Patching Mortar Minimum Requirements

Characteristic	Test Method	Unit	Epoxy Resin Mortar
Compressive strength	EN 12190	MPa	≥45
Adhesive bond to concrete	EN 1542	MPa	≥2.0
Elastic Modulus E_c	EN 13412	GPa	≥20
Temperature application range	-	-	5°C to 35°C

3.10 Other Materials

Provide details of any material types proposed to be used that are not listed in this Standard in accordance with TS 0711.0 Clause 4.4.

4 Workmanship - General

4.1 Standards and Codes

Comply with the standards, codes and guidelines referenced in this document and as defined in TS 0711.0: Clause 1.3.

4.2 Concrete Repair Constructor Competency

Comply with all parts of TS 0711.0: Clause 4.1.

4.3 Quality Assurance

Comply with all parts of TS 0711.0: Clause 5 Quality and the quality control testing requirements in Clause 18.

4.3.1 Hold Points and Witness Points

Comply with all mandatory quality control and audit hold and witness points, listed in Appendix B.

Advise SA Water's Representative when hold points are reached and ready for inspection.

4.3.2 Inspection and Test Plans

Comply with ITP requirements in TS 0711.0 Clause 5.6.

Show the type, sequence and number of tests to be undertaken in each area and how the pass, rework or reject criteria will be determined on the ITP.

4.3.3 Pre-Start Meeting

Hold a pre-start meeting in accordance with TS 0711.0 Clause 8.6.

4.3.4 Daily Records

Comply with requirements in TS 0711.0 Clause 5.11 Site Records.

Maintain records of the work on a daily basis to enable traceability of workmanship and materials.

4.3.5 As-Repaired Report

Provide an As-Repaired Report in accordance with TS 0711.0 Clause 5.12.

4.4 Health and Safety Requirements

Comply with health and safety requirements in TS 0711.0 Clause 6:

Clause 6.1	General
Clause 6.2	Works on existing sewers
Clause 6.3	Lighting
Clause 6.4	Concrete removal
Clause 6.5	Diving
Clause 6.6	Traffic management
Clause 6.7	Barriers and signs
Clause 6.8	Equipment
Clause 6.9	Hazardous materials.

4.5 Environmental Requirements

Comply with health and safety requirements in TS 0711.0 Clause 7:

Clause 7.1	Noise emissions
Clause 7.2	Compressor silencing
Clause 7.3	Hand tools
Clause 7.4	Waste management/Disposal of contaminants
Clause 7.5	General cleaning and disposal of refuse
Clause 7.6	Dust and water
Clause 7.7	Existing flora.

4.6 Construction Requirements

Comply with the construction requirements in TS 0711.0 Clause 8:

Clause 8.1	Existing structures
Clause 8.2	Temporary works
Clause 8.3	Extent of works identification
Clause 8.4	Materials requirements
Clause 8.5	Trials
Clause 8.6	Pre-start meeting
Clause 8.7	Commissioning and water quality monitoring.

4.7 Temporary Works

Provide temporary works including propping, access systems and plant isolations in accordance with TS 0711.0 Clause 8.2.

4.8 Pre-Work Survey

Undertake the pre-work survey requirements of TS 0711.0 Clause 8:

1. Clause 8.1.1: Verify existing structures and the location of all services located outside or embedded within the concrete structure components
2. Clause 8.3 : Extent of works identification:
 - a. Mark up plan showing extent of work
 - b. Undertake and record pre-repair survey, submit Report
 - c. Undertake further testing if required
 - d. Mark out on the structure all defect areas for repair.

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4.9 Materials Handling

4.9.1 Mixing of Materials

Clean all equipment and tools before use.

Do not use materials that have exceeded their shelf life or deteriorated in any way.

Only mix and use whole bags or containers of each component of the material, do not split mixing between mixes. Do not thin materials or dilute resins with water or solvent unless specifically directed by the manufacturer.

For cementitious materials, measure by volume or weigh water accurately to ensure that the correct volume of water is added to cementitious materials. Include the required mass or volume of water and the minimum mixing time on the ITP.

Add the material components and thoroughly mix prior to use, in accordance with the Manufacturer's recommendations and the approved Work Method Statement, to achieve a uniform consistency, colour and workability appropriate to the method of placing.

Mix the repair material using equipment of a type recommended by the repair material manufacturer and in accordance with the approved Work Method Statement that shall normally be a forced action mixer or a suitably sized drum using a spiral paddle fitted to a low speed (max 600 rpm) heavy-duty drill for cementitious and epoxy materials.

Do not use a free fall mixer to mix concrete repair materials.

Use a stop watch or other timing device to ensure that the material is mixed for the correct amount of time in accordance with the Manufacturer's instructions.

Store resins and coating materials in a bunded store under conditions as recommended by the Manufacturer in a cool dry place out of direct sunlight.

Use resins in accordance with the manufacturers recommended pot life. Discard all resin that has exceeded its stated pot life or exceeds any stated workability parameter.

Take precautions to avoid damage to any surface near the work zone due to mixing and handling of the material.

Properly dispose of waste material and empty containers in accordance with TS 0711.0 Clause 7.4.

4.9.2 Transportation of Materials

Transport the repair material from the mixer to the place of final deposit by means that shall:

1. Prevent segregation or loss of materials
2. Not prevent proper placing or compaction
3. In accordance with material manufacturer recommendations for proprietary repair materials.

4.9.3 Weather Precautions

Plan concrete reinstatement works taking into account the forecast weather conditions and take adequate precautions to ensure that the manufacturer's application temperature requirements for freshly applied repair material are not exceeded, and include this information on the ITP.

Only apply repair material when the site measured temperature falls within the following criteria:

1. Substrate temperature and the air temperature measured at the point of application is above 5°C, or 5°C and rising
2. Air temperature measured at the point of application does not exceed 35°C.

Stop the material reinstatement if the temperature of the repair material or the concrete surface to be repaired exceeds these limits or the limits recommended by the repair material manufacturer.

Where the ambient temperature at the point of application of material is above 30°C and the area to be treated is subject to direct sunlight, provide protective shading and keep equipment that comes into direct contact with the repair material cool and not exposed to direct sunlight.

Provide wind breaks and use aliphatic alcohol evaporative retarder if required to minimise early age drying shrinkage prior to final set and subject to the repair material manufacturers written approval.

4.10 Trial Repairs

Undertake trial repairs for all types of specified repair in accordance with TS 0711.0 Clause 8.5.

Trial locations shall be as agreed with, or instructed by, SA Water's Representative.

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4.10.1 Concrete Repair Trial

The concrete repair trial area shall be a minimum of 0.5 m² or as directed by SA Water's Representative and the entire trial repair process shall be observed by SA Water's Representative.

As a minimum demonstrate compliance for the following repair steps:

1. Concrete surface preparation
2. Reinforcement cleaning
3. Welding of reinforcement
4. Achievement of electrical continuity if required
5. Installation of sacrificial anodes if required
6. Application of reinforcement coating
7. Achievement of concrete surface saturated dry(SSD)
8. Application of bonding agent if required
9. Application of all types of repair material to trial repair area
10. Curing of repair material
11. Quality control testing.

4.10.2 Operative Competency Trial

Undertake competency of application trial panels for all sprayed concrete operatives in accordance with Clause 10.7.

4.10.3 Flowable Concrete Trial

Undertake competency of application trial flowable concrete repair in accordance with Clause 11.5.

5 Removal of Defective Concrete

5.1 Maintenance of Structural Integrity During the Works

Comply with TS 0711.0 Clause 8.2.1 to avoid over-stressing any part of the existing structure during the remedial works through removal of excessive concrete from single or multiple structural elements, which might compromise the structural integrity of that element.

Include all identified requirements in WMS's and ITPs for all components of the work and verify the Works Supervisor and operatives understanding through documented toolbox talks.

Actively manage and supervise the risk of excessive concrete removal.

5.2 Pre-Breakouts Tasks

Remove all defective concrete, contamination and debris prior to concrete reinstatement.

Before commencing concrete breakout/removal:

1. Obtain hold point releases and permission to proceed from SA Water's Representative
2. Protect the area surrounding the breakout from potential damage caused by the breakout operation
3. Install access and temporary works
4. Complete all pre-work surveys to identify and mark out defects, identify existing embedded services and relocate services
5. Plan the concrete removal and reinstatement works to avoid any over-stressing or adverse weakening of the structure, refer Clause 5.1.

5.3 Concrete Removal Methods

Remove areas of deteriorated concrete using methods that are safe to all personnel in the vicinity and that minimise damage to the concrete substrate, reinforcement and other nearby material.

Comply with the concrete removal health and safety requirements in TS 0711.0 Clause 6.4.

Use Hydro-demolition as the concrete removal method unless specific site constraints prohibit its use, as agreed with SA Water's Representative.

Other approved concrete removal and surface preparation methods are:

1. Abrasive blast cleaning
2. Grinding
3. Scarifying
4. Scabbling
5. Coring.

These methods are detailed in ICRI Guideline No 310.2R-2013.

Acid etching is **NOT** an approved method to remove cement paste from the surface and surface pores of concrete. Do not use acid etching under any circumstances.

Remove all dust and debris arising from surface preparation using a vacuum method.

5.3.1 Hydro-Demolition

Use a Hydro-demolition operator experienced in operation and maintenance of high and ultra-high pressure water equipment.

Implement all required safety requirements for operation of high and ultra-high pressure water equipment.

Use Hydro-Demolition equipment suited to the defect size and accessibility of the structural components, including:

1. Hand lance
2. Small push or self-propelled units
3. Robotic tractor.

Use extreme caution if using hydro-demolition methods on prestressed or post tensioned concrete, in particular in the vicinity of anchorages to not reduce structural capacity or cause sudden release of prestress force.

Use water pressure required to achieve the required extent of concrete removal and the surface profile specified in Clause 5.4.4.

5.3.2 Scabbling/Scarifying

Use sharp tools for mechanical breaking out to avoid unnecessary vibration and damage to the structure.

Following breaking out, assess for surface bruising (micro-cracked and fractured layer 3 to 10mm deep) and remove any such weakened material that will reduce bond strength using abrasive blasting or hydro-demolition methods.

5.3.3 Coring

If concrete coring is required as part of concrete removal or installation of repair components:

1. Use a coring machine with diamond-impregnated coring bit, with the facility to apply water as a cooling fluid to the cutting edge
2. Use an electrical or hydraulic coring machine for atmospheric vertical or horizontal coring
3. Do not use hand-held coring machines or electric powered water-cooled coring machines for overhead (inverted) coring
4. Use a hydraulic coring machine for confined space, underwater and overhead (inverted) coring
5. Use bolt down stands or vacuum secured coring equipment
6. Use water control equipment, including collection collars and wet vacuum extractor, and water supply equipment including pump if running water is not available or is not to be used, with a stand-by pump, as required.

5.4 Concrete Removal Methodology

5.4.1 General Method

Break out the agreed and marked out areas of deteriorated concrete as follows:

1. Clean areas for repair and adjacent surfaces to remove any dust, unsound material, plaster, oil, paint, grease, corrosion deposits, organic growth, etc.
2. Remove oil and grease deposits by steam cleaning, detergent scrubbing or the use of a proprietary degreaser
3. Locate the reinforcement passing through the marked out repair areas using an electronic covermeter or concrete Ground Penetrating Radar and measure the depth of concrete cover. Mark the locations of reinforcing bars, or other reinforcement, on the concrete surface, using chalk, crayon or a water based marker pen. Note the cover depth on the concrete surface
4. Make straight cuts to a minimum nominal depth of 20 mm to delineate the edges of the breakout, **ensuring first that this will not cut or damage any existing reinforcement or services**. Avoid feathered edges and square off the repair area
5. Adjust the minimum saw cut depth to match the selected repair material manufacturer's requirement
6. Remove areas of deteriorated concrete, with the marked boundary remaining visible, using methods listed in Clause 5.3
7. Remove any tying wire, nails or other metallic components on or near the surface of the concrete, or remove the concrete surrounding metallic component and cut back the metallic component a minimum of 25 mm behind the original profile
8. Remove concrete around any exposed or partially exposed reinforcement to a depth of at least 15mm behind the reinforcement to ensure adequate encapsulation of the reinforcement in the repair material
9. Remove any previous repairs where there is clear evidence that the repairs have failed (e.g., cracks and/or delamination)
10. If necessary, at the completion of the concrete removal process, make fresh cuts to avoid feathered edges and to square off the repair area
11. Manage waste produced by the concrete removal works operations.

5.4.2 General Criteria for Concrete Removal

Completely remove all designated cementitious materials, and test to Clause 18.7 until the substrate meets all of the following conditions:

1. Sound, hard and free of visible contamination
2. Nil delamination or cracking
3. Concrete alkalinity is >pH 9.5 (sound concrete substrate has a magenta (reddish-purple) colour when phenolphthalein is applied)
4. Exposed aggregates are not fractured or damaged
5. Any exposed reinforcement is not corroded.

5.4.3 Action if Reinforcement is Corroded

If corroded reinforcement is found, remove sound concrete along the corroding reinforcement for a maximum length of 100 mm, or until at least 50 mm of un-corroded reinforcement is revealed. Notify SA Water's Representative if, after 100 mm of sound concrete is removed, the reinforcement is still corroded.

Removed additional concrete along the length of visibly corroding steel reinforcement until the length of exposed corrosion free bar meets the minimum required effective length (depending on lap or weld) for reinforcement augmentation if required in accordance with Clause 0.

Subject to structural capacity review, the breakout must continue behind any exposed corroded reinforcement to create a clear gap of at least 20 mm and maximum 30 mm all around the reinforcement.

Check the minimum and maximum depths of breakout using a straight edge across the break out area.

Record the exact locations and size of the breakout on relevant drawings for approval by SA Water's Representative. Use the drawings for the purposes of recording and measuring the work.

Do not proceed with the reinstatement work until the breakout, or a group of breakouts, has been inspected directly or via photographic evidence and consent has been given to proceed by SA Water's Representative.

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5.4.4 Concrete Surface Profile

Prepare the concrete surface to achieve the ICRI Technical Guideline No 310.2R, concrete surface profile range CSP 5 to CSP 10, as specified by the repair material manufacturer for the application.

Verify the achieved surface profile at all areas using the ICRI replica profiles.

5.4.5 Bond Strength of the Prepared Substrate

Conduct substrate bond strength testing to all prepared surfaces in accordance with Clause 18.8.

5.5 Concrete Removal for Live Assets

Comply with the following requirements if working on live assets:

1. Undertake a site survey in accordance with TS 0711.0 Clause 8.1 to verify the thickness of the concrete component and embedded reinforcement arrangement subject to the repair
2. Seek and obtain a work permit from SA Water for working in a live asset
3. Submit a WMS for the proposed works to SA Water's Representative that includes but is not limited to:
 - a. Structural design of the repair indicating the maximum size of repair, in terms of depth and surface area that will not affect structural capacity or integrity taking into account all structural loads including hydrostatic load from retained liquids
 - b. Control criteria for the progressive safe removal of the defective concrete or reinforcement
 - c. Tool box talks
 - d. Use of small diameter pilot hole drilling to verify the soundness of the concrete substrate and risk of leakage as the concrete removal progresses
 - e. Use of a concrete removal method that minimises the risk of unplanned full penetration of the component
 - f. Complete concrete repairs in accordance with relevant parts of this Technical Standard
 - g. Details of a contingency plan to undertake emergency repairs if required including the requirement to have available at the work site rapid setting repair materials and equipment, to be applied if required in accordance with Clause 14.

Undertake a risk assessment as part of Safety in Design for the works in accordance with SAWG-RM-0001 involving sub-Constructors, Responsible Discipline Lead, all relevant site stakeholders and SA Water's Representative, and update the WMS accordingly.

HOLD POINT

5.6 Type 4A Repair – Corrosion Inhibitor Application

For large area repairs >1 m², if the design solution requires application of liquid corrosion inhibitor, allow the cleaned prepared concrete surface to become dry and apply corrosion inhibitor liquid complying with Clause 3.8.6 to the prepared concrete surface by brush, roller or low pressure spray in accordance with manufacturer's consumption requirements.

Ensure the corrosion inhibitor liquid is compatible with subsequent repair materials.

Remove excess liquid and surface residue deposits with high pressure water washing before use of a bonding agent.

5.7 Final Cleaning of Concrete Substrate

Following removal of the defective concrete and completion of quality control testing, and prior to priming of the concrete surface, clean the concrete by mechanical or abrasive blasting means, or by pressure washing all exposed concrete surfaces to remove all concrete dust, debris, laitance and other surface contaminants to provide a sound substrate for the application of concrete repair materials or coatings to the substrate, and prior to the installation of formwork.

Re-clean the prepared concrete surface if it becomes contaminated before the repair can proceed.

SA Water's Representative may inspect the concrete substrate preparation verification.

WITNESS POINT

6 Reinforcement Preparation

6.1 General

Following satisfactory completion of the concrete removal, inspect the exposed reinforcement, obtain photographs of the visible corrosion condition, and measure the loss of cross section after cleaning. Submit to SA Water's Representative.

Report any reinforcement that has been damaged by the concrete removal work to SA Water's Representative. Install additional or replacement reinforcement in accordance with written advice from SA Water's Representative and Clause 0.

6.2 Cleaning of Reinforcement

Remove corrosion product and foreign particles from the exposed reinforcement and any augmented or continuity reinforcement to achieve "grey metal" appearance using a steel wire brush, needle gun, dry or wet abrasive blasting, water jetting or other method recorded in the approved Work Method Statement or approved by SA Water's Representative.

After removing corrosion products by mechanical or abrasive blasting methods, high-pressure wash the steel with clean potable water to remove corrosion products from pits and imperfections within the surface.

Reinforcement preparation by abrasive blasting or high-pressure (~ 600 bar) water jetting is the preferred method as this will remove all corrosion products and contaminants in a single operation.

Surfaces shall be totally clean and any evidence of oxidation removed, including at the rear (all around) of metal elements:

1. Repair Types 4A and 4D: cleaned to Sa 2.5 (AS 1627.4)
2. Repair Types 4B and 4C: cleaned to Sa 2 (AS 1627.4)

Carry out a quality inspection of all reinforcing bars after cleaning.

Note: Corroded steel must be carefully assessed for loss of cross-sectional area and pitting. In the case of conventional reinforcement, significant corrosion can occur without significant weakening of the structure, but in the case of prestressed strand, even slight pitting corrosion can cause significant weakening.

Refer to

Table 10 to assess the loss of bar cross section based on remaining diameter, or corrosion from one side only, measured using a micrometer to one decimal place. If loss is on two or three sides only, determine the loss of section based on detailed measurements.

Table 10: Reinforcement Bar Diameter for Lost Section

Original Bar Diameter (mm)	Diameter if 10% Loss All Around (mm)	Diameter if 10% Loss One Side Only (mm)	Diameter if 25% Loss All Around (mm)	Diameter if 25% Loss One Side Only (mm)
6	5.7	5.1	5.2	4.2
10	9.5	8.4	8.7	7.0
12	11.4	10.1	10.4	8.4
16	15.2	13.5	13.9	11.2
20	19	16.9	17.3	14
24	22.8	20.3	20.8	16.8
28	26.6	23.6	24.2	19.6
32	30.4	27.0	27.7	22.4
36	34.2	30.5	31.2	25.2

If a single reinforcement bar is found to have lost 25% or more of its cross section, or reinforcement across an element has lost an average 10% or more, or the structural integrity is uncertain, notify SA Water's Representative.

Reinforcement may require augmentation in accordance with Clause 0.

HOLD POINT

6.3 Reinforcement Augmentation

If SA Water's Representative nominates augmentation of reinforcement as the appropriate method of strengthening, comply with the following requirements:

1. Provide additional reinforcement either by tying with wire or by welding
2. For tied wire splices, the minimum lap lengths shall be 30 times the diameter of the replacement reinforcement bars on each end of the corroded portion of steel
3. For welded splices, the minimum weld length at each end shall be calculated according to the requirements in Clause 6.6.8
4. The combined cross sectional area of the existing sound reinforcement and the additional bars is to be greater than or equal to the cross sectional area of the original bar
5. Place additional bars level with existing reinforcement
6. Where the existing concrete cover to steel reinforcement is less than the design requirements, profile the concrete repair to ensure that 30 mm minimum cover of repair material is achieved
7. Ensure that additional reinforcement does not prevent full reinstatement of the concrete
8. Record and submit to SA Water's Representative details of all reinforcement augmentation including:
 - a. Location
 - b. Minimum cover to bars
 - c. Bar diameters (existing and proposed new)
 - d. Bar type encountered
 - e. Bar spacing
 - f. Presence of any original laps or bar terminations
 - g. Amount of additional breakout required to accommodate the lap length and terminations of reinforcement
 - h. Actual bar anchoring systems, lap lengths adopted, their locations or similar information to fully describe the work performed.

HOLD POINT

6.4 Dowels and Mesh Reinforcement

If required based on the depth of repair material and the manufacturers requirement, provide dowel bars and additional light mesh reinforcement to ensure the patch repair integrity:

1. Type 4A and 4D Repairs: Use minimum grade 316 stainless steel dowels and mesh
2. Other repair types can use either galvanised steel or minimum grade 304 stainless steel dowels and mesh, without requirement for a protective coating.

Embed the dowel bars in drilled holes.

Blow out dust before setting bars in a proprietary epoxy resin anchoring adhesive.

Submit to SA Water's Representative details of the mesh reinforcement, dowel size, depth of embedment and epoxy resin type.

6.5 Electrical Continuity for Type 4A Repairs (SACP or ICCP)

6.5.1 Electrical Continuity Testing

Confirm electrical continuity for all reinforcement that is to be protected by SACP or ICCP as part of Type 4A repairs and associated ancillary steelwork that may be affected by the CP current in accordance with the test method in Clause 18.12.

Record the position and length of all 'continuity bars' on as-built drawings.

6.5.2 Achieving Reinforcement and Ancillary Steelwork Continuity

Where electrically isolated/discontinuous reinforcement or ancillary steelwork is identified, make them electrically continuous with the main reinforcement.

Achieve continuity by welding a suitable length of 6 mm diameter hot rolled plain bar between the isolated reinforcement and the nearest electrically continuous main reinforcement or ligature.

Undertake welding in accordance with Clause 6.6.8. The minimum weld thickness shall be 3 mm.

Clean all 'continuity bars' to the same standard as required by Clause 6.2.

Record the position and length of all 'continuity bars'.

Re-test the electrical continuity of each additional bar in accordance with the test method in Clause 18.12.

6.6 Reinforcement Reinstatement Workmanship

6.6.1 General

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

Before installation maintain reinforcement free from surface contamination, loose mill scale, loose rust, mud, oil, grease and other coatings.

Re-fix all loosely fastened exposed corroded reinforcement that is to be retained, including loosely fastened reinforcement identified after delaminated concrete is removed.

6.6.2 Mild steel

Provide a protective bar coating to all exposed and cleaned steel reinforcement, unless the repair will be subject to ICCP.

6.6.3 Stainless Steel

Stainless steel bars do not require protective bar coatings when fully embedded in cementitious material, including when in direct contact with mild steel, other than at welds to mild steel.

Provide a protective coating to stainless steel that is partly embedded in concrete within ± 50 mm of the concrete to an external atmospheric environment interface.

Electrically isolate from the concrete reinforcement any stainless steel elements that will be permanently exposed at a concrete surface in contact with water (e.g., as ferrules or hold-down bolts).

Do not contaminate stainless steel reinforcement by contact with other steel, grease, oil and iron. Grinding, welding or cutting of other steel or any other structural steel shall not occur after any stainless steel reinforcement has been placed.

Use dedicated sets of tools for fabricating, lifting, fixing or bending stainless steel reinforcement that have not/will not be used for other materials.

6.6.4 Galvanising

Undertake galvanising of reinforcement after all cutting and bending of bars and after welding of reinforcement into mesh or cages is complete. Undertake repairs to cut ends and breaks in the coating in accordance with AS/NZS 4680.

After galvanising and before installation, passivate the galvanised reinforcement using a 0.2% sodium dichromate solution by the galvaniser.

Do not use galvanised reinforcement in conjunction with stainless steel reinforcement.

6.6.5 Bar Bending

Cut and bend reinforcement to comply with the dimension shown on the Drawings or to suit the specific break out area to diameters and using methods that meet the requirements of AS 3600 and AS 5100.5 (steel) and BS 8666 (stainless steel).

Do not bend or strain reinforcement in a manner that damages it.

Do not heat or hot bend Ductility class L reinforcement.

Undertake hot bending of stainless steel reinforcement in accordance with methods recommended by the manufacturer. Only use stainless steel pins for bending stainless steel.

6.6.6 Fixing

Comply with the reinforcement fixing requirements set out in AS 5100.5 Cl 17.4.5.

Ensure that reinforcement is fixed with the correct cover and that spacers and chairs are correctly spaced if required and have the required performance characteristics.

Adequately tie together reinforcement to form a rigid cage, which prevents displacement of bars or meshes and maintains dimensional tolerances under all applied loads applied before and during the concrete placement.

The minimum clear cover to the reinforcement shall be 30 mm, profiled to suit, or the original design cover, whichever is greater.

Projecting ends of ties shall not encroach into the concrete cover zone.

All steel reinforcement in position shall be inspected and approved by SA Water's Representative before the concrete placement commences.

HOLD POINT

6.6.7 Splices

Provide splices in accordance with the requirements of AS 3600 or AS 5100.5, where appropriate and Clause 0.

Submit details of the locations of splices to SA Water's Representative.

Tie the ends of reinforcements forming a lapped splice together in at least two places.

Mechanical couplers can be used in lieu of lap of welded splices.

6.6.8 Welding

Reinforcement shall not be welded unless it is:

1. required by the Project
2. approved in writing by SA Water's Representative; or
3. required to provide electrical continuity for SACP or ICCP
4. of weldable grade.

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

Do not butt weld reinforcement unless detailed and specified by a structural engineer.

Do not weld galvanised reinforcement.

Clean all weld areas using mechanical or power tools to comply with Clause 6.2.

6.6.8.1 Steel

Undertake all approved steel welding in accordance with AS/NZS 1554.3, TS 0420, and this Technical Standard.

With the exception of fabricating reinforcing mesh by an Australasian Certification Authority for Reinforcing and Structural Steels certified fabricator, Ductility class L reinforcement shall not be welded unless the Constructor can demonstrate by way of testing that the weld procedure does not result in the loss of ductility.

6.6.8.2 Stainless steel

Undertake all approved stainless steel welding in accordance with AS/NZS 1554.6, TS 0420 and this Technical Standard.

Welded stainless steel shall be low carbon grade L.

Only weld stainless steel pre-fabricated reinforcement in a welding workshop specifically set up for the purpose. Such facility shall maintain conditions preventing any contamination of the stainless steel and consumables used in the proper performance of the welding of stainless steel.

6.7 Application of Reinforcement Protective Coating

Provide reinforcement bar coatings complying with Clause 3.8.1, applied as follows:

1. Coat by stiff paint brush all exposed prepared reinforcement with the protective coating within one hour of preparing and cleaning the steel
2. Apply a full and unbroken coat to the entire bar circumference and exposed length to the manufacturers recommended layer and thickness requirements
3. Avoid the occurrence of pinholes and holidays in the coating and ensure that all exposed steel surfaces are coated including behind reinforcement where applicable
4. Avoid over-coating of the concrete substrate with the steel primer unless it is a requirement of the overall repair system
5. Allow each coat to fully cure in accordance with the manufacturers requirements before applying a subsequent coat
6. Undertake detailed visual inspection of coated bars to ensure bars are fully coated
7. If the coating is incomplete apply an additional full coat
8. Do not coat stainless steel reinforcement
9. Test the DFT in accordance with Clause 18.13.

SA Water's Representative may inspect the application of the coating.

WITNESS POINT

Should the selected cementitious reinforcement primer not be stated as AS/NZS 4020 compliant, apply a suitable AS/NZS 4020 compliant epoxy coating over and compatible with the applied cementitious reinforcement coating.

If sacrificial anodes are to be installed, leave uncoated an area of reinforcement equal to the contact patch between the anode and the bar (see Clause 7.2).

Where the reinforcement coating system fails to comply with the requirements of this clause, remove the extent of non-complying reinforcement coating as indicated by the DFT measurements and re-apply the reinforcement coating system.

7 Sacrificial Anode Installation

7.1 General Requirements

Use SA Water pre-approved sacrificial anodes that meet the requirements in Clause 3.8.5.

Install sacrificial anodes at locations and up to the maximum spacing along the repair boundary as determined by the SACP design, depending on the anode type.

Provide SACP anodes either within holes drilled into the original concrete or within the repair as close as practical to the edge of the broken out repair zone.

Other than for small patch areas, do not install anodes within the main body of a repair.

Provide anodes with the equivalent cover as the reinforcement to which they are attached, except that in no case less than 30 mm cover shall be provided.

Comply with requirements of the anode MSDS. Handle sacrificial anodes using gloves and other personal protective equipment, as for cementitious materials.

Before installing sacrificial anodes:

1. Check the exposed reinforcement within the repair area for electrical continuity in accordance with Clause 6.5.1
2. Provide additional electrical continuity as required in accordance with Clause 6.5.2.

7.2 SACP Anodes Installation Method

7.2.1 Cast in Repair Type

Sacrificial anodes designed to be cast into the patch repair material, shall be placed:

1. Between reinforcement bars around the perimeter of the open repair
2. So as to achieve all round contact with the repair material
3. To enable full compaction of the repair mortar without voids or shadowing
4. To ensure the anodes will be fully encased in repair material
5. To ensure the contact patches for the anodes are clean and clear of both corrosion products, primer or any other contaminants.

7.2.2 Set in Original Concrete Type

Sacrificial anodes designed to be placed in drilled holes in original concrete shall be placed:

1. To ensure hole orientation and size enables sufficient embedment mortar around the anode
2. To ensure placed anode does not short circuit the reinforcement through down-hole cover meter checks and electrical continuity checks
3. Provide chases as required to run connection cables.

7.2.3 General Requirements

Re-clean the reinforcement locally at the designated connection sites to bright metal. Connect the SACP anode tie wire to the reinforcement bar and tighten using the manufacturer's recommended method or tool so that no free movement is possible.

Trim tie wires to prevent them impinging on concrete cover.

Test and confirm the electrical continuity between the reinforcement and each installed sacrificial anode using a high impedance voltmeter. If measured voltages are greater than 0.1 mV, or contact resistance greater than 0.5 ohm, re-clean reinforcement contact patch or tighten tie wires until good contact is achieved. Record all voltages for review by SA Water's Representative. Complete works to secure wires in place using plastic ties.

Prime the steel reinforcement immediately following attachment of the sacrificial anodes in accordance with Clause 0, subject to:

1. Do not paint the sacrificial anode surface with reinforcement primer or concrete bonding agent.

Complete anode installation:

1. Anode in mortar - place concrete repair material in accordance with this Technical Standard
2. Anode in hole – remove dust, pre-soak holes, embed in proprietary mortars using caulking gun, ensure nil air voids.

WITNESS POINT

Measure the resistivity of the applied and cured concrete repair material associated with Type 4A Repairs Galvanic Anodes in accordance with Clause 18.11.

8 Concrete Reinstatement – General Requirements

8.1 Inspection and Quality Review

Reinstatement of concrete to prepared areas shall not commence until:

1. All concrete substrate and reinforcement preparatory works have been completed
2. A joint inspection and measurement of the repair area by SA Water's Representative and the Constructor has taken place
3. SA Water's Representative sights the Constructor's quality procedures and completed ITPs for the preparatory works, to include evidence that the preparation of the repair area conforms to the requirements of this Technical Standard.

HOLD POINT

8.2 Concrete Surface Moisture Condition

Concrete is considered "DRY" for application of a surface coating or adhered liner when the concrete residual moisture after surface preparation does not exceed the limits for successful coating application, bonding and curing in Table 11.

Table 11: Concrete Moisture Test Criteria for "Dry" Concrete

Moisture Test	Criterion for "Dry" Concrete
ASTM D4263 Plastic sheet method	No visible moisture
ASTM F1869 Calcium chloride test	$\leq 15 \text{ g}/24 \text{ hr}/\text{m}^2$
ASTM F2170 Relative humidity	$\leq 80\%$

The concrete surface moisture condition immediately before application of a repair material or component of a repair system shall be nominally as listed in Table 12, however shall meet the material manufacturer's specific requirements.

Do not apply a repair material to a wet surface, remove any excess water immediately prior to material application.

Do not use direct heat or artificial drying to achieve the required surface moisture condition.

Table 12: Required Concrete Surface Moisture Condition

Repair Material Type	Surface Moisture Condition
Moisture intolerant epoxy based primers, coatings and mortars	Dry / Slightly Moist
Moisture tolerant epoxy based primers, coatings and mortars Certain cement based coatings, acrylic bonding agents	Moist
Cement based materials that do not have a primer or bonding agent, or use a waterproof slurry bonding agent	SSD

8.3 Surface Finishing

8.3.1 General Requirements

Profile the repair concrete to finish flush with the existing adjacent surfaces.

Finish all repaired areas to match the original profile, texture and existing falls.

Use a trowel with the desired surface profile to reproduce the existing profile.

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

8.3.2 Tolerances

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

Maximum allowance for irregularities when measured with a 2.0 m straightedge shall be 3 mm.

In addition, evenness shall not deviate by more than 1 mm when checked with a 300 mm straightedge.

WITNESS POINT

8.4 Concrete Repair Material Curing

Cure all cementitious repair material as soon as practicable after casting or placing subject to ambient conditions using a method listed in Clause 0 for a minimum period of 7 days to retain moisture, or an extended period determined by the Structural Engineer to achieve the required concrete compressive strength.

Where a curing compound is used, apply two coats immediately after the surface has been trowelled to a finish, or the surface to have additional layers applied has been scarified ready for the next repair material layer.

Cure large areas as staged completion progresses without waiting for completion of the entire area.

Apply the curing agent or other curing method in accordance with the approved trial repair report.

Protect the repaired area whilst it cures.

Remove curing compounds prior to the application of any protective or decorative coatings in accordance with TS 0711.5, unless the manufacturer provides documented evidence is to SA Water's Representative satisfaction that the applied curing compound is compatible with the proposed coating.

8.5 Quality Control Inspections

Following curing of repair materials, undertake quality control inspections and tests in accordance with Clause 18:

1. Sprayed Concrete Insitu Compressive Strength (Clause 18.6)
2. Soundness of Repair (Clause 18.9)
3. Repair Bond Strength (Clause 18.10).

Undertake any necessary remedial works within two weeks of the date of identifying defects.

9 Type 3A Repair: Hand Applied Patch Repair

9.1 Concrete Substrate Preparation

Complete concrete removal and preparatory works in accordance with Clause 5 and 6 and undertake quality control verification as per Clause 8.1.

Check and ensure that the repair material selected is suited to the required depth and surface area of each repair area.

Provide and apply a concrete repair material bonding agent in accordance with Clause 3.8.2 to the prepared concrete substrate immediately prior to application of patch repair mortar.

Work the bonding agent into the concrete substrate using a short bristle brush to enhance the bond at the repair interface, taking into account environmental constraints. If used, ensure that the bonding agent does not dry out prior to the application of the re-surfacing material. Where drying/curing of the bonding agent has exceeded the level specified by the manufacturer for application of the repair mortar, reapply the bonding agent in accordance with the manufacturer's instructions.

Remove and replace all concrete repair material that has not bonded properly due to the incorrect application or drying out of the bonding agent.

SA Water may inspect the application of the bonding agent.

WITNESS POINT

9.2 Patch Mortar Application

Provide concrete repair material suited to the intended type of repair and performance requirements when placed by hand methods in accordance with Clause 3.2.

Mix and transport repair mortar in accordance with Clause 4.9.

Place the patch repair mortar by hand methods in strict accordance with the manufacturer's written application instructions.

The applied material shall have no voids, be properly compacted and not sag.

Build up to the original surface profile in layers not exceeding the repair material manufacturer's recommendations and in accordance with the approved Work Method Statement.

Roughen each previous layer to provide a mechanical key for the next layer. Cure each layer for a period recommended by the repair material manufacturer before subsequent layers are applied.

WITNESS POINT

9.3 Curing

Cure the patch repair concrete in accordance with Clause 8.4.

10 Type 3B Repair: Sprayed Concrete Application

10.1 Competency of Personnel Involved in Sprayed Concrete

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

The nozzle operator shall have a demonstrated competence and ability to produce sprayed concrete complying with this Technical Standard and have prequalification to the sprayed concrete procedure requirements as stated in Clause 10.7.

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

Provide documented evidence to demonstrate experience, qualification, skills and training of personnel.

WITNESS POINT

10.2 Equipment

The spraying equipment shall be in accordance with the manufacturer's requirements and shall have successful performance records of carrying out similar/equivalent applications.

The equipment shall be capable of allowing the mortar to leave the nozzle in a continuous uninterrupted flow.

The diameter of the delivery hoses shall be such as to accommodate the maximum size of aggregate without affecting the delivery.

10.3 Sprayed Concrete Application

Provide concrete repair material suited to the intended type of repair and performance requirements when placed by spraying methods in accordance with Clause 3.2, including cement based, CAC based, Geopolymer and Inorganic Polymer based materials.

Complete concrete removal and preparatory works in accordance with Clause 5 and 6 and undertake quality control verification as per Clause 8.1.

Check and ensure that the repair material selected is suited to the required depth and surface area of each repair area.

Mix and transport repair mortar in accordance with Clause 4.9.

Sprayed concrete may be dry or wet spray material, including a range of materials as indicated in Clause 3.2.

Ensure that concrete surface is in a saturated surface-dry condition or as otherwise recommended by the sprayed concrete manufacturer immediately prior to concrete reinstatement.

Do not use bonding agents.

The sprayed concrete application shall be continuous and the delivery shall be uniform at a controlled velocity to ensure adequate compaction.

If the spraying operation is interrupted for more than 10 minutes, unless otherwise recommended by the manufacturer, form a cold joint consisting of a tapered section over a distance of 300 mm. Keep the joint moist. Prior to resuming the concrete spraying operation, clean the joint surface.

Immediately remove any rebound or loose-sprayed concrete material and do not incorporate it in the finished concrete.

At no stage shall the sprayed concrete come in contact with any mechanical or electrical components or surfaces outside the repair area.

Remove sprayed concrete that may be inadvertently applied onto these surfaces before hardening.

10.4 Surface Finishing

For intermediate layers, the material shall be left in off-the gun finish.

Level the final layer progressively as the concrete is sprayed using the minimum necessary trowelling to produce an even and smooth flat surface.

Immediately after spray application finish the surface using steel trowel floats or as otherwise recommended by the manufacturer.

Do not overwork the surface. Excessive trowelling may tend to cause surface crazing and may reduce durability.

10.5 Curing

Cure the sprayed concrete in accordance with Clause 8.4.

10.6 Repair

When the sprayed material lacks uniformity, exhibits segregation, shadowing of reinforcement, honeycombing, or laminations, remove and replace the defective material to the satisfaction of SA Water's Representative.

10.7 Prequalification of Spraying Procedure

10.7.1 General

Sprayed concrete shall conform to the requirements of the CIA Z05 except as modified by the requirements of this Technical Standard.

Submit details of the proposed sprayed concrete operations, including the proposed type of sprayed concrete or repair mortar, mix design or TDS, substrate preparation, method of application, equipment and nozzle operators for review by SA Water's Representative prior to commencement of the sprayed concrete operation.

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

10.7.2 Preparation of Test Panels

Construct two test panels minimum 1000 mm x 1000 mm and the greater of the specified thickness or 200 mm for each nominated nozzle operator prior to commencing full scale spray concrete operation, for the purpose of checking the suitability of the proposed mix design, materials, plant and equipment, the method of working and the competence of the operators intended for the Project.

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

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

Do not spray concrete into the test panels when placed horizontally on the ground.

Construct additional panels for any change of the mix design, plant and equipment or operator.

After the test panel has been formed, mark with the date of application, the time of application and the name of the nozzleman. Store the test panels and cure them under similar conditions as the sprayed concrete when placed in situ and in accordance with the requirements of this Technical Standard.

10.7.3 Sampling and Testing of Panels

Obtain and test concrete cores for compressive strength testing in accordance with Clause 0

10.7.4 Prequalification

Sprayed concrete shall not be placed until the SA Water's Representative has reviewed all prequalification procedures, mix design/TDS, the results of testing, and visual inspection of both the cores sampled and the test panels in accordance with the requirements of Clause 10.7.3.

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

Adhere to the prequalified sprayed concrete procedure throughout the sprayed concrete operations.

Sprayed concrete shall only be carried out by the same nozzle operators who performed the prequalification procedure and produced the conforming test panels.

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

HOLD POINT

11 Type 3C Repair: Flowable Micro-Concrete Application

11.1 Concrete Preparation

Complete concrete removal and preparatory works in accordance with Clause 5 and 6 and undertake quality control verification as per Clause 8.1.

Ensure that overhanging concrete under which concrete is to be placed is profiled and vented as necessary to prevent entrapment of air voids.

Check and ensure that the repair material selected is suited to the required depth and surface area of each repair area.

Ensure that concrete surface is in a saturated surface-dry condition or as otherwise recommended by the micro-concrete concrete manufacturer immediately prior to concrete reinstatement.

Do not use bonding agents.

11.2 Formwork

Provide formwork in accordance with TS 0710 Clause 26.

Construct formwork to comply with AS 3610 and Clause 17.6 of AS 3600 where this is more stringent so concrete will have the dimensions, shape, location and finish specified.

Pre-treat formwork such that it prevents moisture absorption from the repair mortar.

Position formwork such that it does not inhibit effective self-compaction of the repair material.

Seal joints between formwork panels, and to hardened existing concrete with a flexible rubber strip, silicone sealant, timber, plastic or similar.

Provide holes in rebate formers, etc., as required to prevent air entrapment.

Provide sealable drain holes in the base of the formwork to enable cleaning with water prior to concreting.

Remove all debris and drain all water from formwork prior to concreting.

Do not strip formwork prior to 36 hours after placement.

SA Water's Representative may elect to undertake a pre-pour inspection.

WITNESS POINT

11.3 Flowable Concrete Placement

Provide concrete repair material suited to the intended type of repair and performance requirements when placed by casting or pumping methods in accordance with Clause 3.2.

Prepare a trial mix of the flowable concrete as per Clause 11.5.

Mix and transport repair concrete in accordance with Clause 4.9.

Avoid contamination with any other type of cement or concrete (dry, wet or dried/set).

Use a placement method that will prevent plastic settlement and plastic shrinkage cracking.

For vertical repairs, limit vertical free fall by use of chutes, tremie pipes, etc. Keep tremie pipes vertical, full and immersed in concrete during placement.

Place the flowable concrete to ensure the void is completely filled without entrapped air.

Provide sufficient material, mixing capacity and labour so that the pour is completed in a single operation.

Do not use internal vibration.

11.4 Curing

Cure the micro concrete in the formwork and then in accordance with Clause 8.4.

11.5 Flowable Concrete Mix Trial

Prepare a leak proof test panel formwork with minimum dimensions of 1600 mm high x 600 mm wide by 200 mm deep.

Mix and place the flowable concrete in accordance with the WMS and ITP to the full panel height. Undertake workability/flow tests to verify the concrete mix design is suitable for the intended purpose. Immediately after concrete application, cure the test panel in the same manner as the concrete repairs incorporated in the permanent works.

Prepare sets of three standard 100 mm diameter x 200 mm cylinders of repair concrete as sampled from a batch of mixed material for compressive strength testing to AS 1012.9.

Remove the cylinders from the moulds within 16 to 20 hours of casting. Clearly label using permanent marker with the time and date of casting, and place in sealable polyethylene bags.

Obtain and test concrete cores for compressive strength testing in accordance with Clause 0.

12 Type 3D: Underwater Repair Application

12.1 Concrete Preparation

Complete concrete removal and preparatory works in accordance with Clause 5 and 6 and undertake quality control verification as per Clause 8.1.

Check and ensure that the repair material selected is suited to the required depth and surface area of each repair area.

Provide concrete repair material suited to the intended type of repair and performance requirements when placed by hand methods in accordance with Clause 3.2.

If required undertake Diving in accordance with TS 0711.0 Clause 6.5.

WITNESS POINT

12.2 Hand-Applied Underwater Mortar Application

Mix underwater repair material to a putty like consistency.

Place the patch repair mortar by hand methods in strict accordance with the manufacturer's written application instructions, taking into account the rapid setting time and requirement to only mix small quantities commensurate with placement constraints.

Discard mixed material that has lost its plasticity.

The applied material shall have no voids, be properly compacted and not sag.

Build up to the original surface profile in layers not exceeding the repair material manufacturer's recommendations and in accordance with the approved Work Method Statement.

If required, roughen each previous layer to provide a mechanical key for the next layer.

WITNESS POINT

12.3 Curing

The underwater mortar does not require curing.

13 Type 3E: Water Leakage Patch Repair Application

13.1 Concrete Substrate Preparation

Treat active/high flow water leakage in accordance with Clause 13.2.

Treat leaking cracks in accordance with TS 0711.3 Clause 8.

Complete concrete removal and preparation in accordance with Clause 5, other than the patch repair edges shall be dovetailed and the sawcut edge roughened to CSP 3-5. Refer Clause 5.4.4.

Complete concrete removal and preparatory works in accordance with Clause 5 and 6 and undertake quality control verification as per Clause 8.1.

Check and ensure that the repair material selected is suited to the required depth and surface area of each repair area.

Mix waterproof cementitious repair material components at the water:powder ratios recommended by the system Manufacturer.

For concrete that is not to have a full coverage protective coating or render after patching in accordance with TS 0711.5, ensure that the concrete surface within 100 mm of the repair edge has been cleaned in accordance with Clause 0 and meets the requirement of Clause 8.2.

Provide and apply by brush to the substrate a bonding agent slurry mix of the waterproof mortar material to a minimum thickness of 1.25 mm thickness immediately prior to application of waterproof repair mortar. Work the slurry into the concrete substrate, using a short bristle brush to enhance the bond at the repair interface, taking into account environmental constraints. Ensure that the bonding agent does not dry out prior to the application of the concrete repair material.

Remove and replace all concrete repair material that has not bonded properly due to the incorrect application or drying out of the bonding agent.

SA Water may inspect the application of the bonding agent.

WITNESS POINT

13.2 Active Water leaks

Open up high flow actively leaking hole to minimum 15 mm x 15 mm hole or rout the crack forming a U shape, square or dovetailed shape. Do not form a V shape.

For holes with very high flow, insert a plastic tube to divert water.

Mix up a waterproof cementitious mortar to a stiff consistency and form into a hand sized ball.

Ram the mortar into the leaking hole and hold in place until the initial set.

If required, allow the mortar to partly harden and compress it into the base of the hole or routed crack with a hammer and block until the water flow stops.

Tie off the water diversion.

Check for further leaks and repeat application if required.

13.3 Waterproof Patch Mortar Application

Provide concrete repair material suited to the intended type of repair and performance requirements when placed by hand methods in accordance with Clause 3.2. This method also applies to hand placed materials for Type 5B repairs.

Mix and transport repair mortar in accordance with Clause 4.9.

Place the waterproof patch repair mortar to reinstate the concrete by hand (in accordance with Clause 9.2) or spray methods (in accordance with the requirements of Clause 10), and in strict accordance with the manufacturer's written application instructions.

The applied material shall have no voids, be properly compacted and not sag.

Build up to the original surface profile in layers not exceeding the repair material manufacturer's recommendations and in accordance with the approved Work Method Statement.

Roughen each previous layer to provide a mechanical key for the next layer. Cure each layer for a period recommended by the repair material manufacturer before subsequent layers are applied.

Apply additional coatings or layers of the cementitious waterproofing after the prior coat or layer has reached an initial setting time and while it is still "green", typically within 24-30 hours.

If required brush apply a slurry mix of "concentrated" hydrophilic crystalline cementitious material to coat the repair area and the area 100 mm outside the repair area to minimum 1.25 mm thickness.

Inspect the completed work in accordance with Clause 18.

WITNESS POINT

13.4 Patch Repair Edge Treatment

For concrete that is not to have a full coverage protective coating or render after patching in accordance with TS 0711.5, immediately after patch repair curing is completed, apply a 100 mm wide "concentrated" hydrophilic crystalline cementitious material coating strip compatible with the repair concrete centred around the edge of the patch repair.

13.5 Curing

Following initial set, cure the material using a fine mist spray three times daily for a minimum three days or apply the manufacturer's nominated curing agent in accordance with Clause 8.4.

During curing, protect the material from adverse climatic conditions and other external environments. Do not lay plastic sheeting directly on the waterproof material as air contact is required for proper curing.

Allow minimum 14 days curing time before the waterproof repair material is trafficked.

If the area is required to be trafficable prior to 14 days, provide suitable protection as recommended by the Manufacturer.

14 Type 3F: Rapid-Set Horizontal Repair Application

14.1 Concrete Substrate Preparation

Complete concrete removal and preparatory works in accordance with Clause 5 and 6 and undertake quality control verification as per Clause 8.1.

Check and ensure that the repair material selected is suited to the required depth and surface area of each repair area.

Ensure that the finished surface is even with a profile less than half the maximum aggregate size. Remove all debris by vacuum.

Provide and apply a concrete repair material bonding agent in accordance with Clause 3.8.2 immediately prior to application of rapid setting patch repair or flowable mortar.

Work the bonding agent into the concrete substrate using a short bristle brush to enhance the bond at the repair interface, taking into account environmental constraints. If used, ensure that the bonding agent does not dry out prior to the application of the re-surfacing material. Where drying/curing of the bonding agent has exceeded the level specified by the manufacturer for application of the repair mortar, reapply the bonding agent in accordance with the manufacturer's instructions.

Remove and replace all concrete repair material that has not bonded properly due to the incorrect application or drying out of the bonding agent.

SA Water may inspect the application of the bonding agent.

WITNESS POINT

14.2 Rapid Set Mortar Application

Provide concrete repair material suited to the intended type of repair and performance requirements when placed by hand or pouring methods in accordance with Clause 3.2.

Mix and transport repair mortar in accordance with Clause 4.9.

Place the patch repair mortar by hand or pouring methods in strict accordance with the manufacturer's written application instructions, taking into account the rapid setting time and requirement to only mix small quantities commensurate with placement constraints.

Discard mixed material that has lost its plasticity.

The applied material shall have no voids and be properly compacted.

Build up to the original surface profile in layers not exceeding the repair material manufacturer's recommendations and in accordance with the approved Work Method Statement.

Roughen each previous layer to provide a mechanical key for the next layer.

Cure each layer for a period recommended by the repair material manufacturer before subsequent layers are applied.

WITNESS POINT

14.3 Curing

Cure the repair concrete in accordance with Clause 8.4, apply curing as the works progress.

The completed repair shall have nil cracks or delamination.

15 Type 3G: Grouting Voids Application

15.1 Concrete Preparation

Complete concrete removal and preparatory works in accordance with Clause 5 and 6 and undertake quality control verification as per Clause 8.1.

Ensure that overhanging concrete under which grout is to be placed is profiled and vented as necessary to prevent entrapment of air voids.

Check and ensure that the grout material selected is suited to the required depth and surface area of each repair area.

Ensure that concrete surface is in a saturated surface-dry condition or as otherwise recommended by the grout concrete manufacturer immediately prior to grout application.

Do not use bonding agents.

15.2 Formwork

Provide formwork in accordance with TS 0710 Clause 26.

Construct formwork to comply with AS 3610 and Clause 17.6 of AS 3600 where this is more stringent so grout will have the dimensions, shape, location and finish specified.

Pre-treat formwork such that it prevents moisture absorption from the grout.

Position formwork such that it does not inhibit effective self-compaction of the grout material.

Seal joints between formwork panels, and to hardened existing concrete with a flexible rubber strip, silicone sealant, timber, plastic or similar.

Provide holes in rebate formers, etc., as required to prevent air entrapment.

Provide sealable drain holes in the base of the formwork to enable cleaning with water prior to grouting.

Remove all debris and drain all water from formwork prior to grouting.

Do not strip formwork prior to 36 hours after placement.

SA Water's Representative may elect to undertake a pre-pour inspection.

WITNESS POINT

15.3 Grout mix design trial

Use a cementitious grout that complies with the material requirements in Clause 0

Undertake a trial mix for the grout and carry out all performance tests listed in Table 8 for the trial mix.

Use the same make and type of mixing equipment used for approval of the grouting system for grout production.

Equipment different to that used for approval may be used subject to SA Water's Representative's approval.

15.4 Grout Equipment

Grout pumps shall be of the positive displacement type with an outlet pressure of at least 1.0 MPa. The pumps shall be capable of pumping the grout at the required rate. A standby grout pump shall be available for use on Site at all times.

Grouting supply lines shall connect the pumps directly to the grout inlets. All pumps, lines, tubes, connections, and valves shall be pressure rated to at least 1.0 MPa.

Fit pumps with seals to prevent oil and air contamination of the grout or the loss of constituent materials during the grouting operation.

Pumps shall be capable of operating continuously with little pressure variation and shall have a system for recirculating the grout while actual grouting is not in progress.

Fit pumps and grout inlets with pressure gauges capable of reading grout pressures up to 1.0 MPa. Pressure gauges shall have a full scale reading less than 1.5 MPa and shall be maintained in calibration.

15.5 Grout Mixing

Carry out batching of grout by mass for all mix constituents except liquids, which may be measured by volume.

Only use whole bags of cement or pre-packed grout mix. Check weight of all bags of cement or grout before batching.

Accurately control the water / cement ratio and additives for each batch of grout.

Supply admixtures for the grout mix in single dose containers made up to suit each grout batch size.

Place the water and premixed additive in the agitator tank first, then disperse the cement uniformly within the agitator tank.

Heat or cool the mixing water if necessary to keep the grout temperature between 5°C and 30°C during mixing and grouting.

Mix the grout at a minimum of 1000 rpm in a high-speed mixer capable of imparting a high shear to the grout components so that a colloidal grout of uniform consistency is produced in a mixing time of less than five minutes.

15.6 Grout Installation

All personnel involved in grouting shall be appropriately trained and experienced.

Determine the volume of grout required and hold adequate stocks of cement or pre-packaged grout mixes at the grout mixer to ensure no interruptions to the continuity of grouting operations.

Before commencing grouting, conduct sampling for production acceptance testing in accordance with Table 8.

Where fluidity testing is required, determine the efflux time before proceeding with grouting. The efflux time shall not vary from the target efflux time by more than ± 2 seconds.

Feed the mixed grout to the pump by gravity from a hopper attached to and directly over the pump. Always keep the hopper at least partially full of grout during grouting operations.

Pass the mixed grout through a screen with 2.36 mm nominal apertures during its progress between the hopper and the pump.

Use the grout as soon as possible after mixing and in any case within 45 minutes of adding cement to mixing water.

Inject the grout at a suitable pressure from a low point and maintain an even, slow, continuous flow of grout until the interstitial space between substrate and liner material is completely filled with pure grout and all entrapped water and air has been expelled.

Close off any vents and drains used progressively once pure grout issues from them, except for vents located less than 1 m downstream of a high point. The downstream vent shall be closed off before the high point vent. Ensure that no air is entrapped.

Do not subject the grouted liner to shock, vibration, construction traffic or similar loads, until 24 hours after completion of grouting.

Remove grout inlets, outlets and vents the following day.

WITNESS POINT

15.7 Curing

Where possible, cure the grout in accordance with Clause 8.4, apply curing as the works progress.

The completed repair shall have nil cracks or delamination.

16 Type 3H: Fairing Coat

Requirements for the application of fairing coats to fill blowholes and imperfections on concrete structure surfaces are set out in TS 0711.5.

17 Type 3I: Epoxy Mortar Patch Repair - Application

17.1 Concrete Substrate Preparation

Complete concrete removal and preparatory works in accordance with Clause 5 and 6 and undertake quality control verification as per Clause 8.1.

Check and ensure that the repair material selected is suited to the required depth and surface area of each repair area.

Provide and apply a low viscosity primer bonding agent in accordance with Clause 3.8.2 to the prepared concrete substrate immediately prior to application of patch repair epoxy mortar if part of the manufacturer's recommendation.

Work the bonding agent into the concrete substrate using a short bristle brush to enhance the bond at the repair interface, considering environmental constraints. If used, ensure that the bonding agent does not dry out prior to the application of the re-surfacing material. Where drying/curing of the bonding agent has exceeded the level specified by the manufacturer for application of the repair mortar, reapply the bonding agent in accordance with the manufacturer's instructions.

Remove and replace all repair material that has not bonded properly due to the incorrect application or drying out of the bonding agent.

SA Water may inspect the application of the bonding agent.

WITNESS POINT

17.2 Patch Mortar Application

Provide epoxy resin repair material suited to the intended type of repair and performance requirements when placed by hand methods in accordance with Clause 3.9.

Mix and transport repair mortar in accordance with Clause 4.9.

Place the patch repair epoxy resin mortar by hand methods in strict accordance with the manufacturer's written application instructions.

The applied material shall have no voids, shall be properly compacted and shall have no sagging of the repair material.

Build up to the original surface profile in layers not exceeding the repair material manufacturer's recommendations and in accordance with the approved Work Method Statement. Use the manufacturer's recommended filler if required.

Roughen each previous layer to provide a mechanical key for the next layer.

Wipe the trowel frequently with a cloth dampened with thinners to facilitate trowelling/finishing.

Protect the surface whilst the material hardens.

WITNESS POINT

17.3 Curing

Cure each layer for a period recommended by the repair material manufacturer before subsequent layers are applied.

18 Quality Control Testing

18.1 General

Comply with all Quality Control Testing requirements in TS 0711.0 Clause 5 and this Technical Standard.

Use an independent testing organisation to conduct all testing and quality control activities as required by this Technical Standard and the ITPs as the works proceed.

Allow for all samples, their production, retrieval and storage, testing and reporting required by the Contract.

Provide access, undertake sampling by coring (if requested by SA Water's Representative) and make good to reinstate to the profile of the surrounding surfaces using the approved repair materials and workmanship for any tests.

SA Water's Representative is at liberty to witness the carrying out of any test performed by the Constructor or its representative. The Constructor will be given one copy of any test result or report upon request.

Where testing is to be performed by a laboratory, supply one (1) copy of the laboratory report.

WITNESS POINT

18.2 List of Quality Control Tests

The minimum testing requirements are listed in Table 13 and the test details follow. Additional testing may be included in the submitted ITP.

Table 13: Concrete Repairs Quality Control Tests and Frequency

Test Required	Performed By	Procedure	Minimum Frequency of Testing
Inspection of Concrete Break Out	QC Engineer	Clause 18.7	Each and every repair area.
pH Test of Prepared Concrete Surface	QC Engineer	Clause 18.7	Each and every repair area.
Concrete Surface Profile	QC Engineer	Clause 5.4.4	Each and every repair area.
Hammer Tap Test of Prepared Concrete Surface	QC Engineer	Clause 18.7	Each and every repair area.
Adhesive Bond to Prepared Concrete Surface	QC Engineer	Clause 18.8	3 tests per 10 m ² of repair area.
Inspection of Cleaned Reinforcement	QC Engineer	Clause 6.2	Each and every repair area.
Inspection of Reinforcement Coating	QC Engineer	Clause 0	Each and every repair area.
Electrical Continuity Testing of Reinforcement Type 4A Repairs	QC Engineer	Clause 18.12	All reinforcement: Testing sufficient for Constructor to confirm reinforcement continuity.

Test Required	Performed By	Procedure	Minimum Frequency of Testing
Reinforcement Protective Coating	QC Engineer	Clause 18.13	3 tests per 20 m ² repaired concrete surface area.
Encasement of Reinforcement	QC Engineer	Clause 10.7.3	Test panels.
Compressive Strength Of Repair Mortar	Independent NATA accredited laboratory	Clause 18.3	Three cubes for compressive strength and tested from a sample set. Sample sets shall be tested at first repair material applications and at least two further occasions during the works as directed by SA Water's Representative. Not required where the manufacturer can provide written confirmation of strength details from a laboratory with NATA accreditation.
Compressive Strength of Cylinder Samples	Independent NATA accredited laboratory	Clause 18.4	Three cylinders for compressive strength and tested from a sample set. Sample sets shall be 6 hours, 24 hours and 7 days or as directed by SA Water's Representative.
Compressive Strength of Test Panel Core Sample	Independent NATA accredited laboratory	Clause 0	Six cores for compressive strength and tested from a sample set of three. Sample sets shall be tested at 24 hours and 7 days age, or as directed by SA Water's Representative.
Compressive Strength of Sprayed Concrete	Independent NATA accredited laboratory	Clause 18.6	Each and every repair area. Six cores for compressive strength and tested from a sample set of three. Sample sets shall be tested at 24 hours and 7 days age, or as directed by SA Water's Representative.
Conformity of Compaction of Sprayed Concrete	Independent NATA accredited laboratory	Clause 18.6.3	All core samples
Soundness of Repairs	QC Engineer	Clause 18.8	Each and every repair area.
Bond Strength of Repair	QC Engineer	Clause 18.10	3 cores per 10 m ² of applied repair (or 3 cores if repair area is <10 m ²). The testing frequency may be reduced at the discretion of SA Water's Representative once the Constructor demonstrates good site performance via no below strength results from the site testing. For repairs of section size less than 0.09 m ² bond tests are not required to the repaired locations. Complete a repair material sample area to 50 mm thickness and undertake 3 bond strength tests as part of the Trial Repair.
Electrical Resistivity of Repair Materials	QC Engineer	Clause 18.11	Two tests per 10 m ² of applied repair (or 2 tests if repair area is <10 m ²).

18.3 Test Method – Compressive Strength of Repair Mortar

18.3.1 Method

Obtain three 75 mm test cubes from the first batch of material mixed, then three 75 mm cubes for every 250 kg of material used thereafter to test for compressive strength.

Prepare and cure for 7 days cubes under laboratory-controlled conditions standard cubes for compression strength tests in accordance with AS 1012.8.3, including the use of cover plates and clamps. Test two cube samples at 7 days and the third cube at 28 days in accordance with AS 1012.9.

18.3.2 Acceptance Criteria

The compression strength shall be greater than the minimum compressive strength at 28 days specified in

Table 5.

This testing requirement may be waived at the SA Water's Representative's discretion where the manufacturer can provide written confirmation of compressive strength details.

18.4 Test Method – Compressive Strength of Cylinder Samples

18.4.1 Method

Make and store test cylinders in accordance with AS 1012.9

Undertake compressive strength testing of each set of concrete cylinders at 6 hours, 24 hours and 7 days age in accordance with AS 1012.9.

The density of the cylinders will be the as received density and will be determined in accordance with AS 1012.12.

18.4.2 Acceptance Criteria

The compression strength shall be greater than the minimum compressive strength at 28 days specified in

Table 5.

18.5 Test Method – Compressive Strength of Test Panel Core Samples

18.5.1 Core sampling

Obtain six concrete cores samples from the test panel for compressive strength testing in accordance with AS 1012.14.

Cut minimum 75 mm diameter concrete cores at right angles to the plane of the panel six hours after the panel has been cast, complying with the requirements of Clause 5.3.3 for coring work.

In addition, cut at least two cores per test panel from concrete adjacent to or through steel reinforcement for the purpose of visual assessment of the quality of the sprayed concrete adjacent to steel reinforcement.

Take the cores through the full panel thickness of the panel at random locations and not from within 125 mm of the edge of the panel.

After core recovery, label the cores.

Inspect and photograph each core to verify the extent of concrete compaction.

Wrap the cores in double polyethylene for transport and storage.

18.5.2 Laboratory Tests

Send the cores to a NATA accredited laboratory for trimming, density determination, capping and tank curing in accordance with AS 1012.9 and AS 1012.14. The density of the cylinders and cores will be the as received density and will be determined in accordance with AS 1012.12.

Undertake compressive strength testing of the prepared cores samples in accordance with AS 1012.9.

Each set of three cores is to be tested at 24 hours and 7 days age.

18.5.3 Acceptance Criteria

The average strength of the cores after applying adjustments detailed in AS 3600 and AS 1012.14 shall meet the performance requirements of

Table 5.

In the event that the test results of a sample set of crushed cores do not comply with the performance criteria, retrieve additional cores from the test panel as directed by SA Water's Representative. Should these results also fail to meet the performance criteria, the mix design and/or construction method will require revision and the trial be repeated.

18.5.4 Schmidt Hammer Tests

As well as concrete core testing, estimate compressive strength of the test panel at the core test locations at 24 hours and seven days using a calibrated Schmidt hammer.

Obtain at least 10 Schmidt Hammer test values within an area 0.01 m² with a distance of 100 mm of each core location.

Determine a statistical correlation between the Schmidt hammer results and the Compressive Strength test results. Use this correlation for subsequent testing of applied repair material.

18.5.5 Uniformity of compaction

Visually inspect the cores for uniformity of compaction and to assess any shadowing at reinforcement bars.

18.5.6 Acceptance Criteria

The criteria for acceptance of the repair trial mix shall be the fulfilment of the relevant compressive strength performance criteria as required by

Table 5, uniform sound compaction and no shadowing at reinforcement.

If the cores at 24 hours age fail to meet these performance criteria, retrieve additional cores from the panel as directed by SA Water's Representative.

In the event that the 7-day compressive strength test results do not comply with the performance criteria, retrieve additional cores from the panel as directed by SA Water's Representative.

If these results also fail to meet the performance criteria in

Table 5, SA Water's Representative will require that the trial is repeated.

Where the trial relates to a Constructor proposed mix that does not comply with the requirements of the relevant performance criteria, SA Water's Representative will reject the trial mix and the Constructor shall modify the mix design, prequalify the constituent material if different and repeat the trial mix procedure as above.

Following the trial, submit the details of the successful mix to SA Water's Representative.

Dispose of all materials associated with the trial process including test panels and core samples, following submission of the successful mix to SA Water's Representative.

A successful trial shall also demonstrate that the repair works can be completed in the allotted time prior to return to service.

18.6 Test Method – Sprayed Concrete Insitu Compressive Strength

18.6.1 Method

Test all areas of spray-applied repair concrete for soundness as follows:

1. Undertake Schmidt Hammer tests at ten random locations distributed across the sprayed concrete area
2. At each location obtain ten test Schmidt Hammer values within an area 0.01 m²
3. Ensure the concrete surface is smooth to obtain reliable readings
4. Use the statistical correlation obtained as part of the test panel trials (refer Clause 18.5.4) to estimate the compressive strength test results
5. Provide the location and results of the testing to SA Water's Representative.

18.6.2 Acceptance Criteria

The estimated compressive strength shall meet the compressive strength performance criteria as required by

Table 5.

In the event that the test results do not comply with the performance criteria in

Table 5, retrieve three minimum 75 mm diameter cores from the repair area as directed by the SA Water's Representative in accordance with AS 1012.14 and test in accordance with AS 1012.9 (cores to be wet conditioned and sulphur capped).

Obtain full depth cores taken into the original concrete substrate, avoiding all dowels, bolts and other steelwork.

Should the compressive strength test results also fail to meet the performance criteria in

Table 5, remove the defective sprayed concrete and reapply sprayed concrete in accordance with Clause 10.

18.6.3 Conformity of Compaction

If a visual inspection of any cores suggests that uniformity of compaction has not been achieved, or there is shadowing at reinforcement bars, take a further four 75 mm diameter cores.

Test these cores for compressive strength and density in accordance with AS 1012.14 and AS 1012.12.2.

For density compliance the measured values shall exceed 96% of the theoretical concrete mix density.

The average strength of the cores after applying adjustments detailed in AS 3600 and AS 1012.14 shall meet the requirements of

Table 5.

Failure to meet the strength and density criteria shall make the trial liable to rejection by the SA Water's Representative following submission of all documentation.

18.7 Test Method – Concrete Removal - Soundness of Substrate

18.7.1 Method

Test all areas of prepared concrete substrate for soundness as follows:

1. Visually examine the substrate surfaces to confirm no defects including voids, honeycombing, segregation or cracking, or contamination
2. Test soundness of concrete substrate by light tapping of all repaired surfaces using a light ballpeen hammer or delamination wand (metal bulb fixed to a fibre glass rod) to confirm nil delamination exists (solid versus hollow sounding)
3. Spray the freshly broken out concrete surface with a phenolphthalein pH indicator.

18.7.2 Acceptance Criteria

Refer Clause 5.4.2.

18.8 Bond Capacity of Concrete Substrate

18.8.1 Method

Test the adhesive bonding capacity of the prepared surface using a direct pull tensile test in accordance with AS 1012.24 at a rate not less than 3 tests per 10 m² of repair area.

18.8.2 Acceptance Criteria

The prepared concrete surface tensile capacity shall be greater than the minimum adhesion value in

Table 5 for the specified repair material.

18.9 Test Method – Soundness of Repair

18.9.1 Method

Test all areas with applied cured repair mortar or concrete for soundness as follows:

1. Visually examine the repaired surfaces to confirm no defects including voids, honeycombing, segregation or cracking
2. Test soundness of concrete repairs by light tapping of all repaired surfaces using a light ballpeen hammer or delamination wand (metal bulb fixed to a fibre glass rod) to confirm nil delamination exists (solid versus hollow sounding).

18.9.2 Acceptance Criteria

1. Excessive cracking is defined as:
 - a. cracks with width in excess of 0.1 mm in the repair measured at the crack surface
 - b. crazing/cracking covering significant areas of the repair or
 - c. any cracking whatsoever at interfaces between old concrete and the repair.
2. Where evidence of voids around reinforcement exists, cut out and replace the repair material. The area of cut back shall be at least 50 mm both side of the defective area and back to the substrate and behind the reinforcement
3. Areas sounding hollow shall be condemned. If hollow areas are found, cut out and replace condemned areas in accordance with this Technical Standard.

18.10 Test Method - Repair Material Bond Strength

18.10.1 Method

Seven days after repair application on completion of curing, conduct in-situ direct pull-off testing in accordance with AS 1012.24 to verify that the tensile bond strength between the repair mortar and the concrete substrate is satisfactory at locations approved by the SA Water's Representative, at a rate not less than 3 tests per 10 m² of completed repair area.

Take extreme care during the partial coring to ensure that the process has minimal effect on the bond between repair material and the substrate. Where steel is encountered, move the location of the core by the minimum amount to avoid the reinforcement.

Make the fixing holes good with the repair mortar in accordance with the approved Work Method Statement.

18.10.2 Acceptance Criteria

Bond Strength

The mean bond strength at age 7 days shall be not less than the criterion in

Table 5 or the tensile strength of the concrete substrate, with no individual result less than 90% of the mean value.

Failure Mode

Visually inspect the test specimens and determine the mode of failure as categorised in Table 14 based on the cross sectional area at the failure plane.

Where a combination of modes of failure exists, record the percentage of each mode of failure to the nearest 10% based on the surface area of the failure face.

Table 14: In-situ Direct Pull-Off Test Failure Mode

Mode	Description
1	Tensile failure within the existing concrete substrate.
2	Tensile failure within the concrete repair material.
3	Bond failure at the interface between the existing concrete substrate and the repair material.
4	Bond failure between the adhesive layer and the dolly.
5	Partial bond failure at the interface between the existing concrete substrate and the repair material and partial tensile failure within the repair material.
6	Partial bond failure at the interface between the existing concrete substrate and the repair material and partial tensile failure within the existing concrete substrate.

The mode of failure of the pull-off test shall be in accordance with Mode 1, with tensile failure within the existing concrete substrate.

Where failure occurs at the dolly/specimen interface (Mode 4) and the failure stress is less than the mean value required by this Standard, record the result and fix and re-test another dolly as soon as the epoxy adhesive has sufficiently cured. Do not include the failed specimen result in the mean or as one of the tests specified in the frequency of testing.

Where the failure occurs within the substrate concrete (Mode 1), record the result and count the test as a pass, even if the failure stress is less than the minimum value required by this Technical Standard. SA Water's Representative may request additional testing in this situation.

Mean bond strengths less than the criterion in

Table 5 or failure modes 2, 3, 4, 5 and 6 shall be raised as a non-conformance.

18.11 Test Method - Repair Material Resistivity

18.11.1 Method

Measure the resistivity of the repair material at 7 days age and 28 days age, using a hand held instrument with adjustable probe centres which utilises the modified Wenner four probe method.

The probes shall be embedded, not surface mounted.

18.11.2 Acceptance Criteria

Where the resistivity of the repair material does not comply with the performance criteria in Table 6, SA Water's Representative may identify it as non-compliant.

Remove the extent of non-complying repairs as indicated by the resistivity measurement and reinstate the repairs in accordance with this Technical Standard.

18.12 Test Method - Electrical Continuity Testing

18.12.1 General

As the work proceeds conduct electrical continuity testing of the reinforcement, ancillary steelwork and other metallic work at the frequency required in Table 13 by the procedure detailed in this Clause.

Forward the results of testing to SA Water's Representative prior to any reinstatement works. SA Water's Representative may request further testing.

18.12.2 Equipment Required

Use a high impedance digital multimeter with an input impedance of 10 M Ω (minimum), and capable of resolving to 0.1 millivolts or better, and 0.1 Ω or better to perform this testing.

18.12.3 Test Procedure

Switch the multimeter to ON and set to measure resistance.

Record the lead resistance prior to taking any resistance measurements "RL".

Clean the surfaces where the probes are to contact to bright metal prior to contacting the probes.

Contact the probes across the sections of steel to be tested and undertake the following measurements:

1. Record the resistance value "R1"
2. Leave the probes connected, and after a period of 30 seconds record the resistance again "R2".

Reverse the leads and repeat the measurements as per (a) and (b) "R3" & "R4".

Following completion of the above test, record the DC voltage across the section of steel under test "V1". For this test, set the meter to read 200 mV full scale.

18.12.4 Acceptance Criteria

The criteria for an acceptable electrical continuity test are as follows:

1. The measured resistance “R1” is less than 2 Ω (after subtracting the lead resistance “RL” from the measurement)
2. The resistances value “R2” is within 1.0 Ω of “R1”
3. The resistance value “R3” is within 1.0 Ω of “R1”
4. The resistance value “R4” is within 1.0 Ω of “R3”
5. The DC voltage “V1” is less than 5 millivolts.

18.13 Test Method – Reinforcement Protective Coating DFT

18.13.1 Method

Test the dry film thickness (DFT) of the cured applied reinforcement bar protective coating performed in accordance with AS 3894.3 Method B at the frequency required in Table 13.

18.13.2 Acceptance Criteria

Achieve the minimum DFT in Clause 3.8.1.

18.14 Other Tests

Perform routine quality control tests and inspections in accordance with the ITP.

Failure of a sample or repaired area under test to comply with requirements of this Technical Standard shall result in the area of repair represented by the sample set being non-compliant.

Appendix A : Typical Properties Of Cementitious Repair Materials

A1 Typical Build and Physical Properties of Cementitious Repair Materials

Property	Unit	Class R4	Class R3	Class R2	Class R1	Fairing mortar
Build - Hand Placed per Layer	mm	5 mm to 40 mm	5 mm to 40 mm	5 mm to 70 mm	5 mm to 80 mm	0.5 mm to 3 mm
Build - Spray Applied Vertical per Layer	mm	10 mm to 80 mm	10 mm to 80 mm	10 mm to 150 mm	n/a	n/a
Build - Spray Applied Overhead per Layer	mm	10 mm to 80 mm	10 mm to 80 mm	10 mm to 150 mm	n/a	n/a
Build - Flowable	mm	20 mm to 300 mm	n/a	n/a	n/a	n/a
Compressive Strength	MPa	50 to 70	30 to 40	25 to 30	20 to 25	n/a
Adhesive Bond	MPa	2 to 3	1.5 to 3	0.8	0.8	2.5
Elastic Modulus	GPa	20 to 40	15 to 20	10 to 15	8 to 12	n/a
Shrinkage: Hand Applied/Sprayed	µS	500-700	500-700	500-700	500-700	n/a
Shrinkage: Flowable	µS	300-550	n/a	n/a	n/a	n/a

A2 Cementitious Repair Material Application Methods

Application Method	Class R4	Class R3	Class R2	Class R1	Acid Resistant
Hand Placed	Y	Y	Y	Y	Y
Wet Spray	Y	Y	N	N	Y
Dry Spray	Y	Y	N	N	Y
Flowable	Y	N	N	N	N
High Build	Y	Y	Y	Y	Y
Thin Build	N	Y	Y	Y	N
20 MPa in 24 hrs	Y	N	N	N	Y

Appendix B : Schedules of Hold Points, Witness Points and Identified Records

B1 Schedule of Hold Points

Clause	Type	Description
3.2	Hold	Approved concrete repair materials
3.3	Hold	Materials testing
3.4.1	Hold	Performance Requirements
4.8	Hold	Pre-work survey
4.10	Hold	Trial Repair
0	Hold	Inspection and approval of breakouts.
0	Hold	Risk Assessment for Live Assets works
6.2	Hold	Examination of cleaned reinforcement for section loss.
0	Hold	Augmentation of reinforcement
6.6.6	Hold	Inspect steel reinforcement before the concrete placement
8.1	Hold	Inspect breakout work before proceeding with reinstatement work

B2 Schedule of Witness Points

Clause	Type	Description
0	Witness	Visual inspection of final cleaning of concrete substrate
6.7	Witness	Application of protective coating to reinforcement.
7.2	Witness	Installation of sacrificial anodes
8.3.2	Witness	Check geometric tolerance of finished repair
9.1	Witness	Patch repair - Application of concrete bonding agent
9.2	Witness	Patch repair – Application of mortar
11.2	Witness	Inspect formwork prior to flowable concrete pouring
12.1	Witness	Inspection of underwater concrete preparation
12.2	Witness	Application of underwater concrete
13.1	Witness	Inspection of application of the bonding agent for water leakage repair
13.3	Witness	Application of water leakage patch repair material
14.1	Witness	Inspection of application of the bonding agent for rapid-set repair
14.2	Witness	Application of rapid set repair material
15.2	Witness	Inspect formwork prior to grouting
0	Witness	Grout installation
17.1	Witness	Substrate preparation for epoxy repair material
17.2	Witness	Application of epoxy repair material
18.1	Witness	Quality Control testing - General

B3 Schedule of Identified Records

Clause	Description of Identified Record
3.4.1	Provide evidence repair material properties
4.2	Provide evidence Constructor Competency
4.3	Provide QA documentation (QMS, WMSs, ITPs, Pre-Start Meetings, Daily Records)
0	Provide OHS documents (JSEAs, MSDSs, etc.)
4.5	Provide Environmental requirements
4.7	Provide temporary works plans
4.3.5	Provide As-Repaired Report.