Engineering

Technical Standard

TS 0711.3 – Concrete Remedial Works: Concrete Crack Repair

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Government of South Australia

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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-003 Technical Specification - Concrete Repair Works: Crack Repairs
- TS137 – Rehabilitation of Concrete Wastewater Manholes

Document Controls

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Contents

List of tables

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 repair of cracks in reinforced concrete water and wastewater assets up to 5 mm wide.

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

Read TS 0711.3 in conjunction with TS 0711.0: General Requirements.

1.3 General Requirements

Refer to TS 0711.0 for details of the general project requirements:

1. Introduction: Purpose, references
2. Scope: Types of structure 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 Crack 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 cracking
3. Trial repair to verify materials and workmanship
4. Preparation and priming of the cracks for sealing
5. Sealing of cracks
    a. Surface applied crack sealers or barriers
    b. Filling cracks by injection
    c. Routing and filling with cement-based material
    d. Routing and filling with polymer-based sealant material
6. Structural repair of cracks
7. Post-treatment
8. Quality control testing to verify compliant repair works
9. Submission of an As-Repaired report

Undertake additional remedial works if required (concrete repair, joint sealant, surface protection, structural bonding or strengthening) in accordance with TS 0711.1 to TS 0711.5.

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 Standard are defined in Table 1.

Table 1: Definitions of Terms Used in this Technical Standard.

Term	Definition
Active cracks	Live/dynamic cracks, which are subject to further movement (i.e., opening up).
Bandage	A flexible and elastic waterproofing tape installed across static or high movement crack or joints adhered to the concrete using epoxy resin adhesive.
Coating over cracks	Application of an organic or inorganic coating with a crack bridging or sealing capability.
Crack filling material	Material used to fill the crack that may be a resin (or resin adhesive or adhesive) or sealant or cementitious material applied into a crack for the purpose of filling and closing the crack.
Crack injection resin	The crack filling material that is injected or introduced into a crack for the purpose of re-bonding the separated edges to allow the transfer of tensile stress across the crack.
Entry port / injection port	A device or passageway in the surface seal through which the resin adhesive is introduced into a crack.
Flexible sealing	Use of suitable flexible sealants to seal active cracks in the same manner as flexible joints.
Gravity feed	Filling and sealing of horizontally positioned cracks using low viscosity resins by pouring and spreading onto surface or placing into purposely formed reservoirs.
Hydrophilic crystalline cementitious material	A proprietary material used as an additive in slurry coating and mortar materials (or a stand-alone) 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.
Inactive cracks	Dormant/static or “dead” cracks which do not open, close or extend further.
Resin	A resin system based on epoxy materials comprising a thermosetting polymer that is the reaction of an epoxy resin and amino hardener
Resin injection	Crack filling under pressure using a selected polymer resin adhesive such as epoxy or polyurethane to restore structural soundness and penetrability of concrete where cracks are inactive or can be prevented from moving further.
Routing and sealing	Enlarging the crack along its exposed face and filling with a suitable joint sealant or hydrophilic crystalline material to produce a repair method for cracks that are inactive and not structurally significant.
Sealant	The crack filling material that has adhesive and cohesive properties that forms a seal to prevent the ingress of liquid or gases into the concrete.
Stitching of cracks	Anchoring of U-shaped metal legs or bars, or proprietary fibre composite band in predrilled holes on both sides of cracks to restore the tensile strength and structural integrity of the crack affected concrete.
Surface seal	Material used to confine the injection adhesive in the fissure during injection and cure.

2 Crack Repair System Selection

2.1 Crack Assessment

Undertake an assessment of the concrete cracking sufficient to determine:

1. Cause(s) of the crack
2. Type/State of crack (width, moisture condition, movement is active/dynamic/subject to further movement or inactive, static)
3. Implications of the cracking on the structural, serviceability and durability of the structure.

Undertake repair of fire or reinforcement corrosion related cracking in accordance with TS 0711.1.

Reinforced concrete crack classifications are listed in Table 2.

Table 2: Reinforced Concrete Crack Classifications

Crack Type	Width (mm)	Load Transfer
Hairline	≤ 0.1	Full interlock and load transfer
Fine	0.1 to 0.5	Full interlock and load transfer
Medium	0.5 to 1.5	Partial interlock and load transfer
Wide	1.5 to 5.0	No load transfer
Fracture	≥ 5.0	No load transfer

REF: Concrete Society TR22, CIA Z7-06

2.2 Crack Repair Systems

Select a crack repair system based on the crack assessment and the most onerous set of exposure conditions in accordance with Table 3 and the corresponding nominated materials in accordance with the performance requirements of Clause 3 of this Technical Standard.

Eliminate the cause of the crack or select a crack repair method that fully accounts for the future predicted movements. Reinforcement may have yielded for wide cracks or fractures and structural repair may be required.

Table 3: Crack Repair Systems

			Structural Repair					Non-structural Repair								
Repair Type			Rigid setting material injection	Gravity fed epoxy resins (horizontal surfaces only)	Repair to cracked concrete and treating cause of corrosion/ fracture	Stabilisation and sealing of cracks, or transfer of crack into movement joint	Transfer of cracks into movement joint, as per structural assessment - Filling routed cracks with joint sealant	Filling of routed cracks with repair material	Waterproof membrane (applied to positive pressure side)	Crack/ joint bandage system (applied to positive pressure side)	Surface applied pore lining penetrant	Surface applied coating or render	Surface applied elastomeric coating	Flexible resin injection	Flexible resin injection to halt leak	Mortar plug to halt leak
Material Type			Low viscosity epoxy resin or ultrafine cement grout	Low viscosity epoxy resin		Flexible structural resin injection of structural cracks together with crack stitching; or Filling of routed cracks with joint sealant	Joint sealant	Hydrophilic crystalline growth/ cement waterproof mortar system	Liquid applied or sheet waterproof membranes, may require crack filling/support	Epoxy resin adhered flexible surface bandage system, may require membrane support	Silane/ siloxane	Hydrophilic crystalline growth/ cement penetrative treatment	Acrylic/ methacrylate	Polyurethane, Methacrylate resin Acrylic resin limited to <30% crack width movement	Polyurethane resin	Fast setting waterproof hydraulic cement
TS Clauses			3.5, 7	3.5, 6	TS 0711.1	3.5, 3.11, 7, 11 TS 0711.2	TS 0711.2	3.6, 8	TS 0711.5	3.9, 10	TS 0711.5	TS 0711.5	TS 0711.5	3.5, 7	7	TS 0711.1 Clause 13.2
Crack Type																
INACTIVE	Hairline	Atmospheric									X	X	X			
	Fine		X	X				X			X	X	X	X		
	Medium		X	X				X						X		
	Wide		X	X		X	X	X						X		
	Fracture		X	X		X	X	X						X		
	Hairline	Water retaining/ excluding structure							X	X	X	X	X			
	Fine		X	X				X	X	X	X	X	X	X	X	
	Medium		X	X				X	X	X				X	X	
	Wide		X	X		X	X	X	X	X				X	X	
	Fracture		X	X		X	X	X	X	X				X	X	
	Wide, Fracture	High flow leaking cracks, holes													X	X
ACTIVE	Hairline	Atmospheric									X	X	X			
	Fine				X								X	X		
	Medium				X									X		
	Wide				X	X	X							X		
	Fracture				X	X	X							X		
	Hairline	Water retaining/ excluding structure			X				X	X			X			
	Fine				X				X	X			X	X	X	
	Medium				X				X	X				X	X	
	Wide				X	X	X		X	X				X	X	
	Fracture				X	X	X		X	X				X	X	
	Wide, Fracture	High flow leaking cracks, holes													X	X

Note 1: Structural engineer to assess all cracks prior to selection of the crack repair system

3 Materials

3.1 General Requirements

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

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

3.2 Approved 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.

HOLD POINT

3.4 Crack Repair Materials - General Performance Requirements

Select crack repair systems which are of proven quality for concrete protection and demonstrate the properties listed below in the following sub-sections for each of the crack sealing methods:

1. Be suitable for the operating conditions of the asset (temperature, water pressure, thermal expansion/contraction etc.)
2. Maintain its functional properties over the stated minimum service life
3. Exhibit chemical, abrasion and UV resistance as required dependent upon the exposure
4. Be compatible with all materials with which it is intended to come into contact.

3.5 Crack Injection Materials

3.5.1 General Properties

Crack filling/injection materials shall have the following general properties:

1. Ability to fully seal cracks in concrete surfaces over a crack width range of 0.1 to 5 mm
2. Ability to seal cracks in concrete surfaces to a minimum depth of 200 mm from the surface or at least 2/3 of the element thickness whichever is greater
3. Excellent adhesion to concrete
4. Fast curing and solvent free
5. Have sufficient strength and flexibility to tolerate the predicted concrete/substrate cracking, and movement
6. Injection ports/nipples used to direct material into cracks will be proprietary and have a previous track record of use for material injection of cracks in concrete of width 0.1 mm to 5 mm
7. Pot life and working time shall be in accordance with the Manufacturer's recommendation
8. Crack injection materials shall comply with the performance requirements in EN 1504-5, as listed in Table 4
9. Category H materials (cement based), as defined in EN 1504-5 Classification system and listed in Appendix C , are not to be used for structures subject to high frequency changes during hardening, nor for active/dynamic cracks
10. Category F materials (force transmitting rigid epoxy resin or cement based) are not to be used for active/dynamic cracks.

Table 4: Types of Crack Injection Material

EN 1504.5 Use Category "U"Note 1	Type	Required Properties
F1	Structural adhesive epoxy resin	1. Compressive strength ≥55 MPa at 7 days to BS 6319 2. Tensile Strength ≥15 MPa at 7 days to BS 6319.
F2	Structural injection epoxy resin	1. Tensile Strength ≥25 MPa at 7 days to BS 6319.
F3	Structural gravity fed epoxy resin	1. Low viscosity (<200 cps) unfilled two-component epoxy resin adhesive 2. Capable of penetrating cracks by gravity from 0.05 mm width 3. Solvent free 4. Moisture tolerant 5. Cold curing.
S	Waterproofing polymer resin	1. Seal dynamic/active cracks with a two-component, flexible polyurethane, acrylic or methacrylate based polymer resin 2. Injection resin viscosity maximum 300 mPa-s 3. Non-foaming.
S	Rapid foaming polyurethane resin	1. Seal active/high flow water leaks with a low viscosity hydrophobic polyurethane that reacts with water to form rigid polyurethane foam 2. Injection resin viscosity maximum 150 mPa-s. @ 20°C.

Note 1: Refer to Appendix C for interpretation of the EN 1504-5 Classification system.

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

3.5.2 Corrosion Inhibitor

Use a surface applied liquid amino alcohol/carboxylic acid salt based migratory corrosion inhibitor (MCI) where required in chloride bearing cracks.

Achieve an MCI concentration ≥2.5 x 10^{-5} ml/g concrete sample measured using a method recommended by the Manufacturer.

3.6 Waterproof Mortar System

3.6.1 Drinking Water and Raw Water Structures

Use a waterproof cementitious repair mortar system that includes slurry and mortar materials that meets the requirements for Repair Type 3E in TS 0711.1 Table 6.

Use materials which are a single component blend of powders to which clean potable water is the only permitted site addition.

The waterproof repair system Manufacturer shall confirm the compatibility of its material with the proposed corrosion inhibitor for repairs to chloride-bearing cracks.

3.6.2 Wastewater Structures

Use a waterproof cementitious repair mortar system that complies with Clause 3.6.1, that also includes a proven anti-microbial admixture, i.e., meet the requirements for Repair Type 5B(b) in TS 0711.1 Table 6.

3.7 Crack Bridging Coating

Refer to TS 0711.5 Surface Protection and Lining of Concrete, Clause 2.5.

3.8 Waterproof Cementitious Coating

Refer to TS 0711.5 Surface Protection and Lining of Concrete, Clause 8.1.

3.9 Crack Bandage Systems

Crack bandage system materials shall achieve the following performance requirements, unless noted otherwise:

1. All preformed component parts by the same manufacturer
2. High adhesion for tape to epoxy resin without the need for site activation of the tape
3. Moisture / damp surface tolerant
4. Flexible allowing movement
5. Remains permanently flexible
6. Achieves a watertight seal
7. UV and chemical resistant
8. Rated for immersion service
9. Tape elongation at break >600% to to EN 12311-2
10. Tape Tensile strength > 12 N/mm^2 to EN 12311-2
11. Epoxy resin adhesion strength to concrete >2 MPa, failure in concrete
12. Protect bandage material from mechanical damage
13. Provide support for bandage material subject to hydrostatic pressure:
    a. Negative pressure: Use hard foam filler or joint sealant
    b. Positive pressure: Use corrosion resistant metal plate.

3.10 Rout and Sealant

Refer to TS 0711.2 Joint Sealant Clause 2.

3.11 Crack Stitching

Design the crack stitching system based on the proprietary system manufacturer's technical requirements.

The stitching rod or legs shall be variable in length and orientation and located such that the tension across the crack is distributed over an area in the concrete and not concentrated on a single plane within the section.

The structural epoxy adhesive paste shall comply with the requirements in TS 0711.4 Clause 3.4.6.

3.12 Injection Equipment

Use injection equipment recommended by the resin manufacturer for the specific resin.

Equipment for injection shall have the following characteristics:

1. Easy to handle with simple function checking
2. Pressure regulation or limitation in the operating range of the injection equipment
3. Simple cleaning and maintenance
4. Injection pressure suited to the resin and equipment used, to ensure that cracks are completely filled without voids.

3.13 Water

Use potable quality water, drawn from the metropolitan reticulated supply, conforming to AS 1379 for cleaning and surface preparation.

4 Workmanship – General

4.1 Standards and Codes

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

4.2 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 12.

Provide identified records listed in Appendix A.

4.3.1 Quality Control Inspector

At the discretion of the SA Water's representative, and subject to the project size and complexity, an approved Independent Quality Control Inspector shall be appointed for the works.

Nominate the inspector to SA Water's Representative prior to commencement of work.

Otherwise provide site quality inspection personnel qualified in accordance with TS 0711.0: Clause 4.2 for daily site QC purposes in accordance with TS 0711.0: Clause 5.11, and with a minimum of 5 years of experience in application and testing of crack repairs.

4.3.2 Hold Points and Witness Points

The minimum required Hold Points and Witness Points for Concrete Repair works are listed in Appendix A.

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

4.3.3 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.

4.3.4 Pre-Start Meeting

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

4.3.5 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.

Crack Injection Daily Records

Record the following as part of daily records:

1. Volume of crack filling material used over a surface area/element
2. Injection pressure
3. Time to inject crack filling material
4. Ratio tests.

4.3.6 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
   c. Undertake further testing if required
   d. Mark out all defect areas for repair.

HOLD POINT

4.9 Materials Handling

4.9.1 Mixing of Crack Sealing Resin/Adhesive

Do not use crack repair materials greater than 12 months age from the date of manufacture, or less as advised by the manufacturer.

Store materials under conditions as recommended by the Manufacturer in a cool dry place out of direct sunlight.

Supply the resin/adhesive in factory-proportioned units comprising the correct quantities of resin and hardener.

Mix complete container contents of each component. Do not use part container contents. Allow stored materials to attain a suitable temperature before mixing.

Thoroughly stir the two components using a slow speed electric drill with approved paddle.

Mix the two components for at least 3 minutes and according to the manufacturer's instructions to achieve a uniform colour and consistency.

Avoid aeration during mixing. Transfer mixed material to the application equipment.

Ensure the pot life of the material is not exceeded.

Do not install resins when the ambient temperature is < 5ºC, or is 5ºC on a falling thermometer, or is > 35ºC.

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

4.10 Trial Repairs

Undertake trial repairs to verify workmanship 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.

Inspect the completed injection in accordance with Clause 12.

HOLD POINT

4.10.1 Crack Sealing Trial

The crack sealing trial shall be a minimum of 2.0 lineal meter 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. Substrate and crack preparation
2. Delivery/application of the crack sealing material
3. Cleaning of the surface following sealing
4. Compliance with the relevant inspection and testing requirements.

4.10.2 Operative Competency Trial

Undertake competency of application trial panels for all concrete crack repair operatives in accordance with Clause 4.10.1.

5 Crack Repair Workmanship

5.1 Substrate Preparation – General Requirements

Prepare the substrate / cracks for sealing strictly in accordance with the manufacturer's requirements and the following minimum general requirements:

1. Clean concrete surfaces within a minimum 50 mm each side of the crack
2. If the concrete surfaces adjacent to the crack are deteriorated, grind and remove concrete until a sound substrate is achieved
3. Ensure all surfaces for crack sealing are clean and free from: oil, grease, standing water, sand, debris, organic matter
4. Remove contaminants and dust from cracks using oil free, dry compressed air
5. Ensure the substrate is dry prior to crack repair material application, or moisture conditioned if required by the manufacturer's specification
6. The minimum age of newly repaired concrete that may be sealed is 4 weeks, or as nominated by the crack repair material manufacturer
7. Follow any additional specific preparation requirements for each method of crack sealing as specified by manufacturer
8. Ensure the method of preparation does not cause weakness of the interface due to fracture or loosening of aggregates.

HOLD POINT

5.2 Active Water Leaks

Stop active leaks using one of the following methods:

1. Rapid setting waterproof cementitious mortar - refer to TS 0711.1 Clause 13.2: or
2. Rapid foaming hydrophobic polyurethane resin using an injection method – refer to Clause 7.

5.3 Inspection and Testing

Undertake inspection and testing in accordance with Clause 12.

5.4 Non-Compliant Work

If non-compliant work is identified, stop work to verify the cause of failure. Once the cause of failure is identified, undertake corrective measures approved by SA Water's Representative.

The portion of the works yielding unsatisfactory results (e.g., area of a floor/wall, works completed on a particular day or by a particular crew; or using a particular batch of materials) is to be identified by additional testing.

Unless otherwise approved by SA Water's Representative, the entire portion of the works yielding unsatisfactory results or is otherwise non-compliant with this Technical Standard is to be removed and replaced in accordance with this Technical Standard.

6 Gravity Fed Resin Application

6.1 Substrate Preparation

Prepare all cracks for sealing via gravity fed low viscosity resin strictly in accordance with the manufacturer's requirements, the minimum requirements of Clause 5.1 and the following additional crack preparation requirements:

1. Either form a temporary reservoir 5 mm either side of the crack with a bead of silicon or acrylic based sealant, or foam strip, of minimum 10 mm height above the substrate; or
2. Open the crack with a diamond cutting blade to a nominal 3 mm width and minimum 10 mm depth, blow out any debris, or
3. If the rear face is accessible, seal any through cracks using an epoxy resin putty to prevent loss of resin through the crack.

HOLD POINT

6.2 Application

Mix the resin in compliance with the requirements of Clause 4.9.1.

Cracks greater than 3 mm width may require filling with oven-dried sand prior to applying the resin, consult the manufacturer's advice.

Substrate and ambient temperature are to be within the range of 5 to 35°C and in accordance with the manufacturer's recommendation.

Pour the resin into the prepared crack recess or reservoir sufficient to completely fill the crack. Top up as required until the level remains constant.

Remove reservoir sealant and excess resin once gelling occurs, leaving the surface level with the substrate.

Inspect the completed crack sealing in accordance with Clause 12.

WITNESS POINT

7 Resin Injection Application

7.1 Crack Substrate Preparation

Prepare all cracks for sealing via resin injection strictly in accordance with the manufacturer's requirements, the minimum requirements of Clause 5.1 and the following additional requirements:

1. Establish the thickness of the element for crack injection at a minimum of two locations to verify the minimum required depth of resin injection
2. Mark out the location of reinforcement along the crack so as to not damage reinforcement when drilling holes
3. Verify that the area to be drilled does not contain any embedded services
4. Use the Manufacturer's proprietary injection ports/packers/injection nipples
5. Unless otherwise demonstrated effective in the trial injection, or recommended by the manufacturer, use one of the following injection methods:
    a. Fix the injection ports along the line of the crack at a maximum 200 mm centres using an adhesive compatible with the crack sealant and ensure that the adhesive does not block the ports. Where required by the manufacturer, seal the line of the crack using a compatible adhesive. This method is suited to more slender components < 300 mm thick or shallow cracks (<50mm deep)
    b. Fix the injection ports along lines approximately parallel to the joint drilled at a 45 degree angle to intersect the joint at the required depth of the element, at not more than 200 mm alternate centres. Spacing of holes is not to exceed the manufacturer's recommendations. Do not drill holes to a depth greater than 66% of the element thickness. Drill 50 mm deep observation holes along the crack at nominally 250 mm centres to enable assessment of the progress of crack filling. If required seal the face of the crack. This method is suited to thicker components > 300 mm thick and deeper. A typical example of this injection method is shown in Appendix B
    c. If access is available both sides of the crack, fix injection ports to both sides of the crack placed in a staggered pattern at not more than 200 mm alternate centres on each face. For walls, inject each side alternately. For slabs, inject the soffit ports first.
6. Note that closer spacing might be necessary in some circumstances according to the geometry of the element and the observed behaviour of the injection resin during the injection process
7. Place delivery tubes on to the ports when the adhesive has hardened sufficiently
8. Do not commence the injection process until the injection ports are all in place and the adhesive has hardened sufficiently
9. Clean all debris out of cracks by high pressure clean compressed air, industrial vacuum cleaners or flushing with high pressure water, or combinations of these methods.

HOLD POINT

7.2 Leak Test

Depending on the structure geometry, nature of cracks, accessibility, and injection method, check the watertightness and suitability of the injection hole pattern by closing all ports, and hold a suitable water pressure for 3 minutes and monitor to ensure the pressure is held.

Core additional holes and insert additional injection packers or undertake crack surface sealing as required. Allow sealants to cure and re-test the crack's ability to hold the water as part of the test injection process. Repeat until the crack base is sealed.

Allow the cracks and crack zones to dry for a minimum 24 hours.

Undertake ongoing monitoring of sealing performance through re-inspections at 28 days and 6 months to ensure the intended sealing performance is achieved.

7.3 Inhibitor Flushing - Cracks Subject to Chloride

Flush cracks to be injected that have been subject to leakage of saline water, and are not subject to concrete repair as follows:

1. Blow cracks free of excess water with compressed air, allow to dry overnight, and in accordance with the corrosion inhibitor material manufacturer recommendations before corrosion inhibitor application
2. Do not undertake corrosion inhibitor injection works if rain is falling or is forecast for that day
3. Use the injection packers to totally fill the crack with migrating corrosion inhibitor solution using a "leap frog" method, i.e., inject from port 1, close off port 2 once solution appears, continue injection until solution appears at port 3, close port 1 and continue injection from port 3, etc.
4. For horizontal cracks start at one end of the crack and progress to the other end
5. For vertical cracks, start at the lowest part of the crack and progress to the top
6. Wait for minimum 12 hours and repeat crack filling with additional migrating corrosion inhibitor solution
7. Wait for minimum 36 hours and drain/flush the crack with water to remove excess inhibitor solution
8. Undertake resin injection immediately after the final water flushing
9. Use water to clean excess inhibitor from the concrete surface
10. Record the volume of inhibitor used for each crack.

7.4 Resin Application

Ensure that the resin type and mix including any accelerator and the pump equipment is suited to the water leakage rate and crack width at the time of injection.

Note that a hydrophobic resin can be effective for injecting into larger cracks (medium to fracture) when a high rate of water ingress/egress is experienced and hydrophilic resins can be effective for slower water movement, for tighter cracks (fine to fracture) and for secondary sealing of cracks/joints.

Use a proprietary pressurised system recommended by the manufacturer.

Place delivery tubes on to the ports when the adhesive has hardened sufficiently.

Commence the injection process when the adhesive has hardened sufficiently and immediately following material mixing.

If recommended by the Manufacturer, water flush the crack immediately prior to resin injection.

Mix the resin in compliance with the requirements of Clause 4.9.1.

Treat each crack in a continuous operation that completely fills the crack.

Commence the injection at one end of the crack (i.e., the lowest port on vertical cracks).

Inject the resin until the required pressure has been achieved or the resin exudes from the next injection port, or inspection port, cap the port. Hold the pressure for the Manufacturer's recommended time period, nominally 5 minutes, to all total penetration and close the port before releasing the pressure and proceeding to the next port.

If port to port travel is not observed, cease injection immediately and notify SA Water's Representative.

On completion of injection into all ports along a crack, re-inject all injection ports to ensure a complete infill (top-up). Commence 'topping-up' from the first port injected along a crack.

Inspect the injected concrete on the next day. Additional injections may be required if not properly sealed with the first injection repair, repeat process as required until the crack is sealed and/or no water leakage occurs.

WITNESS POINT

Once the resin has fully cured, nominally after 24 hours, remove all injection ports and remove excess adhesive along the crack to achieve a clean, smooth, flat surface suitable for application of a protective coating if required.

Grind away any excess material from all surfaces along the joint to achieve a clean, smooth, flat surface.

Inspect the completed injection in accordance with Clause 12.

8 Rout and Fill using Hydrophilic Crystalline Waterproof Mortar Application

8.1 Substrate Preparation

Prepare all cracks for sealing via routing and hydrophilic crystalline waterproof cementitious repair system application in accordance with TS 0711.1 Clause 5, modified as follows:

1. If required, plug any active leaks in accordance with TS 0711.1 Clause 13.2, applying the waterproof mortar to a nominal 15 mm depth
2. Drill out each end of the crack using a 25 mm diameter masonry drill to a minimum 40 mm depth
3. Cut along the full length of the crack with a diamond cutting blade and chase it out to form a dovetailed shaped rout of dimensions minimum 25 mm width and 40 mm depth
4. Do not from a V shape
5. No requirement to test bond strength of the substrate.

HOLD POINT

8.2 Application

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

Apply the waterproof repair system in general accordance with TS 0711.1 Clause 13, modified as follows:

1. If not already applied as part of sealing active leaks in TS 0711.1 Clause 13.2, apply the waterproof mortar at a putty like consistency to the base of the routed crack or joint to a nominal 15 mm thickness, ensuring it is well compacted and smooth
2. Apply by brush a slurry mix of "concentrated" hydrophilic crystalline cementitious material to the base of the rout to minimum 1.25 mm thickness
3. Mix "concentrated" hydrophilic crystalline cementitious material as a dry pack and whilst the slurry coat is still tacky, apply to the base of the rout to 15 mm thickness, and compact using the hammer and block method to provide a dense material without cracks or indents. Spray water as a fine mist to the dry packed material
4. Apply by trowel the waterproof mortar at a putty like consistency to fill the routed crack, compact and finish flush with the concrete surface, removing any excess material and allow to set
5. Brush apply a slurry mix of "concentrated" hydrophilic crystalline cementitious material to coat the rout and the joint 50 mm each side of the rout to minimum 1.25 mm thickness
6. 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 their recommendation
7. 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
8. Inspect the completed work in accordance with Clause 12.3.

WITNESS POINT

9 Rout and Sealant Application

9.1 Substrate Preparation

Prepare all cracks for sealing via routing and sealant application strictly in accordance with the manufacturer's requirements and the following minimum requirements.

1. Cut along the line of the crack with a diamond cutting blade to form a joint profile complying with the requirements of TS 0711.2 Clause 5.2
2. Ensure all surfaces for sealant application meet the requirements of TS 0711.2 Clause 5.2.

HOLD POINT

9.2 Application

Apply the sealant in accordance with TS 0711.2 Clause 5 and the following requirements:

1. Clean and prime the sides of the formed joint as required
2. Apply a backing material or bond breaker tape across the crack at the bottom of the formed joint
3. Apply and tool the sealant
4. Inspect the completed sealant.

WITNESS POINT

10 Crack Bandaging Application

10.1 Substrate Preparation

Prepare all substrate for sealing via crack banding strictly in accordance with the manufacturer's requirements and the following minimum requirements:

1. Ensure all surfaces for the crack bandage application are clean and free from: oil, grease, standing water, sand, debris, organic matter
2. Remove any loose material and laitance back to a sound, open textured and clean concrete substrate
3. Achieve a rough surface profile (CSP 3 to 5) by standard mechanical abrasive blasting methods
4. Repair any surface defects such as voids or blowholes (refer to TS 0711.1)
5. Ensure the substrate is dry
6. Remove all loose particles and dust using a vacuum method.

HOLD POINT

10.2 Application

Apply masking tape to the concrete surface along the outer edge of where the crack bandage is to be placed.

Mix the adhesive in compliance with the requirements of Clause 4.9.1.

Apply the adhesive evenly across the crack to a thickness of 1 to 2 mm, to a width aligning with the crack bandage width and minimum of 40 mm either side of the crack.

Clean any dirt off the bandage material using a clean dry or damp cloth and ensure the tape is not damaged. Do not use solvents to clean the bandage material.

Apply the crack bandage material across the crack aligning the centreline of both.

Press firmly on the crack bandage using a roller tool to ensure pressure is evenly applied and to remove all air bubbles.

If the system requires, apply masking tape down the centreline of the crack bandage (i.e., above the crack).

Evenly apply a layer of adhesive to the surface of the crack bandage typically 1 mm thick, ensuring complete coverage.

Whilst the adhesive is still wet, remove the centreline tape and edge masking tape.

Avoid connections of different lengths of crack bandage wherever possible. Joints are to be formed in strict accordance with the manufacturer's requirements of minimum overlap and joining method (e.g., adhesive or welding).

Undertake trials and QC tests of membrane welding in accordance with TS0711.5 Clause 9.4.

WITNESS POINT

11 Crack Stitching Application

Undertake a reinforcement cover survey to ensure that the cut chases do not damage the reinforcement.

Drill holes each side of the crack.

Grind a groove to accommodate the metal or FRP composite stitching rods.

Anchor the stitching rods into the concrete holes/grooves using a structural adhesive epoxy resin.

Workmanship and quality control for the application shall be in accordance with all relevant clauses of TS 0711.4 for near surface mounted FRP.

12 Quality Control Testing

12.1 General

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

Use qualified and experienced inspectors 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.

WITNESS POINT

SA Water or SA Water's Representative may carry out additional testing to non-compliant designated areas.

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

12.2 Cracks Repair – Quality Control Tests

The minimum testing requirements are listed in Table 5 as appropriate to the shape of the element and the test details follow.

Additional testing may be included in the submitted ITP.

Table 5: Crack Repair Quality Control Tests and Frequency

Test Required	Performed By	Procedure	Minimum Frequency of Testing
Visual inspection of sealed cracks	QC Engineer	Clause 12.3	All sealed cracks
Penetration depth and adhesion of sealed cracks	QC Engineer	Clause 12.4	All cracks sealed by gravity fed or injected resin.
Adhesion of routed and sealed cracks	QC Engineer	Clause 12.5	All routed and sealed cracks. One test for the first 30 m of crack repair, then one per 100 m crack repair provided each test is successful, otherwise every 30 m of crack repair.
Inspection of crack bandaging	QC Engineer	Clause 12.6	All bandages.
Adhesion of crack bandaging adhesive	QC Engineer	Clause 12.7	One test for the first 30 m of crack repair, then one per 100 m crack repair provided each test is successful, else every 30 m of crack repair.

12.3 Test Method - Inspection of Sealed Cracks

12.3.1 Method

Inspect the full length of sealed crack following removal of excess adhesive or resin.

Assess the extent of crack filling.

Assess for any ongoing water leakage.

Determine the integrity of the concrete surface by hammer tapping using a handheld hammer.

12.3.2 Acceptance Criteria

The applied resin sealant will be deemed to have complied with the Standard where:

1. The finished product is uniform in appearance and profile with no visible defects or deficiencies such as inadequate fill, sagging, voids, pinholes, contamination or any other defects
2. There is no gap between the resin sealant and the concrete crack edges
3. The injection of crack resin sealant has not resulted in delamination of concrete
4. There is no ongoing water leakage.

12.4 Test Method - Depth of Material Penetration

12.4.1 Method

Determine the depth of material penetration by obtaining a 50 mm diameter concrete core across the repaired crack perpendicular to the concrete surface at the rate of one core per 100 linear meters of injected crack or as instructed by SA Water's Representative.

Undertake concrete coring in accordance with TS 0711.1; Clause 5.3.3.

The location of cores is to be agreed with SA Water's Representative. Obtain cores as close to the midpoint between injection sites as practicable.

Provide cores to SA Water's Representative for inspection.

Mark on the project drawings the locations cores are extracted.

Undertake reasonable steps to ensure any embedded reinforcement of embedded structural steel work is not damaged.

Repair the core test hole in accordance with TS 0711.1.

12.4.2 Acceptance Criteria

Under the following circumstances, the applied resin sealant will be deemed to have failed to comply:

1. Where there is a gap between the sealant and the concrete crack edges
2. Where the depth of penetration does not completely fill the crack OR exceed $^2/_3$ of the wall/element thickness, whichever is the greater
3. Where the injection of resin has resulted in delamination of concrete.

Where the depth of penetration of a test does not completely fill the crack OR exceed 2/3 of the wall thickness, undertake further testing at additional sites to demonstrate compliance to the satisfaction of SA Water's Representative.

In the case of criteria 1 or 2, repeat the crack sealing process. In the case of criteria 3, repair the damaged area in accordance with TS 0711.1.

12.5 Test Method – Adhesion of Routed and Sealed Cracks

12.5.1 Method

Undertake in-situ (field) adhesion testing in accordance with TS 0711.2 Clause 6.5.1.

One test for the first 30 m of crack repair, then one per 100 m crack repair provided each test is successful, else every 30 m of crack repair.

12.5.2 Acceptance Criteria

Sealants not evidencing adhesive failure from testing, in absence of other indications of non-compliance with requirements, are to be considered satisfactory.

12.6 Test Method – Inspection of Crack Bandaging

12.6.1 Method

Visually inspect the full length of the cured crack bandage for:

1. Bond to the surface, presence of gaps or voids etc.
2. Full envelopment of the bandage material in the bonding adhesive
3. Presence of contaminants
4. Complete removal of the centreline tape strip, leaving the bandage beneath clear of adhesive.

12.6.2 Acceptance Criteria

The finished product is to be uniform in appearance and profile with no visible defects or deficiencies likely to impede on watertightness and bond strength.

12.7 Test Method – Crack Bandage Bond Strength

12.7.1 Method

Test the adhesive bonding capacity of the prepared surface using a direct pull tensile test to ASTM C1583/C1583M, and ICRI Technical Guideline No 210.3, at a rate one test for the first 30 m of crack repair, then one per 100 m crack repair provided each test is successful, else every 30 m of crack repair.

12.7.2 Acceptance Criteria

The prepared concrete surface tensile capacity shall be greater than the minimum bond strength value in Clause 3.9.

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

A1 Schedule of Hold Points

Clause	Type	Description
3.2	Hold	Approved repair materials
3.3	Hold	Material testing
3.5	Hold	Crack injection material properties
4.8	Hold	Submission of areas for repair marked out by Constructor.
4.10	Hold	Selection of trial location
5.1, 6.1, 7.1, 8.1, 9.1, 10.1	Hold	Preparation of substrate.

A2 Schedule of Witness Points

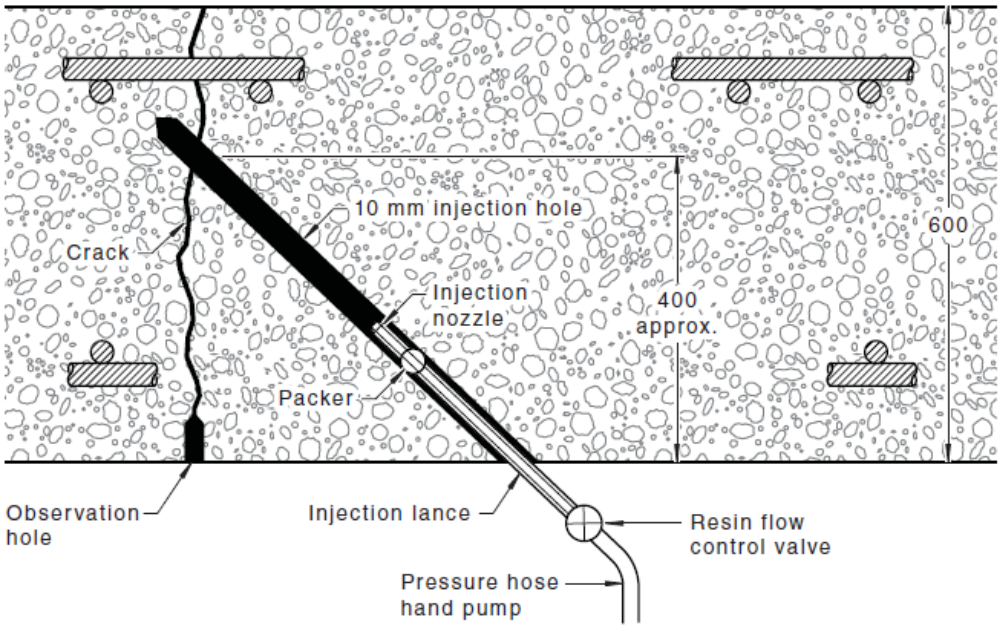
Clause	Type	Description
6.2, 0, 8.2, 9.2, 10.2	Witness	Application of crack sealing material/system
12	Witness	Inspection and testing.

A3 Schedule of Identified Records

Clause	Description of Identified Record
4.3	Constructor submission of WMS & ITP
4.10	Submission of Trial Repair Report, if trial repair is deemed necessary by SA Water.
4.8	Submission of areas for repair marked out by Constructor.
4.3	Submission of completed ITP.
4.3	Submission of the As-Repaired Report.

Appendix B : Drawings

B1 Typical Resin Injection System



DIMENSIONS IN MILLIMETRES

Source: SA HB 84

Appendix C : EN 1504.5 Classification of Crack Injection Material

EN 1504-5 classifies crack filling materials for injection into concrete using an Intended Use/Workability classification system as shown in C1.

C1 EN 1504.5 Injection Product Classification System

Intended Use Category	**Workability**			
U (refer 0)	W(1st Group)	(2nd Group)	(3rd Group)	(4th Group)
Type of Crack Repair	Crack width	Moisture state	Min/Max application temperature	Structural movement

The details for each classification sub-group are provided in the following tables.

The crack material type and category are defined in C2.

Full performance requirements are listed in the nominated EN 1504.5 Tables 6 to 8.

C2 EN 1504-5 Definition of Crack Injection Material Type

Type of Injection Material	**Use**	**EN 1504.5 Intended Use "U" Category**	**Performance Requirements**
Force transmitting filling material	Structural repair	F1, F2, F3	EN1504.5 Table 6
Ductile filling material – flexible to accommodate movement	Seal dynamic crack	D	EN1504.5 Table 7
Swelling filling material – swells repeatedly by water adsorption in the reacted state to waterproof cracks under damp, wet and water flow conditions	Seal leaking crack	S	EN1504.5 Table 8
Binder hardens by curing of a reactive polymer (Polymer)	Resin crack injection	P	-
Hydraulic binder hardens by hydration reaction with water (Cement)	Ultrafine cementitious grout	H	-

C3 Intended Use "U" Categories

Intended Use Category "U"	Binder Category	EN 1504.5 Key Performance Criteria
F1	P- Polymer H - Cement	Adhesion by Tensile Bond Strength ≥3.0 MPa (Min 2.5 MPa) (cohesive failure in concrete if ≤3.5 MPa)
F2	P- Polymer H - Cement	Adhesion by Tensile Bond Strength ≥2.0 MPa (Min 1.5 MPa) (cohesive failure in concrete if ≤3.5 MPa)
F3	H - Cement	Adhesion by Tensile Bond Strength Declared Value Compressive strength > 20 MPa after 7 days (H). (Products intended to fill voids and interstices only)
D	P- Polymer	Elongation >10% to EN 12618-1 Watertight at 2 x 10^5 Pa to EN 14068 Viscosity – manufacturer declared value
S	P- Polymer	Watertight at 2 x 10^5 Pa to modified EN 14068 Viscosity ≤60 mPa-s to EN ISO 3219

The minimum crack width that a product is able to be injected into, as defined by the Manufacturer, is defined in C4 , noting the maximum crack width is not defined.

C4 Workability 1st Group: Minimum Injectable Crack Width

Minimum injectable crack width (mm)	W (workability) 1st Group Number
0.1	1
0.2	2
0.3	3
0.5	5
0.8	8

The Workability second group is the crack moisture state at the time of injection is defined in C5, all applicable moisture states to be specified.

C5 Workability 2nd Group: Definition of Crack Moisture State

Moisture state of crack	Definition	W (workability) 2nd Group Number
Dry	Colour of the crack and dry surface concrete is the same	1
Damp	Difference of colour between the crack surface and the dry surface concrete	2
Wet	Water drops present on the crack surface	3
Flowing water	Water that flows through the crack, voids or interstices	4

The Workability third group is the manufacturer's recommended minimum and maximum temperature for the product's use.

The Workability fourth group number only applies to F category force transmitting filling materials, as set out in C6.

C6 Workability 4th Group: Daily Movement During Binder Curing

Minimum injectable crack width (mm)	W (workability) 4th Group Number
Cracks subject to daily movements higher than 10 % or 0.03 mm, during curing	1
Cracks without daily movements or lower than 10 % or 0.03 mm, during curing	0