

IMPLEMENTATION SPECIFICATION FOR ROAD **WORKS**

SERIES IM/5700 (IMPLEMENTATION)

ROAD PAVEMENTS – CONCRETE REPAIRS



*This Specification Series implements the requirements in
Subsidiary Legislation 499.57, Part II (New Roads and Road
Works Regulations) in accordance with the Agency for
Infrastructure Malta ACT XXVIII, CAP. 588, Part I*

Date: February 2021

Version: v1.0

5700	CONCRETE REPAIRS	6
5701	CONCRETE REPAIR – INTRODUCTION	6
	Specification of Concrete Repairs	6
	Aspects Excluded from the Specification	6
	Scope of Concrete Repair Methods	6
	MSA EN 1504 Terms and Definitions	6
5702	CONCRETE REPAIR WORK – GENERAL REQUIREMENTS	6
	MSA EN 1504 Part 9 Methods of Repair	6
	Quality Management	7
	Technical Approval	7
	Safe Working Certification	7
	Protection of Vulnerable Elements	7
	Method Statements	7
5703	PRODUCTS AND SYSTEMS FOR REPAIR OF CONCRETE STRUCTURES – GENERAL.....	8
	Assessment and Verification of Consistency of Performance	8
	Suitability of Construction Products.....	8
	Repair Product Statement	8
	Product Declaration of Performance	9
5704	MSA EN 1504 PART 3 PRODUCTS FOR CONCRETE REPAIR	9
5705	SUPPLY AND STORAGE OF PROPRIETARY REPAIR PRODUCTS AND OTHER MATERIALS	11
	Supply Data	11
	Marking and Labelling of Products	11
	Storage	12
5706	CONTRACTOR INVESTIGATION	12
	Contractor Investigation and Reporting	12
5707	PRE-CONSTRUCTION CONCRETE REPAIR EXECUTION TRIALS	12
	Trial of Contractor's Proposed Method of Repair	12
5708	QUALITY CONTROL OF REPAIR WORK	12
	Routine Testing by the Contractor	12
	Identity Testing by the Overseeing Organisation – Immediately before and/or during Placement of Material	13
	Samples for Testing of Concrete Consistency	13
	Making of Cube Specimens for Testing of Compressive Strength.....	13
	Other Samples	13
5709	CONCRETE REMOVAL	14

	General	14
	Pre-Breakout Survey (Contractor)	14
	Procedure for Concrete Removal	15
	Sequencing of Concrete Removal	15
	Particular Requirements of Concrete Removal	15
	Post-Breakout Substrate Inspection	15
	Methods of Removing Defective Concrete	16
	General	16
	High Pressure Water Jetting.....	16
	Manual or Mechanical Breakout	16
	Disposal of Waste	17
5710	SUBSTRATE PREPARATION	17
5711	REINFORCEMENT	18
	Treatment of Existing Reinforcement	18
	Additional or Replacement Reinforcing Bars.....	18
	Reinforcement Dowels	18
	Reinforcement Couplers	19
	Splicing Replacement or Additional Reinforcing Bars	19
	Anchoring of Reinforcing Bars and Dowels	19
5712	GALVANIC ANODES FOR CONTROL OF INCIPIENT ANODE EFFECT	20
	General	20
	Performance Requirements.....	20
	Acceptance of Products.....	21
	Contractor Design.....	21
	Products and Materials	21
	Galvanic Anodes.....	21
	Reference Electrodes	22
	Installation of Galvanic Anodes and Reference Electrodes	22
	Cathodic Protection Operatives.....	22
	Electrical Continuity of Reinforcement	22
	Electrical Potential Survey	22
	Fitting of Anodes and Electrodes.....	23
	Electrical Connection with Reinforcement	23
	Junction Boxes	23
	Particular Requirements for Type 1A Galvanic Anodes	24
	Particular Requirements for Type 1B Galvanic Anodes	24

	Particular Requirements for Reference Electrodes	24
	Record of Survey and Installation.....	24
5713	FALSEWORK AND FORMWORK.....	25
5714	SITE MIXING, PLACING, FINISHING AND CURING	25
	General	25
	Mixing	25
	Placing and Compaction of Repair Material	26
	Measuring Ambient Conditions and Limiting Conditions for Placement.....	26
	Construction Joints	27
	Surface Profile and Finish	27
	Protection of a Completed Repair	27
	Curing of a Completed Repair	27
5715	FLOWABLE CONCRETE OR MORTAR.....	28
5716	REPAIR CONCRETE OR MORTAR	28
	Treatment of Areas with Low Cover to Reinforcement.....	29
5717	SPRAYED CONCRETE OR MORTAR	29
	General Requirements	29
	Compressive Strength	29
	Consistence.....	29
	Pre-Construction Quality Control.....	30
	Procedure Trials – Construction of Test Panels.....	30
	Samples to be Removed from Test Panels	31
	Sampling, Inspection and Testing of Concrete Samples from Panels	31
	Test Result Acceptability Criteria.....	33
	Test Results Report.....	33
	Quality Control – Assessment of Conformity.....	33
	Production Control.....	33
	Execution of Sprayed Concrete.....	34
	Construction Joints	34
	Curing	34
	Surface Finishes	34
	Surface Profile	34
	Contract Compliance Tests for Completed Repairs	34
5718	REPAIRS TO STRUCTURES TO RECEIVE IMPRESSED CURRENT CATHODIC PROTECTION	35
	General	35
	Removal of Detrimental Objects and Old Repairs.....	35

	Treatment of Areas with Low Cover to Reinforcement.....	35
	Treatment of Steel Reinforcement.....	35
	Testing of Completed Repairs	36
5719	REPAIRS TO STRUCTURES USING GALVANIC ANODES FOR CONTROL OF INCIPIENT ANODE EFFECT	36
	General	36
	Testing of Completed Repairs.....	36
5720	CONCRETE INJECTION	36
	Introduction	36
	General Requirements	37
	Requirements for MSA EN 1504 Part 5 Products for Concrete Injection.....	37
	Inspection to Identify Cracks for Treatment.....	39
	Quality Control Tests	39
	Preparation of Cracks.....	39
	Execution of Concrete Injection.....	39
	Contract Compliance Tests on Completed Repairs	40
5721	CONTRACT COMPLIANCE TESTING ON COMPLETED REPAIRS	40
	General	40
	Repair Sounding – Integrity of Repair	40
	Conductivity of Repair – Electrical Resistivity Measurement	40
	Cores – General	40
	Cores – Integrity of Repair.....	41
	Cores – Adhesion to Substrate.....	41
	Cores – Compressive Strength	41
	Cores – Injection/Filling of Cracks	41
	Electrical resistivity of repairs	42
	Inspection of Bores.....	42
	Repair Integrity	42
	Adhesion to Substrate	42
	Compressive Strength	42
	Filling or Injecting of Cracks	42
	Reporting of Observations, Measurements and Test Results.....	43
	Repair Completion and Reinstatement of Cores.....	43

5700 CONCRETE REPAIRS

5701 Concrete Repair – Introduction

Specification of Concrete Repairs

- 1 This Series is part of the Specification for Highway Works. Whilst this Series is particularly relevant to the subject matter in its title, it shall be read in conjunction with the general requirements in Series 000 and 100 and with all other Series relevant to the specification for the particular works to be undertaken.
- 2 This Series gives requirements for rehabilitation, repair or partial reconstruction of existing highway structures, and open drainage channels that are wholly or partially constructed of reinforced, pre-stressed, post-tensioned or plain concrete.

Aspects Excluded from the Specification

- 3 Surface protection systems for concrete and structural bonding are not covered by this Series.
- 4 Designed mix sprayed concrete and designed mix flowable concrete for repair are not covered by this Series.
- 5 Repairs to concrete pavements are not covered by this Series.
- 6 Lightweight repair concretes and mortars are not covered by this Series.

Scope of Concrete Repair Methods

- 7 This Series covers the application of MSA EN 1504 Part 9, Table 1 repair methods 1.5, 3.1, 3.2, 3.3, 4.1, 4.2, 4.4, 4.5, 4.6, 5.3, 6.3, 7.1, 7.2, 10.1 and 11.1.

MSA EN 1504 Terms and Definitions

- 8 Terms and definitions applicable to this Series are given in MSA EN 1504 Parts 1, 3, 5, 6, 7, 8, 9 and 10.

5702 Concrete Repair Work – General Requirements

MSA EN 1504 Part 9 Methods of Repair

- 1 The repair methods listed in MSA EN 1504 Part 9, Table 1 required for each construction activity and each structural element to be repaired shall be as stated in contract specific Appendix 57/1 for concrete repairs, and contract specific Appendix 57/5 for concrete injection. The specified MSA EN 1504 Part 9 methods of concrete repair shall be executed in accordance with this Series and MSA EN 1504 Part 10, Section 5 General Requirements.

Quality Management

- 2 Concrete repair work shall be undertaken by organisations operating a quality management system as required in sub-Clause 104.5 which includes processes and procedures for concrete repair work required for the works within its scope.

Technical Approval

- 3 Where temporary works associated with concrete repairs are required, or where removal of concrete may affect the strength of a structure, technical approval procedures specified in Clause 106 shall be followed. The Contractor shall comply with particular requirements including site specific constraints stated in contract specific Appendix 1/11. Work shall not commence until design and check certification has been accepted by the Overseeing Organisation.

Safe Working Certification

- 4 The Contractor shall supply to the Overseeing Organisation copies of permit to load certification for temporary supports and temporary access platforms before commencing concrete repair work. The certification shall confirm that temporary supports and temporary access structures are safe for their intended use.

Protection of Vulnerable Elements

- 5 All cabling, suspended drainage, ducts, adjacent structural steelwork, structural bearings, electrical boxes and any other parts of the existing structure including existing cathodic protection systems, shall be protected against damage during the concrete repair work.

Method Statements

- 6 The Contractor shall submit detailed construction method statements as described in contract specific Appendix 1/24.
- 7 Detailed construction method statements shall comply with the constraints listed in contract specific Appendices 1/13 and 57/3 and also include at least the following:
- a) Erection, maintenance and removal of temporary access and protection work;
 - b) Removal of defective concrete, preparation of substrate, treatment of reinforcement;
 - c) Technical data sheets and COSHH sheets for repair products and other proprietary products proposed for the permanent works;
 - d) Disposal of arisings e.g. hazardous materials, water, concrete;
 - e) Erection, maintenance and removal of formwork;
 - f) Application of repair products and other proprietary products;
 - g) Curing and protection of repairs; and,
 - h) Testing for contract compliance.

5703 Products and Systems for Repair of Concrete Structures – General

Assessment and Verification of Consistency of Performance

- 1 The system of Assessment and Verification of Consistency of Performance (or Attestation of Conformity) for all Products or Systems used for concrete repair work shall be 2+ in accordance with Annex ZA.2 of MSA EN 1504 Parts 3, 5, 6 or 7.

Suitability of Construction Products

- 2 The Contractor shall select construction products that are suitable for their intended use. The selected products shall satisfy the following requirements:
 - a) Clause 5704 for concrete repair, and contract specific Appendix 57/1 for the class of repair product required;
 - b) Clause 5711 and contract specific Appendix 57/2 for reinforcement corrosion protection and anchoring of reinforcing steel bar;
 - c) Clause 5720 for concrete injection, and contract specific Appendix 57/5, for the function of injection product required.
- 3 When selecting repair products associated with cathodic protection, the Contractor shall comply with the performance required of completed repairs, the restrictions specified in Clauses 5718 and 5719, and take account of the published recommendations of the Corrosion Prevention Association for the following applications:
 - a) concrete repairs incorporating galvanic anodes tied to reinforcement within a repair patch;
 - b) concrete repairs executed before and located beneath impressed current anode embedded within a cementitious layer to be installed later, or as required by contract specific Appendix 57/3.

Repair Product Statement

- 4 The Contractor shall prepare and submit a statement to the Overseeing Organisation, including a list of proposed repair products or systems, and where these will be used in the works. The repair product statement shall be submitted prior to repair work commencing on site, and no later than the period specified for construction method statements in contract specific Appendix 1/24.
- 5 The repair product statement shall include at least the following:
 - a) A general description of the required repairs, including name of structure or structures and which structural elements to be repaired, with reference to contract specific Appendix 57/1 and Appendix 57/5;
 - b) A list of construction products proposed for repair work, and the proposed application of them, including the extent and type of repair for which a product would typically be used;

- c) The Declaration of Performance for each product or system in accordance with Clause 104;
- d) The manufacturer's instructions for use, technical data sheets; and,
- e) Manufacturer's health and safety information, including COSHH data as necessary.

Product Declaration of Performance

- 6 The Declaration of Performance for each repair product shall demonstrate that it meets the specification requirements.

5704 MSA EN 1504 Part 3 Products for Concrete Repair

- 1 The performance characteristics of Products and Systems in accordance with MSA EN 1504 Part 3 shall comply with the minimum requirements stated in Table 5700-1.
- 2 The MSA EN 1504 Part 3 class or classes of repair product required for the repair work shall be as specified in contract specific Table 5700-1 for each structural element to be repaired. When no class is specified in contract specific Appendix 57/1, the required class shall be R4.
- 3 Class R1 products shall not be permitted. Class R2 products shall only be permitted for repair material types shown in Table 5700-1.
- 4 The Contractor shall comply with contract specific constraints on the location, extent or depth of application for types of repair material stated in contract specific Appendix 57/3.

Table 5700-1: Minimum Performance Requirements for MSA EN 1504 Part 3 Structural and non-Structural Repair Products and Systems

Essential characteristic	Type of repair material (see Note (i))	Level(s) or class(es)/MSA EN 1504 Part 3 requirement/contract specific		
		Class R4	Class R3	Class R2
Compressive strength (at age of 28 days)	F, N, S	≥ 45 MPa, Appendix 57/1*	≥ 25 MPa	N/A
	M, R			≥ 15 MPa
Chloride ion content	All	≤ 0.05 %		
Adhesive bond	F, N, S	≥ 2.0 MPa	≥ 1.5 MPa	N/A
	M, R			≥ 0.8 MPa
Restrained shrinkage / expansion (dimensional stability). [Not required if thermal cycling data available.] [Not required for sprayed concrete or mortar.]	F, N	≥ 2.0 MPa	≥ 1.5 MPa	N/A
	M, R			≥ 0.8 MPa
Carbonation resistance (For durability of corrosion protection or inhibition)	All	Pass	Pass	Pass
Elastic modulus	All	≥ 20 GPa	≥ 15 GPa	N/A
Thermal compatibility. Part 1, Freeze-thaw	All	≥ 2.0 MPa	≥ 1.5 MPa	≥ 0.8 MPa
Thermal compatibility. Part 2, Thunder shower [not requ'd if compliant with Pt 1]	All	≥ 2.0 MPa	≥ 1.5 MPa	≥ 0.8 MPa
Skid resistance **	F, N, M, R	Class III : > 55 units wet tested		
Coefficient of thermal expansion. [Not required if thermal compatibility testing is carried out.]	R	$8 \times 10^{-6}/K < \alpha < 12 \times 10^{-6}/K$		N/A
Capillary Absorption	All	≤ 0.5 kg m ⁻² h ^{-0.5}		
Reaction to fire	All	Appendix 57/1		
Dangerous substances	All	Comply with MSA EN 1504-3 clause 5.4		

General notes to Table 5700-1.

* Subject to higher minimum compressive strength specified in contract specific Appendix 57/1.

** Performance for skid resistance characteristic is only required for products intended to be used for concrete surfaces which will be trafficked.

- a) Codes for types of repair material are F = high flow (defined in MSA EN 1504 Part 3); M = repair mortar

(MSA EN 1504 Part 1 type CC or PCC); S = sprayed; N = normal flow (see Clause 5715); R= resin mortar

(MSA EN 1504 Part 1 type PC). Chemical classification types CC, PCC and PC are defined in MSA EN 1504 Part 1.
- b) See also Clause 5711 for required performance characteristics when reinforcement corrosion protection products and anchoring of reinforcement are specified.
- c) See also Clause 5720 for required performance characteristics when concrete injection products are specified.

5705 Supply and Storage of Proprietary Repair Products and Other Materials

Supply Data

- 1 Supply of proprietary products and other materials covered by Series shall comply with the requirements of Clauses 104 and 105.
- 2 Supply of galvanic anodes and reference electrodes shall also be accompanied by a certificate of conformity affirming that the product and any associated system components comply with Clause 5712.

Marking and Labelling of Products

- 3 Marking and labelling on individual containers of repair product shall comply with Clause 6 of MSA EN 1504 Part 8. Bulk consignments of repair product delivered to site shall be accompanied by written confirmation of the information indicated in Clause 6 of MSA EN 1504 Part 8.
- 4 The following information shall also be supplied for cement-based/cementitious products if not indicated elsewhere:
 - a) Quantity of water to be added for the various applications.
- 5 All product container markings shall be examined upon delivery to site to ensure the contents are within the manufacturer's stated use-by dates, and that they will continue to be useable during the works.
- 6 Galvanic anodes and reference electrodes shall be marked with a manufacturer's unique product identifier.

Storage

- 7 Repair products and other materials shall be stored on site in a controlled environment in accordance with the manufacturer's instructions, and where applicable MSA EN 1504 Part 10.

5706 Contractor Investigation

Contractor Investigation and Reporting

- 1 The Contractor shall investigate the condition of existing concrete, at the locations and to the extent described in contract specific Appendix 57/6.
- 2 Where a concrete investigation is required, the Contractor shall supply the Overseeing Organisation with a copy of a report on concrete condition for each structure, the format and contents of the report shall comply with the Overseeing Organisation's specific requirements which may refer to CS 462 'Repair and Management of Deteriorated Concrete Highway Structures' (DMRB). The report may be subdivided to reflect phases of investigation.
- 3 The report shall be submitted to the Overseeing Organisation at least to the period specified in contract specific Appendix 1/13 before commencement of concrete removal or repair work for each phase of investigation.
- 4 If no period is specified, the following shall apply:
 - a) 2 working days for investigation of a single or multi-span bridge deck, up to 60m in length between abutment bearings;
 - b) 5 working days for investigation of a multi-span bridge deck, 60m or more in length.

5707 Pre-Construction Concrete Repair Execution Trials

Trial of Contractor's Proposed Method of Repair

- 1 Where required in contract specific Appendix 57/3, a trial of the Contractor's proposed method of executing repairs shall be undertaken to the requirements described in contract specific Appendix 57/3.
- 2 The Contractor shall give the Overseeing Organisation at least 2 days notice of executing the trial and provide access for witnessing the trial and later inspection of the completed trial repair.

5708 Quality Control of Repair Work

Routine Testing by the Contractor

- 1 The Contractor shall carry out routine sampling and testing of fresh repair material and routine testing of hardened repair material in accordance with contract specific Appendix 1/5.

- 2 Quality control of concrete repair work shall be undertaken by the Contractor in accordance with Table 5 of MSA EN 1504 Part 10.
- 3 Routine testing or observation of the characteristics of substrate conditions, and measurement of ambient weather conditions and precipitation shall comprise the observations marked “for all intended uses” in Table 5 of MSA EN 1504 Part 10 for the relevant repair methods specified in contract specific Appendix 57/1, and in accordance with contract specific Appendix 1/5.
- 4 Records of the method used and results of all routine observations, measurements, sampling and testing shall be prepared and kept by the Contractor. Copies of these shall be made available to the Overseeing Organisation upon request.

Identity Testing by the Overseeing Organisation – Immediately before and/or during Placement of Material

Samples for Testing of Concrete Consistency

- 5 Where required in contract specific Appendix 1/6, the Contractor shall provide samples of fresh repair material for independent testing of flowability and/or air content.

Making of Cube Specimens for Testing of Compressive Strength

- 6 Where required by contract specific Appendix 1/6, the Contractor shall make cube specimens for monitoring strength gain of repair concrete or mortar and supply them to the Overseeing Organisation for testing. The cube specimens shall be made by the Contractor as described below.
- 7 Cube specimens for repair concrete shall consist of a minimum of six 100mm cubes made in accordance with MSA EN 12390-1 and MSA EN 12390-2. Flowable mixes shall not be compacted in the cube moulds. Cube specimens for repair mortar shall consist of a minimum of six 40mm cubes made in accordance with MSA EN 12190. Cube specimens of repair concrete and mortar shall be cured for 24 hours in the moulds with the top surfaces covered by polythene sheets. After 24 hours the specimens shall be stripped and placed in sealed polythene bags adjacent to repaired areas for a further 48 hours. The specimens shall then be removed from the bags and continue to be stored alongside repaired areas at ambient temperatures until required for testing.

Other Samples

- 8 Samples of repair products and other materials shall be provided to the Overseeing Organisation as required in contract specific Appendix 1/6.

5709 Concrete Removal

General

- 1 The extent of existing concrete to be removed, area and depth, shall be as shown on the contract drawings or described in contract specific Appendix 57/3.
- 2 Concrete shall be removed in accordance with the general methods given in MSA EN 1504 Part 10 and the particular requirements stated in this clause.
- 3 Protection measures shall be designed and installed to avoid damage to areas of the structure or structural elements outside the repair area, and to avoid damage to reinforcement within the repair area. Requirements for protective measures shall be as given in contract specific Appendix 57/3.
- 4 Concrete removal shall not commence until technical approval procedures in accordance with Clause 5702 are complete, temporary supports associated with it are fully in place, loading has been transferred and a copy of permit to load certification for temporary supports and temporary access platforms has been supplied to the Overseeing Organisation.
- 5 Temporary support systems shall be maintained in place in accordance with MSA EN 1504 Part 10 to ensure safety and structural stability until repairs have achieved the full-strength class required by the specification, or any minimum interim strength specified in contract specific Appendix 57/3.
- 6 The Contractor shall comply with any special requirements listed in contract specific Appendix 1/23 for handling, disposal or monitoring of hazardous materials that are known or suspected to be present in structural elements.
- 7 Work areas including the working platform, shall be kept clean and free of any standing water and concrete debris arising from concrete removal activities.

Pre-Breakout Survey (Contractor)

- 8 Prior to the repair works commencing, the current extent of concrete delamination in all exposed structural elements specified for repair, shall be identified and marked by the Contractor using a hammer-sounding survey, MSA EN 1504 Part 10, Table 5, Test No. 1. Where specified in contract specific Appendix 57/3, old repairs exceeding the acceptable limits of electrical resistivity, and detrimental metal objects as defined in Clause 5718, shall be identified, and marked.
- 9 The Overseeing Organisation shall be notified at least 2 working days in advance of the pre-breakout survey and be given the opportunity to be present during the survey. If the pre-breakout survey identifies significantly increased areas of existing concrete to be removed, details shall be referred to the Overseeing Organisation.

Procedure for Concrete Removal

- 10 Repair of concrete shall be undertaken in accordance with general procedures stated in contract specific Appendix 57/3, including any hold points for inspection and certification by the Contractor or the Overseeing Organisation.
- 11 Principles to be followed for treatment of superficial defects on the surface of unformed concrete e.g. bridge decks shall be as stated in contract specific Appendix 57/3.

Sequencing of Concrete Removal

- 12 Removal of concrete in stages shall be undertaken in accordance with sequencing restrictions indicated on the drawings or specified in contract specific Appendix 57/3.
- Where stages of repair are specified, the second and subsequent stages of repair in a restricted sequence shall not be commenced until the previously repaired concrete has gained the minimum strength specified in contract specific Appendix 57/3, and adequate integrity of the newly completed repairs have been confirmed by concrete sounding (hammer tapping).
- When not stated in contract specific Appendix 57/3, the required minimum strength shall be the characteristic compressive strength of the MSA EN 1504 Part 3 Strength Class as required by contract specific Appendix 57/1.

Particular Requirements of Concrete Removal

- 13 Existing concrete to be retained adjacent to, or beneath the specified repair areas shall not be damaged, except when existing reinforcement is corroded at the perimeter of the specified breakout area, when further concrete shall be removed until a continuous length of not less than 100mm of un-corroded bar is exposed. The limit of allowable corrosion is defined by rust grade A in MSA EN ISO 8501 Part 1.
- 14 Existing steel reinforcement being retained in the works shall not be damaged during removal of concrete, or prior to concrete reinstatement.
- 15 The edges of each repair patch shall be trimmed back to a regular shape comprising straight lines, e.g. a square, rectangular or rectilinear polygon. The perimeter of each repair area shall be prepared to prevent feather edging or overbreak. Concrete shall be removed at the perimeter to a depth of 15mm or more, but no closer to the existing reinforcement than 10mm.
- 16 Defective concrete shall be removed to the specified depth. No significant localised peaks shall remain in the substrate, and the concrete shall be removed to an accuracy of between + 5mm, profile peak to - 15mm, profile trough.

Post-Breakout Substrate Inspection

- 17 When defective concrete has been removed in a repair area to the depth and extent required by the specification, the entire substrate in the repair area shall be hammer sounded in accordance with MSA EN 1504 Part 10, Table 5, Test No. 1.

Where there are additional areas of hollow sounding or loose concrete beneath the substrate, they shall be marked out. The Overseeing Organisation shall be informed of additional defects, and at least 2 working days' notice of an intention to proceed to the next stage of repair.

Unless instructed otherwise by the Overseeing Organisation, hollow or loose concrete beneath the substrate shall be treated by removal of defective concrete and replacement with repair products complying with Clause 5704.

Methods of Removing Defective Concrete

General

- 18 The following methods of concrete removal are permitted except when working around and adjacent to tensioned structural components, as described in sub-Clause 5709.19:
- a) high-pressure or ultra-high-pressure water jetting (hydro-demolition);
 - b) lightweight electric or lightweight pneumatic demolition breaker (mechanical breakout);
 - c) Hand tools (manual breakout).
- 19 Concrete around pre-stressing strand and post-tensioning tendons and anchorages shall be removed by high-pressure water jetting. A lightweight electric demolition hammer or hand tools may be used for final trimming of the area broken out. Removal of concrete around tensioned strand and strand anchorages shall comply with specified sequencing stated in contract specific Appendix 57/3.

High Pressure Water Jetting

- 20 The Contractor shall provide written evidence to the Overseeing Organisation demonstrating that:
- a) proposed operatives are appropriately trained and qualified to undertake hydro-demolition, and have recent experience of removing concrete using high pressure water jetting; and,
 - b) a suitable and sufficient risk assessment of the concrete removal has been completed, and there is a safe system of work in place.
- 21 Water used for high pressure water jetting shall not contaminate the repair surface, and the water shall be clean, fresh, and potable complying with MSA EN 1008. The Contractor shall not add anti-freeze or any other chemical to water used for water jetting.

Manual or Mechanical Breakout

- 22 The Contractor shall provide the Overseeing Organisation with written evidence of suitable qualifications, training and experience of operatives proposed for this activity prior to commencing concrete breakout.

Disposal of Waste

- 23 Solid waste material removed from the structure shall not be reused for repairing the existing concrete.

Water arising from high pressure water jetting operations shall be assumed to be contaminated. It shall be collected and contained near the working area and processed in a manner which ensures that pollution of the environment does not occur.

The contaminated water must not be allowed to drain away into the ground, surface water sewers (including highway drains), hidden voids in the existing structure, watercourses or the sea. Disposal of contaminated water shall be in accordance with relevant waste management legislation and regulations.

The Contractor shall consult with appropriate environmental authorities and make and keep records of consultations, agreement and permissions relating to disposal of solid and liquid arisings from high pressure water jetting activities. Copies of these records shall be supplied to the Overseeing Organisation when requested.

5710 Substrate Preparation

- 1 The existing concrete substrate within a repair area, including any smooth cut edges round the perimeter, shall be prepared in accordance with the repair product manufacturer's instructions, or if this is not given to concrete surface profile grade CSP6 or higher in accordance with Technical Guideline 310.2R (formerly no. 03732). Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, Polymer Overlays and Concrete Repair, published by the International Concrete Repair Institute (ICRI).
- 2 Where there is a risk that the profile of the prepared concrete substrate at the formwork could allow air to be trapped during concreting, the concrete substrate for soffit breakout areas shall be additionally profiled to encourage repair material to flow freely into all voids and be continuously in contact with the existing concrete.
- 3 The concrete substrate exposed by mechanical percussive breaking in sub-Clause 5709.18 (b) and 5709.18 (c) shall be further prepared as described in sub-Clause 5710.1.
- 4 Immediately before mixing and placing repair material, the Contractor shall carry out a final hammer sounding check of the existing concrete substrate within the repair area and the existing unbroken concrete immediately surrounding the repair area to detect any remaining loose, or hollow sounding concrete which has occurred since the main concrete breakout activities. Where formwork would prevent access for this sounding check, it shall be done before formwork is installed. Any defective concrete shall be removed in accordance with Clause 5709.
- 5 The surface of the prepared concrete substrate in the repair area shall then be checked for cleanliness in accordance with MSA EN 1504 Part 10, Table 5, Test No. 2. Dust or contaminants shall be removed.
- 6 Where MSA EN 1504 Part 1 chemical type CC and PCC products are proposed, and when pre-wetting of the substrate is recommended by the manufacturer for MSA EN 1504 Part 1

PC chemical product types, the prepared substrate shall be continuously wetted with potable water for a minimum period of four hours, or some shorter wetting period recommended by the repair product manufacturer's instructions. Any surface water remaining on the concrete breakout surface or reinforcement shall be removed prior to placement of the repair material.

- 7 A bonding primer shall only be permitted for use on the prepared concrete substrate when recommended by the manufacturer's instructions. A bonding primer shall be applied strictly in accordance with manufacturer's instructions.

5711 Reinforcement

Treatment of Existing Reinforcement

- 1 The exposed steel reinforcement within the breakout area shall be cleaned of all corrosion products and contamination (e.g. chlorides) on the surface and from within pits. The whole exposed surface of each bar shall be prepared to standard Sa 2.5 in accordance with MSA EN ISO 8501 Part 1.
- 2 Immediately prior to application of the repair material, the treated surface of exposed steel reinforcement shall be clean with only light flash-rusting permitted.
- 3 Primers or barrier coatings shall not be used on the prepared reinforcement or structural steelwork except where specified in contract specific Appendix 57/2 or where shown on the drawings.

When stated in contract specific Appendix 57/2, reinforcement coating shall comply with MSA EN 1504 Part 7, and the performance requirements in Table 5700-2.

Table 5700-2: Minimum Performance Requirements of MSA EN 1504 Part 7 Products for Reinforcement

Essential characteristic	Performance requirement
Corrosion protection	Pass
Release of dangerous substances	Comply with MSA EN 1504-7, Section 5.3

Additional or Replacement Reinforcing Bars

- 4 Where existing reinforcement exposed within a breakout area is excessively corroded as defined in contract specific Appendix 57/2, the Contractor shall restore the original cross-sectional area of reinforcement lost to corrosion using new steel reinforcement bars.
- 5 Replacement reinforcement and additional reinforcement bars or mesh shall be carbon steel and comply with Clause 1712. The Contractor shall maintain on site a stock of new reinforcement comprising at least the bars or mesh detailed in contract specific Appendix 57/2.

Reinforcement Dowels

- 6 Reinforcement dowels shall be stainless steel and comply with Clause 1726.

Reinforcement Couplers

- 7 Reinforcement couplers shall be carbon steel and comply with Clause 1716, BS 8597 and requirements stated in contract specific Appendix 57/2.
Couplers shall be installed in accordance with the manufacturer's instructions.

Splicing Replacement or Additional Reinforcing Bars

- 8 Lapping and mechanical coupling of bars are permitted methods of splicing new reinforcing bars to existing reinforcing bars.
Additional or replacement reinforcement shall be positioned to achieve at least the same concrete cover as the adjacent existing bars.
New reinforcement shall be lapped in accordance with contract specific Appendix 57/2 and secured using tying wire. Existing and new bars shall be fixed at all bar intersections visible within the broken-out repair area using new tying wire. Tying wire shall be stainless or soft annealed iron wire and shall comply with Clause 1714.
- 9 New reinforcement bars shall not be fixed by welding, unless permitted in contract specific Appendix 57/2. Where permitted by the contract, welding of reinforcement shall comply with the requirements in Clause 1717, MSA EN 13670 and contract specific Appendix 57/2.
Welded joints between existing and new bars shall be deemed to be load bearing. Welding shall be carried out in accordance with MSA EN ISO 17660-1 and be subject to the demonstration of the satisfactory performance of trial joints.
Testing of welded joints shall comply with requirements specified in contract specific Appendix 1/5.
- 10 Contractor alternative proposals for welded reinforcement shall verify each joint location that the fatigue life and durability of the member will not be adversely affected by the welding proposal in accordance with Clause 6.8 of MSA EN 1992-1-1. Any proposal shall be subject to the approval of the Overseeing Organisation through its Departure from Standard process.

Anchoring of Reinforcing Bars and Dowels

- 11 Reinforcing bars and dowels anchored into existing concrete shall be fixed using an anchoring product which complies with the minimum performance requirements listed in Table 5700-3, and the requirements specified in contract specific Appendix 57/2.
Reinforcement anchoring products shall be mixed and used in accordance with the manufacturer's instructions.

Table 5700-3: Minimum Performance Requirements of MSA EN 1504 Part 6 Anchoring Products for Anchoring of Reinforcing Steel Bar Dowel

Essential Characteristic	Performance requirement (reference MSA EN 1504 Part 6, Table 3)
Pull out strength	Displacement ≤ 0.6mm at 75KN
Chloride ion content	≤ 0.05%

Glass transition temperature *	≥ 60° C
Reaction to Fire *	Contract specific Appendix 57/2
Durability/ creep under tensile load *	≤ 0.6mm after continuous loading of 50KN after 3 months
Dangerous substances	Comply with MSA EN 1504-6 Section 5.3

General note to Table 5700-3.

* Tests required for polymer-based anchoring products only. All other tests are for polymer and cementitious products.

5712 Galvanic Anodes for Control of Incipient Anode Effect

General

- 1 This Clause refers to proprietary galvanic anodes and anode systems connected to existing steel reinforcement within and immediately adjacent to the internal edge of a concrete repair. The following anode types shall be permitted:
 - a) Type 1A – tied directly to the existing reinforcement and embedded within the proposed concrete repair; and,
 - b) Type 1B – installed in holes drilled into the existing concrete substrate within the repair area and connected to the existing reinforcement.
- 2 This Clause also applies to permanent proprietary reference electrodes when monitoring of galvanic anodes is specified.
- 3 This Clause does not cover galvanic anodes installed into or onto areas of existing concrete which are contaminated by chloride or sulfate ions but otherwise intact and not affected by delamination, cracking or spalling.
- 4 This Clause covers galvanic anodes consisting of pure zinc or zinc with limited alloying additions. Proposals for galvanic anodes consisting of other types of sacrificial material shall be subject to the approval of the Overseeing Organisation through its Departure from Standard process.

Performance Requirements

- 5 A galvanic anode system using anodes of the types and for the applications permitted by this clause shall have a maintenance-free service life of at least 10 years when used to protect steel reinforcement located within existing chloride contaminated concrete, which is subjected to ambient weather conditions similar to the contract specific location.
- 6 The galvanic anode system, including the galvanic metal element, the activating agent and the backfill where needed, shall not introduce or otherwise increase a corrosion risk to the reinforcing steel throughout the service life of the system.
Chemical reaction products of a galvanic anode shall not expand and cause cracking or spalling of the concrete cover or cause any other deleterious effects.

- 7 Reference electrodes embedded in concrete shall have a declared maintenance-free service life of at least 20 years and the reference electrical potential shall remain thermodynamically stable during that time.

Acceptance of Products

- 8 Galvanic anodes and reference electrodes shall have a proven successful performance in service of at least five years on similar structures, with comparable environmental exposure. The Contractor shall demonstrate this by providing examples of installations where the proposed anode has performed satisfactorily in repair patches without evidence of corroding reinforcement within concrete adjacent to and up to 300mm away from the repair perimeter.
- 9 The Contractor shall, for each type of proposed anode or reference electrode, provide the Overseeing Organisation with evidence of the quality of the anode manufacturing process, and Appendix H, Quality Records Category C in accordance with sub-Clause 104.11. Galvanic anodes and reference electrodes shall be delivered to the site with the Category C certificates certifying conformity with Clause 5712 and provide the following additional information:
- a) manufacturer of products;
 - b) data sheet including technical specifications, and installation instructions; and,
 - c) health & safety and COSHH data.

Contractor Design

- 10 Where required by contract specific Appendix 1/10, the Contractor shall design the galvanic anode system in accordance with this Clause and contract specific Appendix 57/7.
- 11 Unless otherwise stated in contract specific Appendix 57/7, galvanic anodes used within repair patches shall be designed to protect for a minimum of 10 years, the existing reinforcement located within unrepaired concrete up to 300mm away from the repaired area.
- 12 Reference electrodes required for monitoring of the galvanic anode system shall comply with the requirements stated in contract specific Appendix 57/7.
- 13 Galvanic anodes and reference electrodes shall be compatible with each other, and all ancillary components that make up the galvanic anode system.
- 14 The designer of a galvanic anode system shall be qualified and certified to MSA EN ISO 15257 Level 4 in reinforced concrete structures.

Products and Materials

Galvanic Anodes

- 15 Galvanic anodes and anode systems shall be supplied with sufficient galvanic metal and activating agent to deliver reinforcement protection for the duration of the specified service life

of the anode system, so that further repairs to existing concrete surrounding the repair patch are not necessary during this period.

- 16 Galvanic anodes shall have a core of primary zinc, complying with Z2 grade, colour coded yellow to MSA EN 1179 Zinc and zinc alloys – Primary zinc, or Special High-Grade zinc to ASTM B418 Standard Specification for Cast and Wrought Galvanic Zinc Anodes. Alternatively, the anode shall be made from Special High-Grade zinc to ASTM B6 with suitable alloying additions conforming to the limits in ASTM B418 Table 1.
- 17 One or more corrosion resistant wires or strip shall be attached to the anode and shall extend outside of the anode unit. The wires or strip shall be long enough to form an effective electrical connection between the anode and the existing steel reinforcement.

Reference Electrodes

- 18 Reference electrodes for monitoring of a galvanic anode installation shall be permanently embedded in the concrete or shall be portable and shall comply with MSA EN ISO 12696. Reference electrodes shall comply with the requirements given in contract specific Appendix 57/7.

Installation of Galvanic Anodes and Reference Electrodes

Cathodic Protection Operatives

- 19 Cathodic Protection senior technicians supervising the installation of anodes or reference electrodes shall be qualified and certified to at least MSA EN ISO 15257 Level 3 in reinforced concrete structures.
- 20 Cathodic Protection technicians testing the anodes or reference electrodes or undertaking the electrical potential survey shall be qualified and certified to at least MSA EN ISO 15257 Level 2 in reinforced concrete structures.

Electrical Continuity of Reinforcement

- 21 Prior to installation of the galvanic anode system, electrical continuity of the steel reinforcement exposed within a broken-out area shall be tested by the Contractor at all intersections of reinforcement within the repair patch in accordance with MSA EN ISO 12696. Electrical continuity shall not be tested until reinforcement has been cleaned in accordance with Clause 5711. If electrical discontinuities are found, the reinforcement intersections shall be continuity bonded in accordance with MSA EN ISO 12696 prior to applying repair material. Tying wire used to restore continuity of reinforcement shall comply with Clause 1713.

Electrical Potential Survey

- 22 A survey of electrical potential shall be undertaken by the Contractor on the surface of the existing concrete outside the repair area. Survey points shall be located 250mm outside the

perimeter of the repair area, and shall be spaced 500mm apart. The electrical potential survey shall be done after removal of defective concrete, but before galvanic anodes are attached to the reinforcement. The method of survey shall comply with ASTM C876.

The electrical potential survey shall be repeated by the Contractor after completion of the repair using the same potential survey instrument with new readings taken at the same survey grid points. The repair concrete should be at least 28 days old.

Electrical potential surveys shall be undertaken by a laboratory accredited for carrying out the required tests.

Fitting of Anodes and Electrodes

- 23 Preparation and installation of galvanic anodes and reference electrodes shall comply with MSA EN ISO 12696 and product manufacturer's instructions.
- 24 The spacing of galvanic anodes shall be as specified in contract specific Appendix 57/7 or as shown on the drawings. Galvanic anodes shall be located around the perimeter and close to the edge of the broken-out repair zone.
- 25 Anode installation shall be as soon as possible following preparation and cleaning of existing steel reinforcement, but not more than 3 hours afterwards.
- 26 Each anode unit shall be electrically connected to the existing steel reinforcement inside the broken-out area using conductive wire attachments.
- 27 The anodes shall be attached to reinforcement using integral wires, strip or tying wire complying with Clause 1714, so that no free movement is possible and shall ensure good electrical continuity with the reinforcement.

Electrical Connection with Reinforcement

- 28 Electrical connection between the anode or reference electrode wire attachments and the reinforcement bar shall be confirmed by the Contractor in accordance with MSA EN ISO 12696.

Junction Boxes

- 29 Where permanent monitoring of anodes is required, junction boxes shall be provided and installed as described in contract specific Appendix 57/7.
Electrical connection from anodes to reinforcement shall be routed via a junction box. Electrical connection shall be made directly from reference electrodes to a junction box. Junction boxes for monitoring shall contain terminations for wires to permit measurement and disconnection of either individual anodes or a group of anodes as specified in contract specific Appendix 57/7.

Particular Requirements for Type 1A Galvanic Anodes

- 30 Type 1A galvanic anodes shall be fixed to the existing steel reinforcement to ensure all round contact with the reinstatement material and positioned so that concrete cover is not reduced. Where this is not possible, concrete cover from the external surface of the repair patch to the galvanic anode shall not be less than 20mm for deck repairs or 15mm for vertical and overhead repairs.
- 31 Each anode unit shall be electrically connected to the steel reinforcement at least 25mm inside the broken-out area, using conductive attachments.
- 32 Concrete repair products for repair areas which include Type 1A galvanic anodes shall comply with Clause 5719.

Particular Requirements for Type 1B Galvanic Anodes

- 33 Type 1B galvanic anodes shall be installed within pre-drilled holes and provided with a minimum concrete cover over the anode, of not be less than 20mm for deck repairs or 15mm for vertical and overhead repairs.
- 34 Type 1B galvanic anodes shall be either connected separately to the existing steel reinforcement, located within the repair area or wired together to form an anode string which is connected to the existing reinforcement to facilitate monitoring. Strings of anodes shall be connected to the reinforcement every 5th anode or more frequently.
- 35 The backfill material used for bedding and surrounding the Type 1B anodes placed within drilled holes shall be conductive, surround each anode unit and completely fill the annular void, uniformly connecting each anode with existing concrete to ensure continuous operation of the anode for the duration of the anode service life.
- The backfill material shall be purpose formulated to facilitate and maintain anode performance, accommodate anode corrosion products and resist acids generated at the anode/concrete interface during the service life of the anode.

Particular Requirements for Reference Electrodes

- 36 Permanently embedded reference electrodes shall be located within existing concrete at positions indicated on the drawings or in contract specific Appendix 57/7.
- 37 The backfill material used for bedding and surrounding reference electrodes placed within drilled holes shall be cementitious or polymer-modified cementitious and shall be conductive. The material shall surround the electrode units to completely fill the annular void, uniformly connecting the reference electrode with existing concrete and ensuring continuous operation of the electrode for the duration of the electrode service life.

Record of Survey and Installation

- 38 The Contractor shall keep records of all electrical potential surveys undertaken, and galvanic anodes, wires, monitoring junction boxes or reference electrodes installed. Results of the

electrical potential survey shall be shown on annotated drawings with the location of survey points referenced to each repair area, and the location of repair areas containing galvanic anodes referenced to the structural element. The results shall indicate the make and type of instrument used for the survey. As-built drawings shall be prepared by the Contractor and shall show the positions and type of all components. As-built record drawings shall be supplied to the Overseeing Organisation.

5713 Falsework and Formwork

- 1 Temporary falsework support or temporary formwork necessary as part of concrete repairs work shall be in accordance with Clause 106 and the constraints and details stated in contract specific Appendix 1/11.
- 2 Formwork shall comply with the requirements of Clause 1710, MSA EN 1504 Part 10 and MSA EN 13670. Formwork shall impart an F2 surface finish in accordance with Clause 1708 unless specified otherwise in contract specific Appendix 57/3.
- 3 Where there is a risk that the profile of the prepared concrete substrate at the formwork could allow air to be trapped during concreting encouraging voids to form in the hardened repair concrete, the means for venting air from these areas shall be provided within the formwork arrangement.

5714 Site Mixing, Placing, Finishing and Curing

General

- 1 Management of work quality shall be in accordance with the product manufacturer's instructions and MSA EN 1504 Part 10, MSA EN 13670 Execution Class 2, unless specified otherwise in contract specific Appendix 57/3.
Repair products shall be checked by the Contractor to ensure compliance with MSA EN 1504 before being used in the works.
A record of all products and materials incorporated into the works shall be made and kept in accordance with Clause 105.

Mixing

- 2 Only full containers of repair products shall be mixed for use. On-site proportioning shall not be permitted.
- 3 Water used for mixing with MSA EN 1504 Part 1 type CC and PCC products shall be potable and comply with MSA EN 1008.
No other materials except water shall be added to MSA EN 1504 Part 1 type CC or PCC repair products before application, unless permitted and certified by the product manufacturer.

- 4 Site mixing of all repair products shall be carried out in accordance with the requirements of the product or system manufacturer’s instructions and any relevant guidelines in MSA EN 1504 Part 10.
- 5 More water shall not be added to repair material of MSA EN 1504 Part 1 type CC and PCC products after the original mixing.

Placing and Compaction of Repair Material

- 6 Ambient conditions shall be suitable for placing repair material before commencing. Placement of repair material shall commence before the substrate dries out after pre-wetting as required in Clause 5710, and not more than one hour after completion of wetting. All repair materials shall be placed and compacted in accordance with MSA EN 1504 Part 10, MSA EN 13670 and the manufacturer’s instructions. The repair material shall be placed so it completely fills the repair area without voids.
- 7 Flowable repair material shall not be dropped into place from above the limiting height specified by the product manufacturer, nor from a height exceeding 500mm where there are no manufacturer guidelines.

Measuring Ambient Conditions and Limiting Conditions for Placement

- 8 The Contractor shall during and throughout each day of material placement, take measurements and keep written records of the concrete surface temperatures, shade air temperature, relative humidity, precipitation, wind strength and dew point, as described in MSA EN 1504 Part 10, Table 5, Test Nos. 10, 21, 22, 23, 24 and 25.
- 9 Repair material shall not be placed or continue to be placed if any of the ambient physical conditions shown in Table 5700-4 apply. The temperature of the repair material when deposited shall not be lower than 5°C and not higher than 30°C. Measurements of physical conditions shall be taken for each batch of repair material from completion of mixing, and at intervals of 20 minutes during application. Measurement records shall be kept by the Contractor and a copy made available to the Overseeing Organisation upon request.

Table 5700-4: Limiting Conditions for Ceasing Placement of Repair Material

Physical condition	Location	Criteria for ceasing placement
Surface temperature of the existing concrete substrate [reference MSA EN 1504 Part 10, Table 5, Test No. 10]	Within the repair void	Is less than the higher value of the manufacturer’s minimum recommended temperature or +5°C. Is greater than the lower value of the manufacturer’s maximum recommended temperature or +30°C

Shade air temperature [reference MSA EN 1504 Part 10, Table 5, Test No. 21]	Immediate environment of the repair	Is less than the higher value of the manufacturer's minimum recommended temperature or +4°C
Wind strength [reference MSA EN 1504 Part 10, Table 5, Test No. 24]	Immediate environment of the repair	Is 8 m/s or stronger
Dew point [reference MSA EN 1504 Part 10, Table 5, Test No. 25]	Immediate environment of the repair	Ambient temperature is less than 3°C above dew point temperature

Construction Joints

- 10 Where fresh repair material is to be placed against hardened repair concrete, a construction joint shall be formed as described by the manufacturer's instructions or in the absence of those, as described in sub-Clause 1710.1. Repair material shall be deemed to be hardened when it has been in position for longer than the maximum workable time declared by the product manufacturer or 30 minutes whichever is the shorter period.

Surface Profile and Finish

- 11 The surface profile of a completed repair shall be the same as the existing concrete it replaces unless specified otherwise in contract specific Appendix 57/3.
The allowable tolerance on a finished surface and edges shall comply with Figure G.5a of Annex G in MSA EN 13670.
- 12 Surface finish shall comply with the required Clause 1708 standard described in contract specific Appendix 57/3 for a formed or unformed finish.
- 13 Surface profile and finish of sprayed concrete shall be as specified in Clause 5717.

Protection of a Completed Repair

- 14 Surface temperature of the repair and the immediately surrounding existing concrete shall not be allowed to fall below the minimum temperature specified in the manufacturer's instructions or 2° C, whichever is the higher temperature until the material has cured.
Immediately after placing and for the following 14 days, the completed repair shall be protected from contact with contaminants e.g. chlorides, oil, acids.

Curing of a Completed Repair

- 15 The required MSA EN 13670 curing class shall be as specified in contract specific Appendix 57/3 for each element to be repaired. See Clause 5717 for sprayed concrete curing class.
Curing and protection of a completed repair shall be in accordance with MSA EN 1504 Part 10 and with the manufacturer's instructions.
The use of curing liquids shall comply with Clause 1710 and instructions of the curing liquid manufacturer.

5715 Flowable Concrete or Mortar

- 1 Flowable concrete or mortar products shall be chemical Type CC or PCC as defined in MSA EN 1504 Part 1, and shall comply with the requirements of Clauses 5703 and 5704.
- 2 The flowability class of concrete or mortar required is given in contract specific Appendix 57/1.
- 3 For the purposes of measuring consistency of fresh 'flowable' material before and during placement, the minimum "flowability" of high flow material shall be 750mm, and the minimum "flowability" of normal flow material shall be 450mm when measured in accordance with MSA EN 13395-2 or MSA EN 13395-3 as appropriate.
- 4 For the purposes of measuring air content of fresh 'flowable' material before placement, the maximum air content shall be 7% when measured in accordance with MSA EN 12350 Part 7.
- 5 When making test samples in accordance with MSA EN 12190 for the determination of compressive strength of flowable concrete or mortar, no compaction shall be applied.
- 6 Repair material shall flow freely into the repair void to be filled and shall not be compacted using internal mechanical vibration. Formwork may be tapped lightly with a hammer to expel trapped air.
- 7 Contract compliance testing detailed in contract specific Appendix 1/5 shall be undertaken in accordance with Clause 5721.

5716 Repair Concrete or Mortar

- 1 Repair concrete or mortar products shall be chemical Type CC, PCC or PC as defined in MSA EN 1504 Part 1 and shall comply with requirements of Clauses 5703 and 5704.
- 2 Chemical type PC proprietary repair products shall only be used for small and superficial concrete repairs as defined in contract specific Appendix 57/3. Type PC products shall not be used where carbon steel reinforcement is exposed in the prepared repair void, nor where sub-Clauses 5718.2 and 5719.2 apply.
- 3 Where the product manufacturer's instructions permit repair mortar to be applied in more than one layer, the recommendation on maximum layer thickness shall not be exceeded. The exposed surface of underlying layers shall be prepared in accordance with the manufacturer's instructions. Locations where repair mortar shall be placed in a single layer shall be as given in contract specific Appendix 57/3.
- 4 Finish on the completed surface of a repair patch using repair concrete or mortar shall be U2 or better in accordance with Clause 1708, unless stated otherwise in contract specific Appendix 57/3.
- 5 Contract compliance testing detailed in contract specific Appendix 1/5 shall be undertaken in accordance with Clause 5721.

Treatment of Areas with Low Cover to Reinforcement

- 6 The depth of construction and the surface profile of reinstated concrete for areas which require an increased cover to reinforcement shall be as shown on the drawings, or shall be as specified in contract specific Appendix 57/3.
- 7 Concrete shall be removed in accordance with Clause 5709, and the perimeter of the treatment area shall be prepared in accordance with sub-Clause 5709.15.
- 8 Where concrete is not specified for removal, the whole surface of the area to be built up including the perimeter, shall be prepared in accordance with Clause 5710.
- 9 The prepared area shall then be filled with repair material to achieve the required minimum cover and profile specified.
- 10 MSA EN 1504 Part 1, chemical types CC or PCC shall be used for low cover repairs. Chemical type PC products shall not be used.

5717 Sprayed Concrete or Mortar

General Requirements

- 1 Sprayed concrete or mortar shall be a proprietary repair product type CC or PCC as defined in MSA EN 1504 Part 1 and shall comply with Clauses 5703 and 5704.
- 2 The nominal maximum aggregate size shall be 8mm for sprayed concrete, and 3mm for sprayed mortar.
- 3 Either a dry-spray or a wet-spray application processes is permissible unless a single application process is specified in contract specific Appendix 57/4. A sprayed product used shall be formulated for the chosen or specified application process. Dry and wet application processes shall not be used together in the same repair.
- 4 Designed mix sprayed concrete is not covered by this Series. Proposals for a designed mix shall be subject to the approval of the Overseeing Organisation through its Departure from Standard process.

Compressive Strength

- 5 MSA EN 1504 Part 3 compressive strength class, shall be as specified in contract specific Appendix 57/1.

Consistence

- 6 Where a wet-mix sprayed concrete is specified, the required consistence of fresh material prior to application shall be as given in contract specific Appendix 57/4.

Pre-Construction Quality Control

- 7 The Contractor shall ensure and provide written evidence to the Overseeing Organisation to demonstrate that:
- a) proposed operatives are appropriately trained and qualified to undertake sprayed concrete activities, and have recent experience of spraying concrete/mortar; and,
 - b) a suitable and sufficient risk assessment of the concrete spraying has been completed, and there is a safe system of work in place.
- 8 Where required by contract specific Appendix 1/5, the Contractor shall demonstrate by procedure trials, the materials, equipment, and method of working; the competence of each proposed sprayed concrete nozzle operator; and test the properties of the sprayed concrete when placed.

Procedure Trials – Construction of Test Panels

- 9 Before concrete repairs commence on site, the Contractor shall prepare sprayed concrete test panels.

Sprayed concrete test panels shall be constructed in timber moulds using the same sprayed concrete product, mixing, spray equipment and spraying method proposed for use in the permanent works. Minimum dimensions of moulds shall be 750mm x 750mm x 150 mm deep unless stated otherwise in contract specific Appendix 57/4. The moulds shall not be coated with release agent.

Two test panels shall be produced for each proposed sprayed concrete product or mix and at each inclination described in contract specific Appendix 57/4 by each spray-gun operator the Contractor proposes for the work. At least three sprayed concrete test panels shall be made for each contract where sprayed concrete test panels are specified in contract specific Appendix 1/5.

The same requirements for test panels shall apply if a robotic concrete spraying machine is proposed.

Categories of inclination shall be as follows:

- a) Horizontal soffit (inclination to horizontal, 0° – 5°);
- b) Horizontal upper surface (inclination to horizontal, 0° – 5°);
- c) Vertical (inclination to horizontal, 80° – 90°);
- d) Inclined (inclination to horizontal, 5° – 80°).

One or more test panels shall contain steel reinforcement bars of similar diameter, spacing and orientation to a typical section of an existing reinforced concrete element intended for repair.

Studs or screws shall be used to measure shrinkage cracking in the concrete test panels. Monitoring points at an equal spacing of 200 mm shall be installed immediately after spraying at three places in a triangular arrangement on three of the test panels. The test panels shall be kept for 56 days.

Stainless steel pins shall be inserted into plain concrete test panels when the concrete is still fresh after spraying where measurements of electrical resistivity are required in contract specific Appendix 1/5.

Sprayed test panels shall not be moved until the concrete is at least 36 hours old.

The concrete shall be cured for 7 days, using the same curing method proposed for the permanent works.

Test panels and samples shall be protected to prevent damage or moisture loss during transportation to a testing laboratory.

Samples to be Removed from Test Panels

- 10 The number, type and dimensions of samples to be removed from the test panels shall be as specified in contract specific Appendices 17/4 and 1/5.

Samples shall be removed from test panels in accordance with MSA EN 12504 Part 1, and shall not include any concrete within 125mm of the edge. Samples shall be removed when the concrete is old enough to resist stresses from cutting or coring equipment without damage or reduction in strength properties.

Samples for testing electrical resistivity of the sprayed concrete shall be 150mm cubes removed from a plain concrete test panel and include stainless steel pins. Alternatively, the samples with stainless steel pins may be left in the test panel.

Sampling, Inspection and Testing of Concrete Samples from Panels

- 11 All core samples taken from the test panels and the bores in the remaining concrete shall be inspected for integrity. Photographic records shall be taken and retained for reference. Inspection and recording shall be completed prior to samples being destructively tested.

- 12 Sampling and testing of concrete samples including concrete remaining in the test panel, shall be undertaken by an accredited testing laboratory as required by sub-Clause 105. 7. Sprayed test panels shall not be transported until the concrete is at least 36 hours old.

- 13 Tests specified in contract specific Appendix 1/5 shall be carried out on samples or on the sprayed panel itself.

- 14 Shrinkage shall be measured using studs or screws left in the concrete remaining in the concrete test panel after removal of other specimens for destructive testing.

Measurements of shrinkage and readings of air temperature and surface temperature of the concrete shall be taken and recorded at casting, and then at 7-day intervals to monitor movement in the concrete until the concrete is 28 days old. One additional measurement shall be taken and recorded when the concrete is 56 days old. The percentage of shrinkage in the concrete shall be calculated from these readings.

- 15 Measurements of electrical resistivity shall be carried out on the cubes removed from the test panel or on concrete remaining in the test panel.

- 16 Testing and performance requirements for sprayed concrete samples are given in Table 5700-5.

Table 5700-5: Performance Requirements for Testing of Samples taken from Sprayed-Concrete Test Panels or Testing of Concrete in the Panels

Type of sample	Performance Characteristic	Test or sampling method	MSA EN 1504 Part 3 class / performance requirement	
			Class R4	Class R3
Core (50mm or 100mm dia.)	28-day compressive strength	(MSA EN 12504-1) (MSA EN 14488-1) MSA EN 12390-3	Appendix 57/1	
Core (50mm or 100mm dia.)	28-day elastic modulus (secant)	MSA EN 12390-13	Appendix 57/1, subject to min. 20 GPa	Appendix 57/1, subject to min. 15 GPa
Core through reinforcement (100mm dia.)	Integrity – containing minimal defects	MSA EN 12504-1, National Annex – inspection	No defect, laminations, voiding etc. (3% max. voidage)	
Test panel including Studs or screws	Percentage shrinkage at 28 days	Measurement in accordance with Sub-Clause 5717.14	≤ 0.07% At 28 days for spray gun method Additionally, at 56 days	≤ 0.07% At 28 days for spray gun method Additionally, at 56 days
150mm cube cut from test panels or remaining concrete in panel	Electrical resistivity at 28 days	4-pin Wenner test	Sub-Clause 5718.10 or 5719.6 (subject to testing being required – see Appendix 57/1)	

Test Result Acceptability Criteria

- 17 The 28-day minimum compressive strength, as stated in contract specific Appendix 57/1, and elastic modulus requirements are satisfied if, for each panel, the average of the measured values is greater than the specified threshold value and the difference between the lowest and highest values is not more than 20% of their average.
- The competence of the sprayed concrete operative shall be deemed to be acceptable for shrinkage, if measured shrinkage at 28 days is less than the Table 5700-5 performance requirement.
- Where the permanent works includes galvanic anodes within repair areas (see contract specific Appendix 57/1) or a surface applied cathodic protection system is part of the works or when detailed in contract specific Appendix 57/3, the electrical resistivity of sprayed concrete shall comply with Clause 5718 or 5719 as appropriate.
- Cores taken from test panels shall not have significant voids or laminations. Inspection of cores from reinforced panels shall identify any shadowing behind bars. Total voidage permitted is up to 3%.

Test Results Report

- 18 The Contractor shall prepare a report on tests carried out on sprayed concrete test panels and for core integrity, and submit a copy to the Overseeing Organisation before sprayed concrete construction commences on site. The test report shall comply with MSA EN 12504 Part 1 and additionally include for each specimen, apparent density, voidage, age and curing conditions, test results, test certificates and performance threshold values.

Quality Control – Assessment of Conformity

Production Control

- 19 Sprayed concrete production in the main works shall not commence until procedure trials have been demonstrated to be satisfactory.
- 20 Production control of the sprayed concrete material during the works shall comply with Clause 5708. Where a wet-spray application process is specified or proposed, the consistency of the wet mix is shall be as stated in contract specific Appendix 57/4, for monitoring and control of quality on site.
- 21 The inspection category for sprayed concrete repairs to concrete highways structures shall be Category 3 in accordance with MSA EN 14487 Part 1, unless otherwise specified in contract specific Appendix 57/4.

Execution of Sprayed Concrete

- 22 Application of sprayed concrete or mortar shall be in accordance with the manufacturer's instructions for use, and MSA EN 1504 Part 10.
- 23 The Contractor shall on completion of the sprayed concrete activities, remove all remaining over sprayed material from structural elements and other elements of the highway adjacent to the working areas.

Construction Joints

- 24 Unless otherwise described in contract specific Appendix 57/4, construction joints in a sprayed area shall be sloped back at approximately 120° to the substrate, or cut back square to the reinforcement and then sloped back at 120° to the substrate. The construction joint shall be thoroughly cleaned, all laitance and loose material removed and the surface pre-wetted as required in Clause 5710 prior to the placement of more sprayed concrete.

Curing

- 25 Repair areas constructed using sprayed concrete or mortar shall be cured and protected in accordance with MSA EN 14487 Part 2, sub-clause 9.3, or in accordance with the period indicated in the manufacturer's instructions whichever is the longer period. MSA EN 13670 curing class 4 shall apply.

Surface Finishes

- 26 The surface finish of sprayed concrete shall be in accordance with MSA EN 14487 Part 2, sub-clause 9.2 and shall be left as-sprayed from the nozzle, unless specified otherwise in contract specific Appendix 57/4.

Surface Profile

- 27 Surface profile of a completed repair shall be the same as the existing unless specified otherwise in contract specific Appendix 57/3.
Geometric surface tolerance for an as-sprayed concrete surface shall be in accordance with MSA EN 13670, Annex G, Figure G.5a (non-moulded surface).

Contract Compliance Tests for Completed Repairs

- 28 Contract compliance testing of performance for the completed sprayed concrete repairs shall be undertaken in accordance with contract specific Appendix 1/5 and Clause 5721.

5718 Repairs to Structures to Receive Impressed Current Cathodic Protection

General

- 1 This Clause applies where the works include repairs to reinforced concrete and an impressed current cathodic protection system within a cementitious overlay, or where indicated in contract specific Appendix 57/3.
- 2 Where embedded metal objects are visible at the concrete surface, and are not specified for connection to the cathodic protection system, the Contractor shall identify, mark and prepare a survey report of the objects if they are likely to cause an electrical short circuit between the system negative and the cathodic protection anode in accordance with MSA EN ISO 12696. A copy of the survey report shall be submitted to the Overseeing Organisation within 2 working days.
- 3 Cement-based or cementitious products, MSA EN 1504 Part 1 Type CC or PCC, shall be used for repair. Polymer-based repair products (type PC) or cementitious repair products containing conductive fibres or electrically conducting additives or admixtures shall not be used.

Removal of Detrimental Objects and Old Repairs

- 4 Where indicated in contract specific Appendix 57/3, detrimental metal objects and surrounding existing concrete shall be removed and the concrete surface shall be reinstated to its former profile using acceptable repair products in accordance with this Series.
- 5 Where indicated in contract specific Appendix 57/3, previously executed concrete repairs with a resistivity greater than 100 k Ω •cm shall be removed, and the concrete surface shall be reinstated to its former profile using acceptable repair products in accordance with this Series.

Treatment of Areas with Low Cover to Reinforcement

- 6 Where low concrete cover to existing reinforcement is required to be increased before installing a cathodic protection system contained within an overlay, the areas shall be treated in accordance with Clause 5716.

Treatment of Steel Reinforcement

- 7 Existing steel reinforcement exposed within a repair patch shall be tested for continuity as described in MSA EN ISO 12696. Any reinforcement failing the test shall be made continuous prior to applying repair material.
- 8 Tying wire used to restore continuity of reinforcement shall comply with Clause 1713.

Testing of Completed Repairs

- 9 Contract compliance testing to demonstrate that electrical resistivity of completed repairs is within permitted limits is detailed in contract specific Appendix 1/5 and shall be undertaken in accordance with Clause 5721. Concrete in the repair patch shall be at least 28 days old.

5719 Repairs to Structures using Galvanic Anodes for Control of Incipient Anode Effect

General

- 1 This Clause applies for concrete repairs to structures which include galvanic anodes complying with Clause 5712 and located within the repair patch.
- 2 Cement-based or cementitious products shall be used, MSA EN 1504 Part 1 Type CC or PCC. Polymerbased repair products, type PC, or repair materials containing conductive fibres or electrically conductive additives, or admixtures shall not be used.

Testing of Completed Repairs

- 3 Contract compliance testing to demonstrate that electrical resistivity of completed repairs is within permitted limits is detailed in contract specific Appendix 1/5 and shall be undertaken in accordance with Clause 5721. Concrete in the repair patch shall be at least 28 days old.
- 4 For repairs containing Type 1A galvanic anodes, the electrical resistivity of the repair shall be not less than 5 k Ω •cm and not greater than 15 k Ω •cm.
- 5 Electrical resistivity greater than 15 k Ω •cm, is acceptable if a bridging conductive material has been provided locally around each anode after attaching to reinforcement. Evidence of this shall be supplied to the Overseeing Organisation on request.
- 6 For repairs containing Type 1B galvanic anodes, the electrical resistivity of the repair shall be within 50% to 200% of the electrical resistivity of the parent concrete, but shall not exceed 100 k Ω •cm.

5720 Concrete Injection

Introduction

- 1 This Clause covers injecting and filling of cracks in concrete satisfying Principles 1 and 4 of MSA EN 1504 Part 9, Table 1.
- 2 This Clause does not cover the following applications of concrete injection described in MSA EN 1504 Part 5:
- a) highly specialised applications in extreme environmental conditions or specialised circumstances (reference Clause 1 of MSA EN 1504 Part 5);
 - b) test methods and performance requirements for special applications (reference sub-Clause 5.3 of MSA EN 1504 Part 5).

Where such applications are proposed they shall be subject to the approval of the Overseeing Organisation through its Departure from Standards process.

General Requirements

- The location and dimensions of cracks requiring treatment, and the function concrete injection products shall perform shall be as stated in contract specific Appendix 57/5.

Requirements for MSA EN 1504 Part 5 Products for Concrete Injection

- The Contractor shall supply the evidence required in Clause 5703 to the Overseeing Organisation including the Declaration of Performance for the proposed materials to demonstrate compliance with MSA EN 1504 Part 5, and the specification.
Products selected for crack filling/injection shall be suitable for their intended use and shall meet at least the minimum performance requirements given in Table 5700-6, Table 5700-7 or Table 5700-8 as appropriate to the function the injection products shall perform, and the requirements stated in contract specific Appendix 57/5.

Table 5700-6: Performance Requirements for MSA EN 1504 Part 5 Concrete Injection Products – Force Transmitting Filling of Cracks (F)

MSA EN 1504 Part 5 Essential characteristic	Description of performance characteristic	Type of binder used in product	Performance requirement (reference tables in MSA EN 1504 Part 5)
Adhesion by tensile bond strength fct	Adhesion by tensile bond strength	H, P	Following MSA EN 1504 Part 9, Principle 4 F1: fct ≥ 3.0 N/mm ² F2: fct ≥ 2.0 N/mm ² as stated in contract specific Appendix 57/5 for required F bond strength
Compressive strength	Compressive strength	H	fct > 20 N/mm ² after 7 days
Shrinkage	Bleeding	H	Bleeding <1% of the initial volume after 3 hours
	Volume change	H	-1% < volume change < +5% of the initial volume
	Non-volatile matter	P	>95%
Workability	Injectability into dry medium	H, P	Table 6 (9), contract specific Appendix 57/5 for minimum width of crack
Workability	Injectability into nondry medium	H, P	Table 6 (10), contract specific Appendix 57/5 for minimum width of crack
Durability	Adhesion by tensile bond strength after thermal and wet-drying cycles	P	F1: fct ≥ 3.0 N/mm ² F2: fct ≥ 2.0 N/mm ² contract specific Appendix 57/5 for required F bond strength

Release of dangerous substances	MSA EN 1504 Part 5, Section 5.4	H, P	Comply
---------------------------------	---------------------------------	------	--------

General notes for Table 5700-6:

- MSA EN 1504, Part 5 codes for type of binder are H = hydraulic, P = reactive polymer.
- Number in parentheses after MSA EN 1504 Part 5 table number denotes item no.
- Function classification of injection product shall be as specified in contract specific Appendix 57/5.

Table 5700-7: Performance requirements for MSA EN 1504 Part 5 Concrete Injection Products – Ductile Filling of Cracks (D)

MSA EN 1504 Part 5 Essential characteristic	Description of performance characteristic	Type of binder used in product	Performance requirement (reference tables in MSA EN 1504 Part 5)
Adhesion and elongation capacity	Adhesion and elongation capacity of ductile injection products	P	Adhesion: as stated in contract specific Appendix 57/5 Elongation: > 10%
Workability	Injectability into dry medium	P	Table 7 (4), contract specific Appendix 57/5 for minimum thickness of crack
Workability	Injectability into non-dry medium	P	Table 7 (5), contract specific Appendix 57/5 for minimum thickness of crack
Durability	Compatibility with concrete	P	Table 7 (8)
Release of dangerous substances	MSA EN 1504 Part 5, Section 5.4	P	Comply

General notes for Table 5700-7

- MSA EN 1504, Part 5 codes for type of binder are P = reactive polymer
- Number in parentheses after MSA EN 1504 Part 5 table number denotes item no.
- Function classification of product shall be as specified in contract specific Appendix 57/5.

Table 5700-8: Performance Requirements for MSA EN 1504 Part 5 Concrete Injection Products – Swelling Fitted Filling of Cracks (S)

MSA EN 1504 Part 5 Essential characteristic	Description of performance characteristic	Type of binder used in product	Performance requirement (reference tables in MSA EN 1504 Part 5)
Watertightness	Watertightness	P	Watertight at 2×10^5 Pa
Workability	Viscosity	P	≤ 60 mPa s Percentage of crack filled >95%

Expansion ratio and rate by water storage	Weight changes by air drying and water storage	P	as stated in contract specific Appendix 57/5
Durability	Sensitivity to water	P	Table 8 (6)
Durability	Sensitivity to drying-wet cycles	P	Table 8 (7)
Durability	Compatibility with concrete	P	Table 8 (8)
Release of dangerous substances	MSA EN 1504 Part 5, Section 5.4	P	Comply

General notes for Table 5700-8

- a) MSA EN 1504, Part 5 codes for type of binder are P = reactive polymer.
- b) Number in parentheses after MSA EN 1504 Part 5 table number denotes item no.
- c) Function classification of product shall be as specified in contract specific Appendix 57/5.

Inspection to Identify Cracks for Treatment

- 5 Where a survey of cracks is specified in contract specific Appendix 57/5, the Contractor shall provide access to enable an inspection of the structure to be undertaken with the Overseeing Organisation to confirm which cracks require treatment. Cleaning of the concrete surface to expose the cracks shall be carried out prior to the inspection.

Quality Control Tests

- 6 The Contractor shall carry out routine quality control works tests as described in Clause 5708. Additional quality control test for concrete injection construction activities shall be undertaken as required in contract specific Appendix 1/5.

Preparation of Cracks

- 7 Debris lodged within the cracks and surface contamination of the crack sides, MSA EN 1504 Part 10, observation No. 14, shall be removed before injection or filling.
Where moisture within the crack or soaked into the sides of the concrete, MSA EN 1504 Part 10, Observation No. 9, is greater than recommended by the manufacturer of proposed injection product, it shall be removed prior to crack injection or filling. Details of the proposed process of moisture removal shall be described in the construction method statement.

Execution of Concrete Injection

- 8 The mixing and application of all concrete injection products for filling or injection of cracks in concrete shall be in accordance with MSA EN 1504 Part 10 and the manufacturer's recommendations for the proposed method of injection.
The procedure for concrete injection shall ensure all cracks and voids interconnected with surface cracks within the structural member are filled.

Injection products spilled onto adjacent surfaces of the structure shall be removed.

Contract Compliance Tests on Completed Repairs

- 9 Testing shall be undertaken in accordance with contract specific Appendix 1/5 and Clause 5721.

5721 Contract Compliance Testing on Completed Repairs

General

- 1 The Contractor is responsible for demonstrating that repairs have been carried out in accordance with the specification. The Overseeing Organisation shall be notified in advance of a repair integrity survey or removal of test samples and be given the opportunity to be present during the work.

Repair Sounding – Integrity of Repair

- 2 The soundness/integrity of all completed repairs shall be demonstrated by hammer sounding, as stated in contract specific Appendix 1/5. Hollow sounding areas shall be removed, and the repairs re-executed as agreed with the Overseeing Organisation.

Conductivity of Repair – Electrical Resistivity Measurement

- 3 Where the work includes galvanic anodes within repair areas as indicated in contract specific Appendix 57/1, or impressed current cathodic protection as required by contract specific Appendix 57/3, the conductivity of completed repairs shall be confirmed by demonstrating that electrical resistivity is within permitted limits, as stated in contract specific Appendix 1/5.
- 4 The electrical resistivity of completed repairs shall be measured using MSA EN 1504 Part 10, Test No. 15 or an equivalent method acceptable to the Overseeing Organisation.

Cores – General

- 5 Indicative core positions shall be located where shown on contract drawings, indicated in contract specific Appendix 57/3 or as directed by the Overseeing Organisation. The exact position of each core shall be chosen on site by the Contractor to avoid damage to reinforcement.
Drilling shall be stopped immediately if a reinforcing bar is encountered and the Contractor shall determine an alternative location for the core as close as possible to the specified location.

Cores – Integrity of Repair

- 6 When required by contract specific Appendix 1/5, the integrity of repair work shall be demonstrated by drilling cores through completed repairs. Cores shall be drilled in accordance with MSA EN 12504-1. The frequency and distribution of cores shall be as specified in contract specific Appendix 57/3.

The drilling of cores to demonstrate integrity in each repaired area shall be carried out as soon as practicable after the removal of formwork (if used), but not until the repair concrete strength is estimated to exceed 15 MPa.

Cores – Adhesion to Substrate

- 7 When stated in contract specific Appendix 1/5, the Contractor shall demonstrate that repaired areas have adequate adhesion to the substrate by drilling cores through completed repairs. The frequency and distribution of cores shall be as specified in contract specific Appendix 57/3.

Cores to determine adhesion in each repaired area shall not be removed and tested until the repair is estimated to have attained its characteristic compressive strength required by the Class specified in contract specific Appendix 57/1. In the absence of compressive test results, the testing of cores for adhesion shall be at least 28 days after placement of repair material. Cores shall be drilled in accordance with MSA EN 12504 Part 1, with reference to MSA EN 14488 Part 4 for depth of bore.

Cores – Compressive Strength

- 8 When stated in contract specific Appendix 1/5, the Contractor shall demonstrate repaired areas have adequate compressive strength by drilling cores through completed repairs. The frequency and distribution of cores shall be as specified in contract specific Appendix 57/3. Cores shall be drilled in accordance with MSA EN 12504 Part 1, with reference to MSA EN 14488 Part 4 for depth of bore.

Cores – Injection/Filling of Cracks

- 9 When stated in contract specific Appendix 1/5, the Contractor shall demonstrate the extent of crack filling by drilling cores through injected/filled cracks. The frequency and distribution of cores shall be as specified in contract specific Appendix 57/5.

- 10 Cores shall be drilled in accordance with MSA EN 12504 Part 1, but shall be 50mm diameter x 100mm long, however the Contractor shall allow for taking 25mm diameter x 100mm long cores in place of the 50mm diameter cores where directed by the Overseeing Organisation.

Electrical resistivity of repairs

- 11 For repairs associated with an impressed current cathodic protection system, the electrical resistivity shall be within 50% to 200% of the electrical resistivity of the parent concrete, but shall not exceed 100 kΩ•cm. The electrical resistivity of the parent concrete shall be as stated in contract specific Appendix 57/1.
- 12 For repairs containing Type 1A or Type 1B galvanic anodes, the electrical resistivity requirements are specified in Clause 5719.

Inspection of Bores

- 13 The Contractor shall provide access for the Overseeing Organisation to carry out an examination of the core holes, provide 2 working days' notice it is available and shall allow a period of 4 hours for such inspection.
The Contractor shall also make the concrete cores available for inspection.

Repair Integrity

- 14 The Contractor shall compare all exposed surfaces of bores and cores removed with photographs in NA.4 of MSA EN 12504 Part 1 and measure the total area of voids visible on the exposed faces. Total voidage shall not exceed 3 % of the exposed surface area of the core or the corresponding surface area of the bore hole.

Adhesion to Substrate

- 15 Core testing for adhesion of repair to substrate shall comply with MSA EN 14488-4 for sprayed concrete or MSA EN 1542 for high flow concrete or repair mortar.
Target adhesion strength shall be in accordance with contract specific Appendix 57/3. Any tested cores where failure is fully within the concrete substrate and the adhesion strength is less than 1 N/mm² shall not count as part of the results from which the average is calculated. Additional cores and tests shall be undertaken until a satisfactory set of results has been obtained.

Compressive Strength

- 16 The compressive strength of cores measured in accordance with MSA EN 12390 Part 3, shall be consistent with the Class of repair material specified in contract specific Appendix 57/1.

Filling or Injecting of Cracks

- 17 Core samples shall be inspected to confirm that the penetration requirements are met. The percentage extent of crack filling shall be at least 80% or other higher value specified in contract specific Appendix 57/5. If the minimum percentage is not achieved, the crack filling

shall be declared to be provisionally unsatisfactory. The cores shall then be loaded under compression to destruction. If no fracture occurs on a glue line, the core is acceptable.

If following compression loading, the break occurs on a glue line, the core is acceptable if the calculated bond strength between hardened injection material and existing substrate is not less than 1 N/mm² when tested in accordance with MSA EN 1542.

In the event of non-compliance with this sub-Clause, the Contractor shall be required to provide further remedial proposals.

Reporting of Observations, Measurements and Test Results

- 18 The Contractor shall prepare a report on measurements of electrical resistivity of repairs, core integrity and filling of cracks, and any tests of repair adhesion and compressive strength. Total voidage of each bore and each core shall also be reported. Observations, measurements and testing shall be in accordance with MSA EN 12504-1, MSA EN 14488-4 and MSA EN 12390-3 as appropriate.
- 19 A copy of the report shall be submitted to the Overseeing Organisation in accordance with Clause 105.

Repair Completion and Reinstatement of Cores

- 20 The Contractor shall maintain any temporary support and access systems in place until at least 2 working days after the above testing report has been submitted to the Overseeing Organisation confirming that the concrete repairs are satisfactory. If the repairs do not comply, temporary support and access shall be maintained until remedial work is confirmed as compliant with the specification.
- When the repairs are confirmed as satisfactory, the Contractor shall remove all dust and debris from each test hole, roughen and pre-wet the bore, and then fill the holes with Repair Mortar complying with the requirements of Clause 5716, and product manufacturer's instructions. Filling of core holes shall be done as soon as reasonably practical after completion of the core sampling.