SERIES NG 5700
CONCRETE REPAIRS

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CONCRETE REPAIRS

NG 5701 (02/20) Concrete Repair – Introduction

(02/20) Specification of Concrete Repairs

1 (02/20) This specification Series is intended to cover construction activities related to repair of concrete, the compiler must also refer to other specification Series to fully specify the works. It will be necessary to prepare appendices related to Series 000 and 100, NG 100 and all other Series relevant for the contract works. Reference should be made to Series NG 000 for compilation requirements.

NG Sample Contract Specific Appendices are provided at the end of each Notes for Guidance Series. The contract compiler should use these as stated in Clause NG 003 and provide contact specific requirements and information where these are relevant to the work required.

The Specification Clauses 5702 to 5705, 5707, 5708, 5714, 5718 and 5719 include general requirements for all types of concrete repair materials, with Clauses 5715 to 5717, covering requirements for a particular type of repair material such as those traditionally known as flowable concrete or mortar, repair concrete or mortar and sprayed concrete or mortar. The requirements are based on best practice and experience gained on past schemes.

2 (02/20) Series 5700 Clauses specify repairs or modifications to existing concrete highway structures carried out as part of maintenance or strengthening activities and using proprietary repair products. They apply to repair of open drainage channels as well.

The Specification references relevant parts of BS EN 1504 Products and Systems for the Protection and Repair of Concrete Structures. BS EN 1504 Parts 1, 3, 5, 6, 7, 8, 9 and 10 specify requirements and give advice for protection and repair of concrete. The standards are applicable to highway structures constructed of plain concrete, reinforced concrete, pre-stressed concrete, post-tensioned concrete or a steel/concrete composite.

The use of proprietary pre-mixed products limits the risk of errors in proportioning and mixing of components on site.

The Series 5700 Clauses are applicable for specifying proprietary flowable or sprayed material types to recast cover concrete (up to 150mm thick) over the whole span length of small structural elements e.g. parapet stringcourses or cantilever (where not precast), and may be used for concrete work comprising elimination of deck joints by establishing continuity e.g. by a Kumar method (see BS EN 15050 Annex D); or to recast deck ends after replacement of a large deck movement joint.

However, when the depth of concrete replacement extends well beyond the rear of the outer reinforcement e.g. more than a total depth of 150mm for each face recast, all concrete in the element is to be replaced (e.g. cantilever and stringcourse elements that were cast in-situ and are not CE marked – see Clause 406), or a large volume of concrete is required, it may be more appropriate to use a designed concrete specified in accordance with Series 1700.

BS 8500 Part 2 allows small size aggregate to be specified, but the designer should make sure the existing reinforcement can resist shrinkage stresses which otherwise might cause cracking during the early phase of concrete maturing and strength gain. Many proprietary mixes contain additives to limit shrinkage.

(02/20) Aspects Excluded from the Specification

3 (02/20) Note that this Series may not apply to repairs to proprietary concrete road restraint systems (including precast barriers or parapets, or cast-in-situ barriers), nor precast concrete bridge elements if they were manufactured since first publication of the Construction Products Regulation (see sub-clauses 406.4 and 406.5). Procedure for maintenance and repair of those elements may be dictated by the terms of the product CE marking (see Clause 406).

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4 (02/20) The specification of surface protection systems for concrete (products defined in BS EN 1504 Part 2) and for structural bonding (products defined in BS EN 1504 Part 4), are not covered by Series 5700. Use of those systems currently requires the preparation of specification AR Clauses for consideration by the Departure from Standards approval procedure.

5 (02/20) Neither Series 1700 nor this Series 5700 cover new construction using sprayed concrete e.g. sprayed concrete facing to cast in-situ concrete piles, or sprayed concrete as a new tunnel lining, additional specification AR Clauses should be prepared for consideration by the Departures from Standard approval procedure. BS EN 14487 Part 1 may be used for advice on specifying designed mix sprayed concrete.

6 (02/20) Where a designed mix flowable concrete is proposed for planned large area or anticipated repairs of decks, the mix should be designed in accordance with Series 1700 to achieve similar performance characteristics to BS EN 1504 Part 3 products. Testing will be needed to demonstrate required performance can be achieved before construction, and to prove compliance following casting. Describe testing in Appendix 17/4 and schedule in Appendix 1/5 or 1/6 (see sub-clause NG 1727.1).

7 (02/20) Repairs to concrete carriageways are outside the scope of Series 5700. Refer to HD 32 (DMRB 7.4.2) and Clauses 1032 and 1033).

8 (02/20) The compiler should use Series 1700 to specify lightweight concrete.

(02/20) **BS EN 1504 Terms and Definitions**

9 (02/20) BS EN 1504 provides manufacturers of repair products with a framework for obtaining certification for their repair products under the terms of the Construction Products Regulation.

10 (02/20) Definitions, requirements, quality control and evaluation of conformity for products and systems intended for repair of concrete may be found in:

(i) BS EN 1504 Part 1 – definitions;

(ii) BS EN 1504 Part 3 – structural and non-structural repair products;

(iii) BS EN 1504 Part 5 – concrete injection;

(iv) BS EN 1504 Part 6 – anchoring of reinforcing steel bar; and,

(v) BS EN 1504 Part 7 – reinforcement corrosion protection.

11 (02/20) The BS EN 1504 parts listed above are performance specifications and provided the required minimum performance of essential characteristics specified in the relevant standards is achieved by a product, the manufacturer is free to use different constituent materials in the formulation.

12 (02/20) BS EN 1504 Parts 2 and 4 are also used for manufacturing products but are not part of the scope of this Series 5700 concrete repair specification.

13 (02/20) General terms and definitions useful for understanding the contents of BS EN 1504 are given in Part 1, and more specific terms and definitions may be found in Parts 3, 5, 6, 7, 8, 9 and 10.

NG 5702 (02/20) Concrete Repair Work – General Requirements

(02/20) **BS EN 1504 Part 9 Methods of Repair**

1 (02/20) The compiler should refer to BS EN 1504 Part 9 to categorise the general principle or principles to be followed for remedial work to the structural elements. BS EN 1504 Part 9 lists possible concrete repair methods under each repair principle. The repair methods proposed for each structural element should be added to the table prepared for contract specific Appendix 57/1.

2 (02/20) General aims of construction to be achieved during execution of concrete repairs are listed in Section 5 of BS EN 1504 Part 10.

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(02/20) **Technical Approval**

3 (02/20) The Contractor will be required to prepare technical approval documentation as necessary for temporary support of structural members or temporary access to repair areas. See Clause 106, Clause NG 5713 and BD 2 (DMRB 1.1.1).

4 (02/20) If there are unusual site-specific constraints on the design of temporary works required to facilitate construction of the works, the compiler should complete contract specific Appendix 1/11.

(02/20) **Protection of Vulnerable Elements**

5 (02/20) Concrete repair construction activities may include high pressure water jetting and sprayed concrete which involve propelling liquids and solid particles at high velocity. Structure fixtures required for the safe operation or articulation of the structure could be vulnerable to damage, so should be protected before commencing work.

(02/20) **Method Statements**

6 (02/20) The compiler should ensure that contract specific Appendix 1/24 includes a list of topics for which the Contractor is required to provide detailed method statements for concrete repair activities. This should be limited to those where the method of construction, the design and/or the equipment to be used are crucial to the success of the works or innovative.

7 (02/20) For acceptance the method statements should provide assurance that:

(i) safety risks have been adequately assessed, structural integrity is not compromised, and the proposed method includes sufficient hazard mitigation; and,

(ii) proposed repair products and construction techniques are appropriate for the scope of work.

Some reasons for not accepting the documents are that:

(iii) they are inadequately prepared or not practicable;

(iv) they do not include the information specified;

(v) the approach is not realistic.

NG 5703 (02/20) Products and Systems for Repair of Concrete Structures – General

(02/20) **Assessment and Verification of Consistency of Performance**

1 (02/20) System of Attestation of Conformity referred to in Annex ZA.2 of BS EN 1504 Parts 3, 5, 6 and 7 was replaced by an Assessment and Verification of Consistency of Performance (AVCP) when the Construction Products Directive was replaced by the Construction Products Regulation in 2013. Standards published before July 2013 refer to the former.

(02/20) **Suitability of Construction Products**

2 (02/20) A manufacturer of concrete repair products refers to BS EN 1504 Part 3 for the procedure to formally identify products and obtain certification (CE marking) prior to placing them on the market for use in the construction industry. The essential characteristics of repair products are assessed by testing and the manufacturer declares their performance by a Declaration of Performance, and places CE marking on the products. Product manufacturers are legally responsible for performance of CE marked products.

3 (02/20) Historically, contract specifications included requirements for controlling the risk of Alkali Silica Reaction being activated by the component materials of concrete repair mixes. The control is now achieved before those components are used by repair product manufacturers via product standards e.g. BS EN 12620, BS 8500 Part 2.

4 (02/20) The compiler should complete two tables of information in contract specific Appendix 57/1.

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First table

Specifies mandatory performance characteristics of the repair products required for the works:

(i) Strength class of repairs. BS EN 1504 Part 3 strength R Class should be specified. The Contractor will use the specified strength class and Table 57/1 in the specification to indicate which set of performance requirements should be fulfilled by his choice of repair product;

(ii) Fire class of repairs. Where an assessment of the possible exposure to fire of concrete repairs in a location has identified a reasonably significant risk of fire damage, or when fire resistance is required by a design code of practice, the compiler should specify a fire class in contract specific Appendix 57/1. See BS EN 13501 Part 1 for information about construction product fire classes;

(iii) Flowability of fresh repair material. Where a flowable concrete is or may be required, the flowability of the repair material may be classed as high or normal flow (see definition in 5715 and suggested application in NG 5715);

(iv) Minimum compressive strength or repair product. For repairs to some existing concrete elements, even the highest class R4, may not guarantee an adequate compressive strength and a minimum compressive strength should be specified in addition to "R4" listed in the first table of contract specific Appendix 57/1. A value should only be specified if required compressive strength is greater than 50 MPa.

Second table

This should be populated with further information to assist the Contractor in his choice of BS EN 1504 Part 3 repair product:

(i) Assumed compressive strength of existing concrete. This value can either be the original designed compressive strength, the compressive strength given on as-built drawings, or compressive strength of a tested core taken from the element to be repaired;

(ii) Assumed static modulus of existing concrete in tension or compression if appropriate. The contract specification should aim to match the declared elastic modulus of a proposed sprayed concrete product to the measured or estimated elastic modulus of the existing concrete to limit shear stresses at the interface. It is important that the elastic modulus of a repair matches the estimated short-term elastic modulus of the parent concrete for locations subject to frequent cycles of transient loading. It is particularly important for structural members that are predominantly subjected to compressive forces in service e.g. columns. The modulus of elasticity of the proposed concrete repair product should be within a range approximately the same modulus up to +10 GPa of that estimated or measured for the existing concrete;

(iii) Requirement for galvanic anodes within repair patches. Following completion of a designer assessment of corrosion risk to reinforcement located in the existing intact but contaminated concrete surrounding repairs as part of the design process (see BA 35), the compiler should indicate whether galvanic anodes located within the repair patch are required;

(iv) Range of electrical resistivity of parent concrete. A concrete repair product may be marketed as 'compatible for use with cathodic protection systems.' BS EN ISO 12696 has a general recommendation that repair products should have a resistivity within the range 50 – 200% of the parent concrete. The compiler should include an assumed electrical resistivity of the parent concrete in contract specific Appendix 57/1. Further guidance may be found in Technical Notes on the website of the Corrosion Prevention Association (www.corrosionprevention.org.uk);

(v) Minimum strength of concrete repair patches before loading. Early strength gain for repairs to the deck of a highway bridge. This may be relevant where the allowable road/lane closure is of short duration, or where stages of repair are required to maintain structural stability.

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5 (02/20) The compiler should refer to NG 5711 and NG 5720 for guidance about what information is required in contract specific Appendices 57/2 and 57/5.

6 (02/20) If the compiler wishes to declare a future intention to overlay proposed repairs with a cathodic protection system anode embedded in a cementitious layer, details of this should be included in contract specific Appendix 57/3.

NG 5704 (02/20) BS EN 1504 Part 3 Products for Concrete Repair

1 (02/20) Table 57/1 is based on Table 3 of BS EN 1504 Part 3 and has been sub-divided for types of repair material (high flow, normal flow, sprayed, repair mortar, resin mortar) commonly encountered on highway structure repair contracts.

BS EN 1504 Part 3 has four classes of repair product. In general terms these are:

Class R1 a non-structural grade with minimum compressive strength of 10 N/mm^2;

Class R2 a non-structural grade with minimum compressive strength of 15 N/mm^2;

Class R3 a structural grade with minimum compressive strength of 25 N/mm^2; and

Class R4 a structural grade with minimum compressive strength of 45 N/mm^2.

The BS EN 1504 Part 3 class of repair product specified should normally be chosen so the minimum compressive strength is equal to or greater than the originally designed or actual strength of the existing concrete being repaired. Only one class of repair product should be specified and used in each structural element.

The compiler should specify in contract specific Appendix 57/1 which BS EN 1504 Part 3 repair class or classes of product are required for each element to be repaired also show this requirement on the proposed construction drawings.

2 (02/20) Most repairs to concrete highway structures will be structural. Structural Class R3 represents a lower minimum compressive strength than found on many elements of existing concrete highway structures, so the most commonly used class will be R4.

The Concrete Society defines non-structural concrete as low strength and only strong enough to cope with small compression or temporary loading. Blinding concrete used for new concrete work is ‘non-structural’, and the implication is that any cracking under load that occurs will not be significant. For a concrete to be used structurally it is designed to have a characteristic strength greater than 25N/mm^2. Concretes of lesser strength are termed non-structural.

Corrosion Prevention Association Guidance Note No. 3 gives the following general guidance for structural classification:

(i) Structural concrete. Where repaired element is to be under compressive load, comparable elastic modulus, creep and shrinkage should be comparable to the existing concrete it replaces;

(ii) Semi-structural concrete. Where repair product is in contact with reinforcement, but under no direct compressive loading such as the soffit of a beam. Unlikely to have same elastic modulus as existing concrete; and,

(iii) Non-structural concrete. Where a concrete repair does not extend to reinforcement, elastic modulus, creep and shrinkage are unlikely to be the same as existing concrete. Non-structural repair products should only be specified for small areas of superficial repairs less than 10mm deep, and then only when no form of overlaid electrochemical treatment is proposed e.g. impressed current mesh anode within a cement-based screed. BS EN 1504 Part 3 includes two non-structural classes of repair product, but only non-structural class R2 is permitted for use for repairing highway structures.

Class R1 is not meant for structural applications and is too weak and low quality for use on highway structures. It would not be durable enough. It has similar strength to the old Class E concrete used for blinding of prepared ground prior to casting a structural foundation.

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3 (02/20) Repair products should usually be cement-based/cementitious or polymer-modified cementitious for chemical and strain compatibility with the existing concrete, and to restore an alkaline environment around or near to the existing reinforcement.

Polymer-based products (BS EN 1504 Part 1, type PC) provide much less protection to reinforcement than cementitious products, so should only be specified where reinforcement is not exposed, repairs are small in extent e.g. less than 0.1 m² in area and are superficial, i.e. less than 10mm deep.

The compiler should specify in contract specific Appendix 57/3, restrictions on maximum size and depth of repair patches where a non-structural repair product would be acceptable.

The majority of BS EN 1504 Part 3 proprietary products used for repair of highway structures will be cement/cementitious (BS EN 1504 Part 1 Type CC) or polymer-modified cementitious (BS EN 1504 Part 1 Type PCC). The cement and cement replacement are activated by the addition of water.

Some BS EN 1504 Part 3 proprietary products used for non-structural repair will be resin based (BS EN 1504 Part 1, type PC) products which usually consist of fine aggregate combined with binder which is activated by adding together a resin and a curing agent (hardener). The resin and curing agent when mixed together, chemically react to form a thermoset solid.

The resin and curing agent components of type PC repair products are manufactured by reacting chemical reagents together in an industrial manufacturing process.

NG 5705 (02/20) Supply and Storage of Proprietary Repair Products and Other Materials

(02/20) Supply Data

1 (02/20) There is currently no product standard covering manufacture of galvanic anodes and reference electrodes for use in reinforced concrete, so the manufacturer/supplier will be expected to confirm in writing that the product complies with specification requirements.

(02/20) Marking and Labelling of Products

2 (02/20) Containers of the product delivered to site should have been CE marked in accordance with the relevant standard.

Product containers should be marked with a declaration similar to “this product shall be deemed to comply with BS EN 1504 Part 3 until (date)”.

3 (02/20) CE marking identifies repair products complying with BS EN 1504, but galvanic anodes and reference electrodes are not covered by a harmonised standard and should be marked to identify the manufacturer, type and unique reference.

(02/20) Storage

4 (02/20) Repair products are susceptible to deterioration, particularly when they are exposed to moisture, so it is essential that they are stored properly in accordance with BS EN 1504 Part 10 and the manufacturer’s recommendations.

NG 5706 (02/20) Contractor Investigation

(02/20) Contractor Investigation and Reporting

1 (02/20) Where it is impracticable to survey concrete elements before the construction commences e.g. for the top surface of concrete bridge deck normally hidden below road surfacing, the compiler should specify details of a Contractor Investigation in contract specific Appendix 57/6.

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Sometimes it is appropriate for the Overseeing Organisation to undertake a concrete condition survey during the contract by making use of the Contractor's traffic management. It may also be possible for the whole of a survey to be assigned to the Contractor and the results provided to the Overseeing Organisation in the form of a report for consideration and assessment of the extent of repair required. This option should only be used as a last resort because without the survey information, the design cannot be finalised in advance of construction, and could result in contact programming complications with a possible significant increase in costs.

The Contractor investigation will typically include a concrete defect survey (indentations, cracking, delamination), measurement of concrete cover, electrical potential mapping (using a half cell testing instrument), chloride sampling, cement content, carbonation tests and concrete resistivity testing. The location of measurements should be on a specified regular grid (see advice in BA 35). Locations for testing should be shown on the drawings, alternatively the compiler should describe principles for establishing the survey grid in contract specific Appendix 57/6.

In some cases, it may be necessary to take chloride samples within the delaminated area if there is concern that chlorides may have migrated further into the concrete since the most recent investigation was undertaken. Cores to measure chloride content should be particularly targeted in areas where chloride contamination is expected or known to have occurred, for example locations where potholes in bituminous surfacing have been regularly recorded, and adjacent to deck movement joints.

2 (02/20) Advice about the extent of the concrete condition survey and the format and contents of the survey report may be found in BA 35 (DMRB 3.3.2).

3 (02/20) The compiler should ensure that the timescale for supply of the concrete investigation report is stated in contract specific Appendix 1/13. The time constraints should include a period for Overseeing Organisation to review the report. The time periods should be appropriate for the contract specific programming constraints.

NG 5707 (02/20) Pre-Construction Concrete Repair Execution Trials

(02/20) Trial of Contractor's Proposed Method of Repair

1 (02/20) Specification of repair method execution trials may be considered in the following situations:

(i) concrete to be removed is difficult to access, surrounds sensitive structural components or is known to be particularly strong; a breakout trial may be specified;

(ii) predicted/expected method of concrete removal is unconventional or automated;

(iii) there are doubts about the practicability of achieving full compaction of concrete placed within formwork or sprayed around congested reinforcement.

Some previous projects have included tests on full or part-scale mock-up/models to demonstrate the execution method and performance of the product under site conditions. A trial may be appropriate when products are proposed for which there is little or no evidence or records of past performance.

The compiler should describe the form and details of the trial including its location in contract specific Appendix 57/3.

NG 5708 (02/20) Quality Control of Repair Work

(02/20) Routine Testing by the Contractor

1 (02/20) Quality control tests in accordance with BS EN 1504 Part 10, Table 5 are required to monitor repair activities and to confirm that repairs have been implemented effectively. They fall into three categories:

(i) tests on the repair material to demonstrate its workability properties when in the fluid state and confirm that the batch can achieve its specified compressive strength when hardened;

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(ii) inspection of the repair area substrate after it has been prepared to confirm compliance with the specification; and,

(iii) measurements and observations of ambient weather conditions.

Quality control is required initially before the first batch of fresh material is placed into position, and during placement activities, to indicate consistency of the material and to confirm it has complied with the strength requirements of the specified class.

2 (02/20) The compiler should refer to the list of typical sampling and testing requirements for concrete repair work listed in Series NG 100, Table NG 1/1, and draw up a specific list for Contractor routine quality control and contract compliance. The list should be included in contract specific Appendix 1/5.

Options include:

(i) Flowability (flowable repair materials). Flowability tests to confirm that mixed material complies with the specification, indicating that the correct amount of water has been added and mixing has been carried out effectively. (Reference BS EN 1504 Part 10. Annex A.5.4. Test No. 27);

(ii) Air content (flowable repair materials). Air content test is included to control the site mixing procedure. Too high an air content could reduce concrete strength. (Reference BS EN 1504 Part 10. Annex A.5.4. Test No. 28); and,

(iii) 28-day compressive strength (all materials). Tests for compressive strength on hardened concrete specimens (cubes, prisms) at various ages will provide a good indication of the overall strength in the hardened condition and indicate when the repair is strong enough to carry load. (Reference BS EN 1504 Part 10. Annex A.5.4. Test No. 36).

(02/20) **Identity Testing by the Overseeing Organisation – Immediately before and/or during Placement of Material**

(02/20) **Samples for Testing of Concrete Consistency**

3 (02/20) Close monitoring of the concreting operations may be considered necessary early in the construction programme until the Contractor's method is reliable and results are consistent.

4 (02/20) Where samples of fresh repair concrete for testing by the Overseeing Organisation of workability properties are required, the compiler should refer to the list of typical sampling and testing requirements for concrete repair work listed in Series NG 100, Table NG 1/1, draw up a schedule of sampling and delivery requirements for the Contractor to be included contract specific Appendix 1/6.

5 (02/20) Tests should be carried out by a testing laboratory on behalf of the Overseeing Organisation. Tests may be carried out on the fresh repair material for flowability and air content and are indicated below in table NG 57/1. The testing laboratory should be accredited by UKAS or equivalent and comply with Clause 105 for the tests required.

(02/20) **Making of Cube Specimens for Testing of Compressive Strength**

6 (02/20) Where cube specimens of hardened repair concrete are required for testing by the Overseeing Organisation to confirm the 28-day strength of repair products, the compiler should refer to the list of typical sampling and testing requirements for concrete repair work listed in Series NG 100, Table NG 1/1and prepare a schedule of sampling and delivery requirements to be included in contract specific Appendix 1/6.

7 (02/20) Table NG 57/1 below shows typical laboratory tests that may be used to prepare a schedule of testing to be carried out by a UKAS or equivalent accredited testing laboratory arranged on behalf of the Overseeing Organisation.

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Table NG 57/1 (02/20) **Typical Quality Control Testing by the Overseeing Organisation**

Test characteristic	Type of repair material	Test method	Source of test samples/ frequency sampling and of testing	BS EN 1504-3 class/ testing requirement		
				Class R4	Class R3	Class R2
Consistency/flowability mortar concrete	F	BS EN 13395-2 BS EN 13395-3	Delivered or site batched material	750 mm in 30 secs	750 mm in 30 secs	N/A
Consistency/flowability mortar concrete	N	BS EN 13395-2 BS EN 13395-3	Delivered or site batched material	450 mm in 30 secs	450 mm in 30 secs	N/A
Air content of fresh concrete/mortar (Immediate environment kept at constant temp. between 5°C and 20°C for test duration.)	F, N	BS EN 12350-7	Delivered or site batched material – no compaction of mix	≤ 7%	≤ 7%	N/A
Compressive strength mortar concrete	F, N, S	BS EN 12190 BS EN 12390-3 (BS EN 196-1)	Delivered or site batched material, cast into cubes – no compaction of mix	≥ 45 MPa at 28 days	≥ 25 MPa at 28 days	N/A
Compressive strength mortar	M, R	BS EN 12190 (BS EN 196-1)	Delivered or site batched material, cast into cubes	≥ 45 MPa at 28 days	≥ 25 MPa at 28 days	≥ 15 MPa

General notes for Table NG 57/1

(i) Codes for types of repair material are F = high flow (defined in BS EN 1504 Part 3) and Clause 5715; M = repair mortar (BS EN 1504 Part 1 type PCC); S = sprayed; N = normal flow (see clause 5715); R= resin mortar (BS EN 1504 Part 1 type PC).

(ii) For quality control (assessment of conformity) of sprayed products, see Clause 5717.

(02/20) **Other Samples**

8 (02/20) Where the Overseeing Organisation wishes to inspect small samples of repair products and other materials before construction commences, the provision of these should be included in contract specific Appendix 1/6.

NG 5709 (02/20) Concrete Removal

(02/20) **General**

1 (02/20) Contract drawings should indicate the extent and depth of defective concrete to be removed, and any requirement for staged removal and for associated temporary supports. The extent of defective concrete should include areas of delaminated concrete detected by hammer sounding survey and may include any further areas which are not delaminated but heavily contaminated and where reinforcement is at high risk of corrosion as defined by BA 35 (DMRB 3.3.2).

Annex A of BS EN 1504 Part 10 includes general requirements for carrying out concrete repair and supports these with useful advice about current common construction techniques.

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The depth of concrete removal should usually be to at least 25mm behind the rear face of existing reinforcement, to ensure the repair concrete has an adequate key into the structure. The minimum depth of removal behind reinforcement may be reduced to 15mm where existing reinforcement is particularly congested but should not be less than 2 ½ times the nominal maximum aggregate size of the proposed repair product, to ensure the space behind reinforcement can be adequately filled. If the extent of concrete removal is not shown on the construction drawings, the breakout extent should be described in contract specific Appendix 57/3.

Sometimes parts of a structure are temporarily supported to relieve loading on elements that are weakened by removal and replacement of concrete.

The compiler should ensure that contract specific Appendix 57/3 is completed with a value for minimum strength of new concrete before removal of temporary supports and reloading. The value should cross reference to contract specific Appendix 57/1.

2 (02/20) Concrete removal often involves high pressure water jetting and grit blasting, and both construction activities have the potential to damage adjacent elements of the structure. The compiler should include any requirements for protection of vulnerable areas or other structural features in contract specific Appendix 57/3.

3 (02/20) All hazardous materials known or suspected to be present within the parts of the structure specified for removal or anticipated as requiring removal should be brought to the Contractor's attention. The compiler should add a schedule of hazardous materials, locations and any particular special requirements for handling or disposal in contract specific Appendix 1/23 whilst leaving the Contractor to establish safe systems of work, e.g. asbestos and relevant information from the Asbestos Action Plan Risk Register. (This would be in addition to the compiler's and designer's obligations under the Construction Design and Management Regulations).

(02/20) **Pre-Breakout Survey (Contractor)**

4 (02/20) Often there will be a time interval of months and sometimes years between the most recent concrete condition survey, and repair work starting on site.

A pre-breakout survey is required by the Contractor before the repair works commence to identify if and where areas of defective concrete have increased since the previous survey, to ensure that all delaminated concrete is replaced. The pre-breakout survey is usually undertaken jointly with the Overseeing Organisation.

The structural implications of removing defective concrete from a concrete substructure element which is usually subjected to compressive loading should be carefully considered. Adverse structural effect could be mitigated by phasing of the repair work, by propping of the superstructure or by a temporary restriction of traffic loading. Concrete removal in a tension zone could overstress the existing exposed reinforcement because anchorage length is reduced, and bars may also be corroded.

If additional concrete defects are identified during a pre-breakout survey that are a significant increase to the extent or depth of the original proposals, an addendum to the original technical approval for the structures may be required.

(02/20) **Procedure for Concrete Removal**

5 (02/20) The Contractor is responsible for complying with the contract, and sometimes no further control on concrete removal activities is considered necessary. The designer or compiler should identify areas of the structure where removal of contaminated/defective concrete could be critical to the stability and hence safety. Technical approval of the contractor's proposals may be required.

If closer control of progress on concrete removal is required, further constraints should be added to contract specific Appendix 57/3.

Aspects to consider for inclusion in contract specific Appendix 57/3 could include notification periods, inspection and recording of the substrate, certification and progression to the next stage of breakout and any related hold points for inspection and certification by the Contractor or Overseeing Organisation.

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One example of a procedure is indicated below, but this should be modified to suit the extent of control to be exercised, type of repairs known or anticipated, the extent of repairs and the relationship between the contracting and supervising parties as dictated by the form of contract:

(i) Where defective concrete has been removed in a repair area to the depth and extent required by the contract, the entire substrate in the repair area shall be hammer sounded. If there are any areas of hollow sounding concrete they shall be marked out and the Overseeing Organisation shall be notified;

(ii) The Contractor shall notify the Overseeing Organisation at least <x> hours before requiring an inspection, provide suitable access and allow a period of <x> hours for the recording and inspection;

(iii) Following inspection, the Contractor shall not proceed to the next stage of repair until the Overseeing Organisation has confirmed <by a communication method> either that:

(a) extent of breakout is accepted, and work may proceed; or,

(b) extent of breakout is unacceptable and further breakout is required prior to re-inspection; or

(c) additional breakout is specified prior to a further inspection.

(iv) The Contractor shall not remove additional concrete until the designer has confirmed the structure capacity will be adequate or whether additional temporary supports are required; and,

(v) Where the existing concrete from a specified repair area has been removed in accordance with the contract documents, additional breakout has been carried out, the substrate has been hammer sounded again, and the reinforcement has been cleaned in accordance with sub-Clause <x>, the Contractor shall notify the Overseeing Organisation of an intention to proceed to the next stage of repair.

6 (02/20) Where repairs to the top surface of concrete decks are anticipated, during replacement of existing deck waterproofing, it is often helpful to define the extent of treatment to superficial defects in sound concrete, e.g. hollows, peaks, boot marks, significant cracking, previous road planer damage etc. This may help avoid delays in construction during lane closures of short duration. Note that where delamination of concrete is caused by reinforcement corrosion, repairs to behind reinforcement should always be carried out.

Some guidance on the acceptability of the existing deck surfacing for application of waterproofing may be found in TRL Published Project Report PPR 376

The compiler should define the general procedure for dealing with superficial defects in contract specific Appendix 57/3.

(02/20) **Sequencing of Concrete Removal**

7 (02/20) The structural implications of removing defective concrete from a concrete substructure element which is usually subjected to compressive loading should be carefully considered. There is a risk of reducing the pre-stressing forces in a pre-tensioned concrete member during removal of concrete.

Adverse structural effect could be mitigated by phasing of the repair work, by propping of the superstructure or by a temporary restriction of traffic loading. Concrete removal in a tension zone could place too much reliance on the existing exposed reinforcement which may also be corroded.

While in some cases it may be possible to extend the size of the current repair to deal with all corroded reinforcement, this will not always be the case and the structural implications of further breakout should be considered. Where necessary a further stage in the repair sequence should be added.

If concrete removal and replacement needs to be carried out in stages to avoid weakening and overloading a structural element, sequencing restrictions should be described in contact specific Appendix 57/3.

(02/20) **Particular Requirements of Concrete Removal**

8 (02/20) During concrete breakout, corroding reinforcement may be found to extend beyond the edge of the repair. Breakout should be extended to expose 100mm of uncorroded reinforcement.

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9 (02/20) The primary purpose of a concrete repair is to restore the protective surround to reinforcing bars now lost due to chloride contamination and concrete delamination. However, the appearance of completed repair patches is also a relevant consideration. The perimeter of a concrete repair patch should be made up of a small number (at least 4 no.) of straight edges to form a regular shape.

(02/20) **Post-Breakout Substrate Inspection**

10 (02/20) The post breakout inspection provides an opportunity for a works supervisor to confirm that the removal of concrete in identified repair areas is proceeding satisfactorily and provides feedback to the operatives that workmanship is acceptable.

(02/20) **Methods of Removing Defective Concrete**

(02/20) **General**

11 (02/20) Trials were undertaken in 1989 investigating different techniques of concrete removal. High pressure water jetting was shown as the best technique for removal of concrete at a reasonable rate leaving a competent substrate which would provide a good bond to the repair concrete without the use of bonding agents.

High pressure or ultra-high-pressure water jetting has become popular for using in preference to mechanical breakout, because there is much smaller risk of damaging the remaining concrete by introducing micro cracking.

Break out using mechanical tools can cause micro cracking and create a weak layer or potential failure plane immediately below the broken-out surface. This is also known as concrete bruising.

12 (02/20) The risk of introducing micro cracking into pre-stressed or post-tensioned concrete members should be avoided, and defective concrete in these elements should be removed using high pressure water jetting.

13 (02/20) Other methods of concrete demolition e.g. concrete sawing, concrete removal by laser, are highly specialised processes and details of such a method are required to be prepared and submitted to the Overseeing Organisation as a departure from standard.

(02/20) **High Pressure Water Jetting**

14 (02/20) Water jetting is a potentially dangerous construction activity. The consequences of an accident to an operative when using high pressure water jetting can be severe. There is also a risk of significant overbreak if the operations are not carefully controlled. It is therefore essential that it is undertaken by operatives with appropriate qualifications, training and experience.

(02/20) **Disposal of Waste**

15 (02/20) Water arising from the concrete removal by high pressure water jetting will contain particulates, and its pH will be high. As the water sprayed at high pressure comes into contact with the concrete, the pH of the water may increase up to a value of 13 which is too high for discharge to a watercourse. The water, particulates and debris should be collected, treated and disposed of in an appropriate way.

Causing or allowing pollution of watercourses is a criminal offence and could result in prosecution. Environmental good practice guidance may be found in the Guidance for Pollution Prevention (GPPs) on the NetRegs website (www.netregs.org.uk). This guidance is applicable in the whole of the UK.

Environmental regulatory guidance for construction work in England may be found on GOV.UK website (www.gov.uk). Regulatory guidance for work in Scotland, Northern Ireland and Wales may be found in the GPPs.

Contaminated water may be treated on site to remove contamination (e.g. particulates and high pH), and subsequently discharged to a foul sewer, however the Contractor should obtain from the relevant environmental regulator or water authority prior consent to the water cleaning process and method. The Overseeing Organisation should expect to see details of such consent before the Contractor is permitted to commence disposal.

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NG 5710 (02/20) Substrate Preparation

1 (02/20) Some advice about surface profiles achievable by various methods of preparation is available in the publication "Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, Polymer Overlays and Concrete Repair" ICRI 301.2R:2013 published by the International Concrete Repair Institute (www.icri.org).

2 (02/20) Pieces of coarse aggregate consisting of certain rock types in the concrete matrix which are split by a mechanical breaker can reduce the substrate bond because the broken face is smooth. Records of aggregates used in concrete are often not available, so substrates prepared by mechanical breaking should be additionally roughened to achieve a similar profile to that achievable by high pressure water jetting.

3 (02/20) Removal of intact concrete behind the existing reinforcement may release locked in stresses that subsequently cause localised delamination. The additional hammer sounding before placing repair material is a final opportunity to ensure that all loose concrete has been removed.

4 (02/20) The substrate should be free of dust, debris, oil and any other form of laitance. Sometimes this is achieved by vacuum cleaning, however, pressurised water jetting and shot blasting is also used.

5 (02/20) A dry substrate will draw water out of a repair concrete material leaving cement particles closest to the interface incompletely hydrated and hence reducing the interface adhesion strength. It is therefore essential to pre-soak the substrate to ensure there is an adequate supply of free water present for cement hydration.

6 (02/20) Many cement-based products developed for the repair of concrete structures have been formulated to achieve good bond to a properly prepared substrate without the use of a bonding agent.

NG 5711 (02/20) Reinforcement

(02/20) Treatment of Existing Reinforcement

1 (02/20) The combination of hydro-demolition of the concrete surrounding the reinforcement followed by wet grit blast cleaning of the steel reinforcement itself is usually sufficient to remove surface contaminants and within pits and to minimise the risk of future corrosion. The micro profile imparted to the steel will also promote good bond with the repair concrete.

For cleaning of reinforcement or structural steel embedded in concrete, surface preparation standard SA 2 ½ to BS EN ISO 8501 Part 1 is equivalent to SSPC-SP10/NACE No.2. (Reference BS EN 1504 Part 10. Annex A.9. Observation No. 19)

Flash rust is an oxidation of the steel that will occur as wetted carbon steel dries. Concrete repair materials should be applied within a short period of cleaning the reinforcement to avoid further rusting occurring. Light flash rusting may be identified by inspecting the cleaned steel substrate without magnification, and only small quantities of light tan-brown rust will discolour the metallic surface. The discolouration may be evenly distributed or be in patches but will be tightly adhering and will not be heavy enough to easily mark a dry cloth brushed against it.

2 (02/20) Coating of reinforcement is not normally necessary on highway structures, because preparation of the steel surface to SA 2 ½ is usually sufficient. However, if a design detail requires the use of a reinforcement coating, the coating should comply with Table 57/2.

If the concrete-encasement of structural steel members (e.g. beams, girders, bracing etc.) is to be renewed, the compiler should consider whether to specify a bonding primer on the steelwork as well as surface profiling of the steelwork to improve the bond with the repair concrete.

(02/20) Additional or Replacement Reinforcing Bars

3 (02/20) Where repairs are being made to structures which are badly contaminated with chloride, there is the risk that, in addition to general corrosion on reinforcement, pitting corrosion will be found with potentially significant loss of section. The compiler should include in contract specific Appendix 57/2, a definition of what is assessed to be the limit of acceptable section loss due to corrosion. (Reference BS EN 1504 Part 10. Annex A.5.4. Test No. 18).

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4 (02/20) The cement content of modern-day cementitious repair products is often much higher than used in a typical 1960s concrete. If the design indicates that the existing reinforcement cannot cope with the risk of increased shrinkage forces and early thermal cracking due to anticipated high cement content of the repair concrete, the compiler should add a schedule of additional bar or mesh reinforcement to contract specific Appendix 57/2.

Refer to CIRIA C660/C766 for a guide to providing reinforcement to resist early thermal cracking.

New reinforcement should be made of carbon steel to match existing. Stainless steel is not generally permitted because of the risk of bimetallic corrosion particularly in the splash zones where corrosion has occurred previously.

(02/20) **Reinforcement Couplers**

5 (02/20) Reinforcement couplers should be made of carbon steel to be compatible with existing reinforcement.

Reinforcement coupler fatigue capacity must be suitable for the applied stress range and number of expected occurrences (cycles) of that stress range during the remaining life of the structure. For fatigue sensitive locations, couplers tested and certified to a minimum of fatigue Class D should be specified. Details of couplers certified to Class D or better are published on the CARES (www.ukcares.com) or British Board of Agrément (www.bbacerts.co.uk) websites.

Steel couplers are generally designed for splicing modern metric bar sizes. If couplers are to be used with old imperial sizes and more modern metric diameters, the coupler manufacturer should be consulted about whether the mix of sizes would affect certified strength properties.

The compiler should add in contract specific Appendix 57/2 any contract specific requirements for reinforcement couplers e.g. reinforcement diameters (if known), fatigue class and areas where couplers would not be acceptable because concrete cover could be compromised.

(02/20) **Splicing Replacement or Additional Reinforcing Bars**

6 (02/20) Wherever possible, replacement reinforcement should be lapped. Reinforcement couplers in accordance with Clause 1716 may also be considered, but adequate concrete cover should be provided.

Reinforcement lap lengths and nominal cover should be indicated in contract specific Appendix 57/2.

7 (02/20) Welding of replacement bars may be desirable because of space restrictions.

Design of welded joints should also be checked against the requirements of Clause 3.2.5 of BS EN 1992-1-1, before specifying.

Butt welding of reinforcement is the preferred method, but if this cannot be achieved, fillet welding may be acceptable provided welded bars are proposed in non-fatigue prone areas of the structures. Any proposals for fillet welding in fatigue prone locations (reference BS EN 1992-1-1) should be subject to fatigue verification assessment.

If welding of reinforcing bars is shown to be acceptable, the compiler should specify welding requirements in contract specific Appendix 57/2.

The contract compiler should include in contract specific Appendix 1/5, any requirement for pre-construction welded test pieces to prove competence of welders, and non-destructive testing of the permanent welds on site.

8 (02/20) Contractor proposals for welding should be checked for compliance with Clause 1717 and particularly Clause 3.2.5 of BS EN 1992-1-1.

(02/20) **Anchoring of Reinforcing Bars and Dowels**

9 (02/20) Where it is not practicable to remove sufficient existing concrete to completely encompass existing reinforcement (e.g. repairs to impact damaged pre-stressed beams), or when adhesion provided by the concrete substrate is considered inadequate for the applied interface stresses in service (e.g. extensive and superficial repairs to a concrete deck), additional reinforcement dowels may be provided across the interface to resist in-plane stresses. See EOTA Technical Report TR 29.

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This method of securing a repair using anchored reinforcement or dowels should not be used instead of the preferred repair solution i.e. replacing concrete to behind the outermost reinforcement to achieve a good mechanical key for the repair.

If dowels are to be anchored into a structural element subject to fire requirements, the compiler should specify a reaction to fire classification in contract specific Appendix 57/2.

NG 5712 (02/20) Galvanic Anodes for Control of Incipient Anode Effect

(02/20) General

1 (02/20) Steel reinforcement in elements of highway structures can be electrochemically protected from the risk of future transfer of corrosion to areas adjacent to repair patches (incipient anode effect) by using galvanic anodes placed within concrete repairs.

Use of galvanic anodes within repair patches may reduce the extent of sound but contaminated concrete that needs to be broken out in accordance with the guidelines in BA 35 (DMRB 3.3.2).

Galvanic anodes attached to steel reinforcement generate a protective current because the steel and the metal used in the galvanic anode have different electrochemical potentials.

Galvanic anodes should only be assumed to provide protection to the existing reinforcement within the repair patch and up to 300mm beyond the edge of the repair patch. Protection to other contaminated areas of concrete beyond this limit will not be provided.

BA 35 (DMRB 3.3.2) contains advice about the circumstances when galvanic anodes may be considered for use within proposed concrete repair patches.

Type 1A galvanic anodes are fixed directly to reinforcement within the repair areas and should be located near to and inside the perimeter of the repair. Type 1B galvanic anodes are installed in holes drilled into the substrate near the perimeter of the repair and connected to the reinforcement within the repair area.

BS EN ISO 12696 lists other types of galvanic anode not covered by Series 5700 in an informative Annex. Approval to use alternative systems should be agreed with the Technical Approval Authority and additional specification AR Clauses should be prepared for consideration by the Departure from Standards approval procedure.

2 (02/20) If there is a definite need to monitor the current being supplied by the installed anodes, monitoring points can also be used to check for indicators that protection is being achieved and reference electrodes will be needed. Unlike impressed current Cathodic Protection, the protective current supplied by galvanic anodes cannot be increased, so monitoring by reference electrode can only confirm a current is being supplied, and after the galvanic anode material is consumed, detect an increase in corrosion current.

3 (02/20) Clause 5712 does not cover cathodic protection installations using strings of galvanic anodes (e.g. tubular anodes in drilled holes and wired together). If such a system is proposed as protection to reinforcement in existing concrete contaminated by chlorides but otherwise not delaminated, additional specification AR Clauses should be prepared for consideration by the Departure from Standards approval procedure.

4 (02/20) Clause 5712 does not cover galvanic anodes with the core made from other sacrificial metals or metal alloys that are not predominantly zinc. If such alternative materials are proposed details should be provided to the Overseeing Organisation for consideration by the Departure from Standards approval procedure.

(02/20) Performance Requirements

5 (02/20) The metallic core of the galvanic anode will sacrificially corrode to protect the steel reinforcement to which it is connected. It is important that products of corrosion from the anode and any resulting reactions with activating agents and backfill do not generate chemicals which are themselves a corrosion risk to the existing reinforcement or expand so much during service that adjacent concrete is damaged.

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6 (02/20) Reference electrodes should remain useable for at least 20 years, and during that time it should be possible to reliably interrogate the system potential or corrosion current. Readings should remain stable regardless of variations in concrete temperature. More information can be obtained from BS EN ISO 12696 (monitoring sensors).

(02/20) **Acceptance of Products**

7 (02/20) Galvanic anodes are proprietary products. Their manufacture is not currently covered by a British Standard or British Standard Euronorm. As a result, the Contractor is required to provide evidence of the quality of the manufacturing process; evidence that the proposed anode has performed satisfactorily in service, and examples of installations where the product has achieved the minimum life required by the contract without premature delamination of concrete adjacent to the repair.

(02/20) **Contractor Design**

8 (02/20) Where the Contractor is required to design the galvanic anode system, the compiler should specify this in contract specific Appendix 1/10, and cross reference to contract specific Appendix 57/7.

The compiler should include in the contract appropriate supporting information e.g. the existing reinforcement drawings, concrete testing reports. The minimum free chloride content of the adjacent existing concrete, and maximum reinforcement density to be assumed in the design should be specified in contract specific Appendix 57/7.

9 (02/20) Where a longer service life than 10 years is required, the compiler should specify this in contract specific Appendix 57/7.

10 (02/20) Where permanent reference electrodes are required, the compiler should specify requirements in contract specific Appendix 57/7.

(02/20) **Products and Materials**

(02/20) **Galvanic Anodes**

11 (02/20) The metals and metallic alloys used for proprietary galvanic anodes are more active than steel in the electrochemical series. Zinc and its alloys are currently the principal materials used for manufacturing galvanic anodes. The specification requires zinc or zinc alloy metals to have high percentage purity to ensure a reasonably consistent protective current.

12 (02/20) The design of galvanic anodes relies on the sacrificial zinc element achieving an adequate efficiency/ utilisation factor. High quality zinc is specified for this.

13 (02/20) Galvanic anodes and reference electrodes rely for their operation on the free flow of electrons within the electrochemical circuit consisting of the anodes, concrete and reinforcement. The circuit relies on a durable electrical connection between the anode or reference electrode and the existing steel reinforcement, so electrical continuity of the connecting wires should be confirmed.

(02/20) **Reference Electrodes**

14 (02/20) When required for an installation of galvanic anodes connected in series, the type, number and location of permanent reference electrodes for monitoring of the installation should be specified in contract specific Appendix 57/7.

(02/20) **Installation of Galvanic Anodes and Reference Electrodes**

(02/20) **Electrical Continuity of Reinforcement**

15 (02/20) If galvanic anodes are specified within a concrete repair patch, it is very important to check there is electrical continuity between existing reinforcing bars. Continuity should be established if not present at the intersection of bars.

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(02/20) **Electrical Potential Survey**

16 (02/20) Results of the electrical potential survey will provide initial readings to compare against future readings of electrical potential and may later provide some indication of anode performance. It may take a short time period for the current developed by galvanic anodes to distribute itself throughout the reinforcement cage, achieve polarisation and provide full protection to reinforcement outside the repair patch.

(02/20) **Fitting of Anodes and Electrodes**

17 (02/20) The spacing between adjacent anodes should be specified according to the steel reinforcement surface area density (steel surface area within a 1 m^2 concrete areas), the current output capability of the individual anode and the environmental conditions, including the assumed concentration of chlorides in the neighbouring parent concrete.

The compiler should show on construction drawings the location, extent and spacing of galvanic anodes fixed to reinforcement within repairs or give details of these in contract specific Appendix 57/7. Anodes are fixed around the perimeter of a repair and are not provided in the centre of a patch.

18 (02/20) The location of reference electrodes on a structural element should be shown on construction drawings and the general location should be described in Appendix 57/7 and referenced to construction drawings.

(02/20) **Junction Boxes**

19 (02/20) Where junction boxes are required for monitoring of galvanic anodes within repairs patches, the compiler should give requirements in contract specific Appendix 57/7. This information should include location, maximum size, colour, BS EN 60529 IP rating etc.

(02/20) **Particular Requirements for Type 1A Galvanic Anodes**

20 (02/20) The resistivity of mortar or concrete used to reinstate repair patches where type 1 galvanic anodes are tied to reinforcement and incorporated within the repair should be limited to the range given in Clause 5719. More guidance may be found on the website of the Structural Concrete Alliance (Corrosion Prevention Association) (www.corrosionprevention.org.uk).

(02/20) **Particular Requirements for Type 1B Galvanic Anodes**

21 (02/20) The pH of the hole backfill/surround materials should be high enough to neutralise acid generated at the anode to avoid adversely affecting reinforcement the anode is required to protect.

(02/20) **Particular Requirements for Reference Electrodes**

22 (02/20) If reference electrodes are required for monitoring corrosion current, they should be located within the existing sound concrete, as required by BS EN ISO 12696. The compiler should describe the location of electrodes in contract specific Appendix 57/7, if locations are not shown on contract drawings.

NG 5713 (02/20) Falsework and Formwork

1 (02/20) The compiler should list any relevant drawings and any requirements or constraints on providing falsework in contract specific Appendix 1/11.

2 (02/20) The standard of finish on formed concrete repairs is often specified as F2 in accordance with Clause 1708, however if the contract requires a better finish, the compiler should specify this in contract specific Appendix 57/3.

3 (02/20) Where formwork is required for repairs to soffits, the shutters should be arranged so that a head of concrete repair material can be maintained in the feed pipe above the highest point of the repair void, hence providing enough pressure to expel air voids. Venting tubes may be required to permit trapped air to escape.

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NG 5714 (02/20) Site Mixing, Placing, Finishing and Curing

(02/20) General

1 (02/20) General advice may be found in BS EN 1504 Part 10, Annex A and BS EN 13670, Annex F. Placing and compaction of flowable products as defined in this specification is similar to BS EN 13670, section F.8.4.3 modified by constraints given in the Series 5700 specification.

Products which contain a cement binder may not gain the strength suggested by the R class if used later than the "use by" date. Packaging or containers should be marked with a declaration e.g. "this product shall be deemed to comply with BS EN 1504 Part 3 until (date)".

The specification assumes a minimum BS EN 13670 execution class of 2. If a different execution class is required, the compiler should specify this in contract specific Appendix 57/3.

(02/20) Mixing

2 (02/20) The repair products should not be contaminated by unclean water. Potable water complying with BS EN 1008 is specified in BS EN 1504 Part 10.

3 (02/20) Mixing should be done mechanically to ensure that the constituent materials are mixed thoroughly using a forced action paddle mixer of appropriate capacity. Mixing by hand may not result in the dry components being properly combined with the water or binder so should not be used.

Agitation of the concrete repair material in the mixer should be maintained until concrete is placed to maximise workability. It should be noted however that constituents will segregate if the mix is over-agitated, so the mixing process relies on the skill of the operative.

4 (02/20) The manufacturer's directions for the quantity of water to be added to the dry contents of a Type CC or PCC product will ensure the declared strength is achieved. No more water should be added as the required strength could be reduced.

(02/20) Placing and Compaction of Repair Material

5 (02/20) A dry substrate will draw water out of a cementitious repair concrete material leaving cement particles closest to the interface incompletely hydrated the substrate. It is therefore essential to keep the substrate wet before placing the material.

(02/20) Measuring Ambient Conditions and Limiting Conditions for Placement

6 (02/20) Fresh cementitious material can be damaged by frost or low temperatures and at high temperatures there is an increased risk of cracking and loss of workability. The structure has already suffered from durability problems and stringent temperature requirements are placed on concrete repairs to minimise the risk of early damage from climatic conditions. (Reference BS EN 1504 Part 10. Annex A.5.4. Test No. 10, Observation No. 21)

The rate of gain of strength of cementitious materials will be slower at lower temperatures. In a similar way the polymerisation reaction of resin binder in type PC products will be slower at lower temperatures, and if the temperature is too low, may not occur at all.

Table 57/4 clarifies the allowable limits on ambient weather conditions during placement of repair products.

If the temperature of the freshly placed repair material falls below 5°C, water in the mix will begin to freeze, and the amount available for hydration of the cement will be significantly reduced. If the temperature of the mix is too high there is a risk of rapid cement hydration, increasing evaporation of mixing water and large volume changes which could result in cracking. For a concrete exposed to either of the extremes of temperature, there is an unacceptable risk that the designed strength and bond adhesion will not be achieved.

(02/20) Construction Joints

8 (02/20) The requirements for formation of construction joints and protection of concrete after placing are broadly similar to those in Series 1700.

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(02/20) **Surface Profile and Finish**

9 (02/20) The compiler should specify the surface finish on repairs in contract specific Appendix 57/3 and in accordance with the categories in Clause 1708. Where the required surface profile on a formed or unformed concrete repair is not the same as existing, the compiler should specify profile and finish in contract specific Appendix 57/3 and additionally for sprayed concrete in Appendix 57/4 if a better finish than 'as-sprayed' is required.

(02/20) **Protection of a Completed Repair**

10 (02/20) Newly constructed concrete repairs should be protected from potentially damaging environmental conditions including excessively cold, hot, windy or wet conditions, and from contact with potentially damaging chemicals until the concrete is mature enough to be resistant.

Where repairs are carried out on the top of a bridge deck, permanent waterproofing membrane will be adequate to protect the new concrete, but it should not be applied until the moisture content of the repair has reduced to a suitable level (see CD 358 (DMRB 2.3.4)).

(02/20) **Curing of a Completed Repair**

11 (02/20) The compiler should specify in contract specific Appendix 57/3, the required BS EN 13670 curing class required for repairs, except those executed using sprayed concrete or mortar as curing class for that is specified in Clause 5717.

Adequate curing of the completed repair is particularly important as cementitious products often have high cement content, and a low water-cement ratio. Without proper curing of the repair, there is an increased risk of early thermal cracking in the immature concrete, especially when ambient temperatures are high. Guidance on methods of curing may be found in Annex F of BS EN 13670.

NG 5715 (02/20) Flowable Concrete or Mortar

1 (02/20) Methods and types of concrete repair mixes were extensively trialled for use on bridge structures in the West Midlands area in the late 1980s. The 'flowable' concrete term dates to specifications prepared at that time.

Flowable product formulations contain admixtures which promote a higher consistency at a low water-cement ratio. Only cementitious BS EN 1504 Part 1 type CC or PCC products may be described as 'flowable'.

Flowable concrete is much better than ordinary structural concrete at filling irregular shaped repair voids. Both high and normal flow concrete have been defined, when required for the scheme, the compiler should specify this in contract specific Appendix 57/1.

2 (02/20) High flow concrete is particularly suitable for use within formwork for a repair void which contains a dense arrangement of reinforcement.

Normal flow concrete could be used where reinforcement is spaced further apart or specified for reinstatement of the upper surface of a steeply sloping concrete element, where there is a risk that the "angle of repose" of fresh high flow concrete is less than the gradient of the existing element (e.g. decks with steep super-elevation >5%).

3 (02/20) When test samples (cubes or cylinders) are prepared on site to check the identity and strength of the mix, no compaction should be used as the repair material will not be compacted in-situ.

4 (02/20) Flowable concrete or mortar should distribute itself into the void and compact down to an adequate density under its own weight without need for further mechanical compaction, except light tapping of formwork if it is suspected that air could be trapped at re-entrant corners.

5 (02/20) Where contract compliance testing is required on finished repairs, the compiler should specify requirements in contract specific Appendix 1/5.

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NG 5716 (02/20) Repair Concrete or Mortar

1 (02/20) Hand- applied repair concrete or mortar may be used for reinstatement of small areas or filling core holes. Repair mortars are used for increasing the thickness of concrete cover to reinforcement where this is substandard.

Cement-based repair products BS EN 1504 Part 1, Type CC and PCC are generally suitable for small repairs (less than 1m² in area), such as a render for low cover build-up, filling test holes and the like, and are generally applied using hand-placing techniques.

Polymer-based repair products BS EN 1504 Part 1, Type PC may be suitable for superficial concrete repairs (less than 0.10 m² in area, and less than 10mm deep). Type PC products should not be used where carbon steel reinforcement is exposed in the prepared repair void as the resin does not provide the same level of passive protection to reinforcement as a cementitious product.

2 (02/20) When repair patches containing an epoxy resin binder (BS EN 1504 Part 1 type PC) are overlaid with bituminous surfacing materials hotter than 100°C, the hardened resin can temporarily lose some or most of its flexural strength as the resin warms to above its glass transition temperature. The above recommended restriction on the size of repair patch will limit the amount of deformation in the repair patch likely to occur if repair patches are subjected to wheel loads from construction plant while the bituminous material is still hot.

The epoxy resin binder in the repair patch tends to regain strength when the bituminous overlay cools, but movement of construction plant with high wheel loads over the repair areas should be minimised until the surfacing has cooled to below 100°C.

The contract compiler should specify in contract specific Appendix 57/3, restrictions on maximum size and depth of repair patches where a non-structural repair product like an epoxy resin mortar would be acceptable.

3 (02/20) Although a manufacturer may declare their products can be applied in several layers, the risk of a layer debonding increases each time another layer is placed. Repairs to soffit concrete particularly above traffic lanes, should be placed in one layer and should surround on one or more reinforcement bars to achieve an adequate mechanical key. The compiler should specify in contract specific Appendix 57/3 locations where concrete or mortar needs to be placed in a single layer.

4 (02/20) The compiler should state in contract specific Appendix 57/3, the finish required on repairs where the material is expected to be hand applied.

5 (02/20) Where contract compliance testing is required on finished repairs, the compiler should specify requirements in contract specific Appendix 1/5. U2 is the default finish.

(02/20) Treatment of Areas with Low Cover to Reinforcement

6 (02/20) In areas where the cover to existing reinforcement is low, durability of the reinforced concrete may be improved by increasing the existing thickness of concrete cover. Where possible the repair should be properly keyed into the existing concrete, and some of the existing concrete may have to be removed for the repair to encompass the reinforcement.

The compiler should specify the finished profile and construction of a typical ‘blister’ in contract specific Appendix 57/3. Alternatively, the requirements including depth of concrete removal and minimum finished cover may be shown on a drawing.

7 (02/20) Only cementitious repair products chemical type CC or PCC should be used to achieve a local increase in the cover to existing reinforcement. Type PC products are resin-based and do not provide adequate corrosion protection to the reinforcement.

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NG 5717 (02/20) Sprayed Concrete or Mortar

(02/20) General Requirements

1 (02/20) Use of a sprayed concrete containing aggregate with a maximum nominal size of 8mm should avoid excessive waste of sprayed material as a result of rebound.

2 (02/20) The Declaration of Performance for each proprietary sprayed product complying with BS EN 1504 Part 3 will indicate the manufacturer's recommended application process or processes (i.e. dry or wet spray or both).

A product formulated for dry spraying is fed into an air stream travelling at high velocity to a nozzle, where water is added. A product formulated for wet-spraying is mixed with water before being discharged from the nozzle. More information can be found on the Structural Concrete Alliance website (www.sca.org.uk) under the Sprayed Concrete Association.

By default, both dry-spray or wet-spray processes are permissible (Clause 5717.3). When one of the two forms of application (dry-spray or wet-spray) is required for a project, the compiler should specify it in contract specific Appendix 57/4, otherwise the Contractor will be free to use either form of application process.

3 (02/20) If a designed mix sprayed concrete is required, approval will be required from the Overseeing Organisation via a departure from standards procedure. The mix should be designed to achieve the essential characteristics required by BS EN 1504 Part 3 for the specified strength class.

(02/20) Compressive Strength

4 (02/20) The compiler should indicate in contract specific Appendix 57/1, the BS EN 1504 Part 3 compressive strength classification of the sprayed product required.

(02/20) Consistence

5 (02/20) Where the compiler has specified a wet spray process for placing the product, mix consistence should also be specified in contract specific Appendix 57/4. The consistence will be measured as a quality control test before and during placement.

(02/20) Pre-Construction Quality Control

6 (02/20) Only sprayed concrete operatives who have sufficient and appropriate experience of the spraying operation should undertake the work.

Evidence to demonstrate competence of sprayed concrete operatives could include:

(i) Relevant and current certificates of competence issued under a recognised industry scheme, with at least 2 years post qualification experience of concrete spraying; or,

(ii) 10 years of experience spraying concrete with suitable references being provided.

7 (02/20) Procedure trials are intended to replicate products/materials, equipment and working methods to be used in the main works.

(02/20) Procedure Trials – Construction of Test Panels

8 (02/20) The standard size of a test panel is specified in Clause 5717, although the compiler may specify a different size in contract specific Appendix 57/4. Larger test panels may be required if the concrete is to be applied by a robotic spraying system. The size of each test panel allows for the test samples listed in Table NG 57/2 to be extracted.

The compiler should specify in contract specific Appendix 57/4, the inclination of each test panel required. Panels are intended to simulate a small part of the structural element being repaired in the permanent works.

The moulds should not be coated with release agent, because adhesion developed between the concrete and the timber mould will at least partially simulate the restraint to shrinkage provided by a concrete substrate. Shrinkage will also be restrained in panels with added bar reinforcement.

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The compiler should also show on a contract drawing, details of any reinforcement required in the test panel. The type number and spacing of bars should be representative of a typical part of an element to be repaired.

Studs or screws should be cast into the test panel so that shrinkage can be measured later.

Stainless pins are cast in to measure electrical resistivity where required.

Where repairs are required to many similar structural elements e.g. pier bents, and the pattern of defects to each bent is similar, it might be appropriate to specify construction of a miniature model of an element, and for the Contractor to demonstrate repair technique on that. The mock-up model could be used instead of sprayed concrete test panels to demonstrate operator workmanship and is currently referred to in Clause NG 5707.

(02/20) **Samples to be Removed from Test Panels**

9 (02/20) The compiler should specify in contract specific Appendix 57/4 and contract specific Appendix 1/5 the samples to be removed from the sprayed concrete test panels. Typical sampling is indicated in Table NG 57/2 below.

Table NG 57/2 (02/20) **Typical Examples of Concrete Samples to be Removed from Sprayed Test Panels.**

Type of sample	No. of samples or measurement and type of panel	For testing or measurement of which performance characteristic?
Core through reinforcement (100mm dia.)	4 no. samples from 1 no. reinforced test panel	Integrity – containing minimal air voids and no shadowing behind bars
Core (50mm or 100mm dia.)	3 no. samples from each of 2 no. plain test panels	28-day compressive strength
Core (50mm or 100mm dia.)	3 no. samples from each of 2 no. plain test panels	28-day elastic modulus (secant)
Studs or screws in-situ on test panels	1 no. measurement set from each of 3 no. plain and reinforced test panels	Percentage shrinkage at 28 days
150mm cube cut from panels	3 no. samples from one or more plain test panels	Electrical resistivity at 28 days

(02/20) **Samples Remaining in the Test Panels**

10 (02/20) The Contractor can choose whether to test the concrete remaining in the test panel for shrinkage or electrical resistivity or to remove samples for subsequent testing.

(02/20) **Sampling, Inspection and Testing of Concrete Samples from Panels**

11 (02/20) Tests of concrete samples taken from panels or on concrete remaining in panels will give an indication whether the method, materials is suitable and if sprayed concrete operative has the skill to apply concrete by spraying that complies with the specification.

12 (02/20) The compiler should refer to the list of typical testing requirements for sprayed concrete test panels listed in Table NG 1/1 and draw up a specific list for inspection and testing of samples taken from the constructed test panels, or the test panels themselves. The requirements should be included in contract specific Appendix 1/5.

Options include:

(i) Inspection for voids, lamination or shadowing. To confirm that the sprayed concrete has adequately filled the test mould and achieved the required density, all 100mm diameter cores for each test panel should be inspected for voids or laminations (integrity) and shadowing behind bars. A photographic record of core integrity should be made and retained for future reference;

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(ii) Testing for compressive strength and elastic modulus. The cores taken from the panels may be destructively tested to determine the following performance characteristics when the concrete is 28 days old:

(a) compressive strength;

(b) elastic (secant) modulus.

Where a sprayed product (concrete or mortar) is specified, it may be important that the Elastic (secant) Modulus of hardened sprayed concrete is broadly matched to that of the existing concrete. This could be relevant when concrete is required to restore a cross section which is partly or completely subjected to compressive forces and required to act compositely under variable loading;

(iii) Testing for shrinkage. The concrete shrinkage will be monitored in the concrete remaining in the test panels for a period of four weeks to confirm the operative's skill. A further shrinkage measurement at 56 days will be required;

(iv) Testing for electrical resistivity. The electrical resistivity of the sprayed concrete when the concrete is 28 days old. This test would only be required if the design included galvanic anodes within repair patches or impressed current CP system within an overlay is proposed as part of the contact or planned for a later date.

(02/20) **Test Result Acceptability Criteria**

13 (02/20) If a cathodic protection system is planned to be installed over the sprayed concrete repairs as part of the contract or in the future, the compiler should include in contract specific Appendix 57/3 brief details and if available, the type and form of CP system (see also NG 5718).

(02/20) **Quality Control – Assessment of Conformity**

(02/20) **Production Control**

14 (02/20) The specification permits either the dry spray or the wet spray process for applying sprayed concrete.

Water is added to the mix at the nozzle during the dry spray process, and there is no opportunity to measure consistence before it is placed. The estimated amount of water is first set at the nozzle, then subsequently adjusted by operator judgement according to whether the mix sticks to a vertical surface without slumping off (too wet), or without significant rebound of aggregate (too dry).

The quality of sprayed concrete is easier to control if done by dry spraying. The water-cement ratio is correct if the material consistently adheres to the substrate. If too dry the sprayed material will rebound, and if too wet it will slump off. Consistency can be adjusted quickly by the nozzle operator.

Concrete pre-mixed with water (e.g. wet-spray application process) cannot be altered easily if the water/cement ratio is too high. Most concrete repairs to highway structures are relatively small scale compared with construction of tunnel linings where wet spray concrete is more frequently used. Mix consistence should be given in contract specific Appendix 57/4.

15 (02/20) The default inspection category has been set at Category 3 to permit the elastic modulus of sprayed concrete in test panels to be assessed, however the compiler may specify a lower category in contact specific Appendix 57/4, if testing for elastic modulus is not required.

(02/20) **Execution of Sprayed Concrete**

16 (02/20) Product manufacturer's data sheets give directions on how to apply the product to reliably achieve its declared performance, and any instructions for safe handling and use. BS EN 1504 Part 10 specifies application requirements in general performance terms and what needs to be done to reduce the risk of defects in finished work.

17 (02/20) BS EN 1504 Part 10 and BS EN 14487 Part 2 require over-sprayed materials applied from previous spraying to be removed before the next spraying operation, but do not cover a final clean-up of the area.

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(02/20) **Construction Joints**

18 (02/20) The requirements for construction joints in sprayed concrete are different to those typically employed for other repair methods. The surface of a temporary or permanent construction joint should be tapered back at 30º to provide a better angle of attack to the nozzle. If different parameters are required to define a construction joint, the compiler should provide a description in contract specific Appendix 57/4 or include a detail on the drawings.

(02/20) **Curing**

19 (02/20) Curing of concrete repair work is necessary to minimise the risk of plastic shrinkage and cracking in the immature material, and hence to ensure adequate durability and adequate bond strength between layers.
BS EN 13670 curing class 4 is the highest class. Some advice about curing methods may be found in Annex F of BS EN 13670.

(02/20) **Surface Finishes**

20 (02/20) Surface finish of sprayed concrete should normally be left as-sprayed from the nozzle. This is because any finishing of the surface other than very light trowelling can cause plastic cracking. This is detrimental to appearance and durability.

When there is a strong case for providing a better finish or different finish on the repair executed by spraying, the compiler may specify an alternative in contract specific Appendix 57/4.

The cut and flash method of finish involves trimming the sprayed concrete to true lines, then after an initial set, spraying again with an over-wetted flash coat to produce a textured finish.

The surface material is then trowelled smooth with a wooden float. The finer the aggregate, the easier is it to float off. Alternatively, the final layer could be textured with a brush or sponge.

(02/20) **Surface Profile**

21 (02/20) The default surface profile is specified as the same as existing for an as–sprayed concrete surface. The geometric tolerance on the surface is given in BS EN 13670, Figure G.5a and this applies to plane surfaces. Where the existing surface is curved (e.g. circular columns) the required profile should be defined in contract specific Appendix 57/3 e.g. the perimeter of a circle of diameter <x> m}.

(02/20) **Contract Compliance Tests for Completed Repairs**

22 (02/20) Where further contact compliance testing of completed sprayed concrete work is required, the compiler should include requirements in contract specific Appendix 1/5.

NG 5718 (02/20) Repairs to Structures to Receive Impressed Current Cathodic Protection

(02/20) **General**

1 (02/20) Clause 5718 includes additional requirements for repairs where the works includes cathodic protection of the existing reinforcement, consisting of an anode incorporated within a cementitious layer overlaid on repaired structural elements. The Clause would also apply if the compiler wishes to declare an intention to install a similar cathodic protection system later. The compiler should ensure that details of this have been included in contract specific Appendix 57/3.

2 (02/20) Only products containing a cement binder should be used for repairs to structural members when an additional cathodic protection system (e.g. mesh anode within a cement based overlay) is specified for application over the top.

A concrete repair product may be marketed as compatible for use with cathodic protection systems. Other products might also be suitable subject to confirmation by testing. BS EN ISO 12696 has a general recommendation that repair products should have a resistivity within the range 50 – 200% of the parent concrete.

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Resin based repair mortars are not suitable for use in conjunction with electrochemical treatments, neither are repair products containing conductive additives, admixtures or fibres. This is because current flow associated with the cathodic protection is interrupted by the high resistivity of resin and current defection of additives, admixtures and conductive fibres, and adversely affects the protection of reinforcement.

(02/20) **Removal of Detrimental Objects and Old Repairs**

3 (02/20) Metallic objects embedded and visible within the surface concrete e.g. tying wire, nails, formwork tie bars, unfixed reinforcing bar etc., are likely to interfere with and adversely affect the protective current flowing as part of the cathodic protective system. They should be identified, and a detail of how they should be treated shown on the drawings. The compiler should include a list of elements where embedded objects have been identified in contract specific Appendix 57/3.

If resistivity of an existing concrete repair patch exceeds 100 kΩ•cm, the voltage of an impressed current cathodic protection system may not be able to drive the protective current through the repair to the reinforcement. If the resistivity of an existing concrete repair is higher than permitted, and a cathodic protection system is proposed, the compiler should schedule these in contract specific Appendix 57/3.

(02/20) **Testing of Completed Repairs**

4 (02/20) The resistivity of completed repairs should not be so high it impedes current flow from an impressed current cathodic protection system applied over the top. The compiler should indicate an estimated range of electrical resistivity of the existing concrete in the second table of contract specific Appendix 57/1 (Reference BS EN 1504 Part 10. Annex A.5.4. Test No. 15).

5 (02/20) Guidance on testing of concrete for electrical resistivity may be found in Electrochemical Tests for Reinforcement Corrosion published by the Concrete Society/Institute of Corrosion and Measurement of Concrete Resistivity for Assessment of Corrosion Severity of Steel using Wenner Technique from the ACI Journal published by the American Concrete Institute.

NG 5719 (02/20) Repairs to Structures using Galvanic Anodes for Control of Incipient Anode Effect

(02/20) **General**

1 (02/20) Concrete repair product may be marketed as compatible for use with cathodic protection systems.

2 (02/20) Galvanic anodes generate their own current and drive voltage which is much smaller than an ICCP system. The galvanic current needs to draw chloride ions from the existing concrete just outside the repair patch towards the anodes.

Using a high resistivity repair product for repairs may significantly reduce current flow. The specification includes a range of acceptable electrical resistivity.

Resin-based repair mortars are not suitable for use in conjunction with electrochemical treatments; neither are repair products containing conductive additives, admixtures and fibres (e.g. steel or carbon fibres). This is because current generated by galvanic anodes is impeded by the high resistivity of polymer resin and current deflection is caused by conductive fibres. This reduces the amount of protection to reinforcement.

(02/20) **Testing of Completed Repairs**

3 (02/20) BS EN ISO 12696 has a general recommendation that repair products should have a resistivity within the range 50 – 200% of the parent concrete, however galvanic anodes generate a limited drive voltage, so a limited resistivity of the repair concrete is more important for galvanic anode systems. The range of acceptable electrical resistivity is based on the advice given in Technical Note 19 of the Corrosion Prevention Association (part of the Structural Concrete Alliance).

4 (02/20) Published guidance on testing of concrete for electrical resistivity may be found in Electrochemical Tests for Reinforcement Corrosion and Measurement of Concrete Resistivity for Assessment of Corrosion Severity of Steel using Wenner Technique.

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NG 5720 (02/20) Concrete Injection

(02/20) Introduction

1 (02/20) The underlying cause of concrete cracking should be carefully considered, and the conclusions documented before adopting a solution including crack injection.

Cracking in the existing concrete which is wider than designed or causing concern about long term durability of the structure, may be considered for injection. The structure may predate the publication of crack control codes, and cracking could be extensive if the structural reinforcement was insufficient to prevent cracking in the immature concrete.

If cracking is caused by reinforcement corrosion, a full concrete repair should be carried out because there is a risk corrosion may have caused general delamination of the concrete. Concrete injection should not be specified in an attempt to stick the delaminated concrete to the parent concrete.

BS EN 1504 Part 5 uses codes for binder types used in concrete injection products (H and P), and codes denoting the function of products (F, D and S). It should be noted that only a cementitious injection product (binder type H) will restore full passivity to reinforcement bars exposed in a crack.

2 (02/20) The specification Clause does not cover the following situations:

(i) filling of cracks with a material required to harden under dynamic loading;

(ii) filling of cracks using ductile products for water tightness at higher pressure (700MPa);

(iii) filling of cracks using swelling fitting products in contact with polymeric inserts or subject to freezing temperatures etc.;

(iv) chasing out cracks and filling them with elastomeric sealant;

(v) filling of voids outside of the concrete section;

(vi) injecting other non-concrete constructional materials e.g. Stonework, masonry;

(vii) applications in extreme environmental conditions e.g. Cryogenic use.

(02/20) General Requirements

3 (02/20) The compiler should specify in contract specific Appendix 57/5, the location and dimensions of cracks requiring treatment. In addition, the compiler should specify the function the injection product is intended to perform. BS EN 1504 Part 5 injection product function categories are:

(i) capable of transmitting force (F);

(ii) remaining ductile (D);

(iii) swelling to fill the crack (S).

The Contractor will be free to choose a hydraulic (H) or polymer (P) based product that complies with the specification.

Further information and guidance may be found in Concrete Society publication TR 69, Repair of Concrete Structures with reference to BS EN 1504.

(02/20) Requirements for BS EN 1504 Part 5 Products for Concrete Injection

4 (02/20) Where concrete injection products are required to comply with additional performance characteristics permitted by BS EN 1504 Part 5 for certain intended uses e.g. adhesion by slant shear strength; glass transition temperature; chloride content; water tightness, the compiler should specify these in contract specific Appendix 57/5. Tables 1, 2, and 3 of BS EN 1504 Part 5 indicate which additional characteristics for certain intended uses are permissible, but the compiler should consider before specifying whether the additional requirements are necessary for adequate performance of the repaired element.

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5 (02/20) Tables 57/6, 57/7 and 57/8 are based on Tables 6, 7 and 8 of BS EN 1504 Part 5. The tables have been sub-divided for of the two common classifications of binder (H and P) used for formulating the products. Binder types are defined in the standard.

(02/20) **Inspection to Identify Cracks for Treatment**

6 (02/20) Where the Contractor is required to carry out a survey of concrete cracking, the compiler should specify details in contract specific Appendix 57/5.

(02/20) **Quality Control Tests**

7 (02/20) The compiler should specify routine quality control tests in contract specific Appendix 1/5, with reference to Table NG 1/1 in Series NG 100.

(02/20) **Preparation of Cracks**

8 (02/20) BS EN 1504 Part 10, Annex A.8 contains advice about techniques of concrete injection. Moisture within a crack may be pre-existing or introduced during cleaning. It should be removed prior to filling of cracks. Hot air may be used for this, and a method using nitrogen gas could also be considered.

(02/20) **Execution of Concrete Injection**

9 (02/20) BS EN 1504 Part 10, Annex A.8 contains advice about techniques of concrete injection. Further information and guidance may be found in Concrete Society publication TR 69, Repair of Concrete Structures with reference to BS EN 1504.

Concrete injection should be carried out by an appropriate method that ensures complete filling of the crack. If the proposed method includes combined vacuum and pressure, injection pressures will generally be limited to a positive pressure of 1.5 bar combined with a vacuum negative pressure not greater than –0.75 bar.

(02/20) **Contract Compliance Tests**

10 (02/20) The frequency of contract compliance testing should be indicated in contract specific Appendix 1/5, with reference to Table NG 1/1 in Series NG 100.

NG 5721 (02/20) Contract Compliance Testing on Completed Repairs

(02/20) **General**

1 (02/20) Guidance and background information about quality control methods of assessing compliance the contract specification may be found in the Annex A of BS EN 1504 Part 10 under Tests and Observations.

2 (02/20) Where removal of concrete samples is specified in Appendix 57/3, this should be cross referenced to the completed contract specific Appendix 1/5 for subsequent testing.

(02/20) **Repair Sounding – Integrity of Repair**

3 (02/20) Adhesion between the hardened repair material and the substrate should be allowed to develop during the curing period before the repair is sounded by hammer testing to check for adequate bond. (Reference BS EN 1504 Part 10. Annex A.5.4, Test No. 1).

Ringing of newly placed but hardened repair concrete can be achieved with a light hammer or short length of steel tubing. Hammer tapping is used to detect loose concrete.

The contract compiler should refer to Table NG 1/1 in Series NG 100 to specify hammer sounding of completed repairs in contract specific Appendix 1/5.

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(02/20) **Conductivity of Repair – Electrical Resistivity Measurement**

4 (02/20) Galvanic anodes generate a limited drive voltage, so a limited resistivity of the repair concrete containing galvanic anode is important for effective functioning of the protection.

Where impressed current cathodic protection is to be applied over concrete repairs, the compiler should indicate an estimated range of electrical resistivity of the existing concrete in the second table of contract specific Appendix 57/1 (Reference BS EN 1504 Part 10. Annex A.5.4. Test No. 15).

The contract compiler should refer to Table NG 1/1 in Series NG 100 and refer to Table NG 1/1 in Series NG 100 to complete the required testing schedule in contract specific Appendix 1/5.

The range of acceptable electrical resistivity is based on the advice given in Technical Note 19 of the Corrosion Prevention Association (part of the Structural Concrete Alliance).

Published guidance on testing of concrete for electrical resistivity may be found in Electrochemical Tests for Reinforcement Corrosion and Measurement of Concrete Resistivity for Assessment of Corrosion Severity of Steel using the Wenner Technique.

Methods of measuring the resistivity of concrete both in the laboratory and in-situ are given in RILEM TC-154 Technical Recommendation where 4-pin, 2-pin and surface electrode to reinforcing cage methods are discussed along with temperature compensation.

It should be noted that the document states that a coefficient of variation of 30% in resistivity measurements is normal in the field.

(02/20) **Cores – Integrity of Repair**

5 (02/20) Confirmation that the repair material has properly filled the repair area and whether the repair has bonded to the substrate may be obtained by drilling cores through the repair. Inspection of these cores would be used to assess whether the repair is satisfactory and whether the repair works can proceed to the next stage, including where relevant, the removal of any temporary support (Reference BS EN 1504 Part 10. Annex A.5.4, Observation No. 39).

The contract compiler should specify the frequency and distribution of coring in contract specific Appendix 57/3 and refer to Table NG 1/1 in Series NG 100 to complete reference to contract specific Appendix 1/5 for testing requirements. The exact location will be proposed by the Contractor on site, usually with the aid of a cover meter or by reference to records of the location of the reinforcement obtained during the pre-concreting inspection.

(02/20) **Cores – Adhesion to Substrate**

6 (02/20) The compiler should specify the frequency and distribution of cores in contract specific Appendix 57/3 and should refer to Table NG 1/1 in Series NG 100 to complete the required testing schedule in contract specific Appendix 1/5.

Repairs should be allowed to develop a strength of at least 10 MPa before cores are drilled to reduce the risk of cores disintegrating during cross cutting. Strength may be estimated from compressive tests on cubes or prisms.

Adhesion strength at the interface between newly placed repair material and the existing substrate will increase with the development of compressive strength. Cores taken from a repair should not be tested for adhesion strength until the required characteristic compressive strength has been achieved (Reference BS EN 1504 Part 10. Annex A.5.4. Test No. 35).

(02/20) **Cores – Compressive Strength**

7 (02/20) Cores taken through completed work to assess integrity of the hardened material may also be destructively tested for compressive strength, however a written and photographic record of the cores should be taken, and all records should be retained for future reference (Reference BS EN 1504 Part 10. Annex A.5.4, Test No. 36).

Cores taken through completed work may only be necessary for sprayed concrete where samples have not been taken from test panels.

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The compiler should specify the frequency and distribution of cores in contract specific Appendix 57/3 and should refer to Table NG 1/1 in Series NG 100 to complete the required testing schedule in contract specific Appendix 1/5.

(02/20) **Cores – Injection/Filling of Cracks**

8 (02/20) Coring through filled cracks will provide evidence that the injected product has filled the cracks. If the extent of crack filling is not acceptable, cores can be loaded in compression to destruction as further test.

The compiler should describe the general location for cores in contract specific Appendix 57/5 and should refer to Table NG 1/1 in Series NG 100 to complete the required testing schedule in contract specific Appendix 1/5.

The existing reinforcement should be located and marked before deciding where to drill the core holes (Reference BS EN 1504 Part 10. Annex A.5.4, Observation No. 33).

(02/20) **Adhesion to Substrate**

9 (02/20) BS EN 1504 Part 10, Annex A.5.2, Table A.2 suggests values for adhesion strength of repair mortar. The compiler should specify target adhesion strength for each location in contract specific Appendix 57/3.

(02/20) **Compressive Strength**

10 (02/20) Compressive strength of tested samples should be greater that required by the BS EN 1504 Part 3 strength class of proprietary products, specified in contract specific Appendix 57/1.

(02/20) **Filling or Injecting of Cracks**

11 (02/20) It is normal for the repair industry to specify that cracks being injected should be filled at least 80% full by volume. If the compiler considers that a higher percentage is necessary for a scheme, this may be specified in contract specific Appendix 57/5. It is unlikely that cracks can be 100% filled.

If the cores taken through filled cracks show that they are not filled adequately, the cores may be further assessed for acceptability by compression testing to determine adhesion strength between the hardened injection material and the parent concrete (Reference BS EN 1504 Part 10. Annex A.5.4. Test No. 44).

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(02/20) NG SAMPLE CONTRACT SPECIFIC APPENDIX 57/1: REPAIR PRODUCT – REQUIREMENTS

[Note to compiler: Include here the following contract specific requirements and details:]

1 (02/20) Assumed repair method for each construction activity, reference BS EN 1504 Part 9. *[5702.1, 5708.2]*

2 (02/20) Contract specific requirements for performance characteristics of repair products. *[5703.2(i), 5703.5(i), NG 5703, 5704.2, Table 57/1, 5709.12, 5715.2, 5717.5, Table 57/5, NG 5715, 5717.16, NG 5717, 5721.7, 5721.16]*

Description of structure and/or structural element	BS EN 1504 Part 3 strength class of repair product ⊗	Fire class required (BS EN 13501-1) *0*	Type of flowable material (F, N) +	Minimum compressive strength of repair product (MPa) *

[Notes to compiler. Notes should be removed from contract specific appendices:

(i) *Columns should only be included in the table if the performance characteristic is required.*

(ii) *The requirements should not contradict performance requirements listed in BS EN 1504 Part 3, Table 3 for the required product class.*

(iii) ⊗ *With reference to Specification Table 57/1 This class should always be specified.*

(iv) *0* *Fire class in accordance with BS EN 1504 Part 3, sub-clause 5.5 where the possibility of fire damage to a structure under repair is required by a design code of practice or is reasonably foreseeable. See also BS EN 13501 Part 1.*

(v) + *If a flowable repair material is required, the flowability class should be specified. Otherwise omit column*

(vi) * *Represented by characteristic compressive strength of the existing concrete to be repaired, taken from the design or as-built contract documentation or measured compressive strength of samples taken from the existing concrete. This value should only be specified if a compressive strength greater than 50 MPa is required. Omit this column if not applicable.]*

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3 (02/20) Contract specific information provided to assist Contractor in choice of repair product. *[5703.2(i), 5703.5(i), Table 57/5, 5717.16, NG 5718, 5721.3, 5721.11]*

Description of structure and/or structural element	Compressive strength of existing concrete being repaired. # (MPa)	Static elastic modulus of existing concrete in tension (T) or compression (C) x (MPa)	Galvanic anodes required within repair patches? ϕ (Yes/No)	Range of electrical resistivity of parent concrete ♠ (Ω•cm)	Minimum strength of repair concrete before loading permitted. Ƀ (MPa)

[Notes to compiler. Notes should be removed from contract specific appendices:

(i) # *Compressive strength of existing concrete. This can be compressive strength taken from either design, contract or as-built drawings, or tested compressive strength.*

(ii) x *Static elastic modulus of existing concrete estimated from assumed compressive strength. This could be particularly important for repair to structural elements where repair is in compression and subjected to frequent cycles of transient loading, where repairs are located above trafficked areas. Include only if relevant, otherwise omit column.*

(iii) ϕ *If impressed current or galvanic anode cathodic protection system is proposed for the repaired concrete. Minimum and maximum values of resistivity for the existing concrete should be stated. Declare 'yes' or 'no'. If 'yes' complete column for range of electrical resistivity of existing concrete, and cross reference to contract specific Appendix 57/7.*

(iv) ♠ *If repairs to existing concrete precede the installation of a cathodic protection system, allowable resistivity of completed repairs depends on knowing the resistivity of the existing concrete.*

(v) Ƀ *Minimum compressive strength required before loading. May be relevant for phased working necessary to limit effect of element weakening during concrete removal, or before waterproofing a deck during a short lane closure. Cross reference to contract specific Appendix 57/3. Add if relevant, if not omit column.]*

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(02/20) NG SAMPLE CONTRACT SPECIFIC APPENDIX 57/2: REQUIREMENTS FOR REINFORCEMENT

[Note to compiler: Include here the following contract specific requirements and details:]

1 (02/20) Circumstances when a primer or barrier coating is required to be applied to prepared surface of existing or new reinforcement or to structural steelwork. *[5703.2(ii), 5711.3]*

2 (02/20) Definition of the limiting corrosion condition of existing reinforcement (typical average section loss) Greater loss of steel in the cross section would require the affected reinforcement bars should be cut out and replaced, or new bars lapped. *[5711.4]*

3 (02/20) Schedule of reinforcing bars to be maintained on site or reinforcement bending schedule and lapping requirements. *[5711.5]*

4 (02/20) Requirements for steel reinforcement couplers including type, reinforcement diameter, minimum fatigue class. *[5711.7]*

5 (02/20) Requirements for lapping of new steel reinforcement to existing reinforcement. *[5711.8]*

6 (02/20) Specific requirements for site welding of reinforcement, where it is permitted. *[5711.9]*

7 (02/20) Requirements for anchoring of steel reinforcement or dowels including reaction to fire class for any polymer-based reinforcement anchoring product. *[5711.11, table 57/3]*

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(02/20) NG SAMPLE CONTRACT SPECIFIC APPENDIX 57/3: EXECUTION OF CONCRETE REPAIRS

[Note to compiler: Include here the following contract specific requirements and details:]

1 (02/20) Notification to Contractor to allow for a known proposal to install impressed current cathodic protection mesh anode within an overlay as part of a separate contract. *[5703.3(ii), 5717.17, 5718.1, 5721.3]*

2 (02/20) Any contract specific constraints on the location, extent or depth of repair patches for application of BS EN 1504 Part 1 types (CC, PCC or PC) repair product. *[5704.4, 5716.2]*

3 (02/20) Details, including location, of required trial of concrete repair method on the structure or a smaller scale reinforced concrete mock up/model of the structure. *[5707.1, NG 5707.1]*

4 (02/20) Depth of existing concrete to be removed relative to surface or to existing rebar or both. *[5709.1]*

5 (02/20) List of structural elements that are particularly vulnerable to damage from concrete removal activities and any protection requirements e.g. measures identified during safety risk assessment. *[5709.3]*

6 (02/20) Requirements/constraints including hold points for phased removal of existing delaminated or contaminated concrete including minimum strength of concrete repair (cross reference to Appendix 57/1) before progress to adjacent repair areas. *[5702.7, 5709.5, 5709.10, 5709.12, 5709.19]*

7 (02/20) List of old high resistivity repairs and description and location of detrimental metal objects to be removed from the existing concrete. *[5709.8, 5718.4, 5718.5]*

8 (02/20) List type, extent and depth of defects (shallow blemishes, cracking or damage etc.) in the existing non-delaminated concrete deck surface, and principles of treatment by breakout and reinstatement to be applied prior to applying surface protection systems e.g. deck waterproofing. *[5709.11]*

9 (02/20) Requirement for better than an F2 formed surface finish. *[5713.2]*

10 (02/20) BS EN 13670 execution class for each element of repair work, if not Class 2. *[5714.1]*

11 (02/20) Required surface profile of completed repairs if not the same as existing. *[5714.11, 5717.27]*

12 (02/20) Required formed or unformed surface finish on concrete repairs. *[5714.12, 5716.4]*

13 (02/20) Required BS EN 13670 curing class for each element to be repaired. *[5714.15]*

14 (02/20) Locations where repair concrete or mortar should be applied in only one layer e.g. soffits above live traffic. *[5716.3]*

15 (02/20) Minimum cover to reinforcement required for areas where existing cover is low, surface profile of reinstated concrete "blisters" to restore cover to reinforcement, construction depth of repair and description of how repair should be tied into existing concrete. *[5716.6]*

16 (02/20) Distribution of cores to prove conductivity, integrity, adhesion and compressive strength of repair areas as part of contract compliance testing. *[5721.5, 5721.6, 5721.7, 5721.8]*

17 (02/20) Target adhesion strength of repair mortar material at interface with concrete substrate in accordance with BS EN 1504-10, Table A.3. *[5721.15]*

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(02/20) NG SAMPLE CONTRACT SPECIFIC APPENDIX 57/4: SPRAYED CONCRETE

[Note to compiler: Requirements for proprietary sprayed concrete products should be specified in terms of product classes in accordance with Clause 5704.2.]

1 (02/20) Requirement for a particular sprayed concrete application process i.e. dry-spray or wet spray. *[If not completed the Contractor will be free to choose.] [5717.3]*

2 (02/20) If a wet-spray application process is specified, the required consistence of the mix in accordance with BS EN 206. *[5717.6, 5717.19]*

3 (02/20) Different requirements for size of sprayed concrete test panels. *[5717.9]*

4 (02/20) Required inclination of each pre-works sprayed concrete test panels. *[5717.9]*

5 (02/20) Samples to be removed from the pre-works sprayed concrete test panels for later testing. *[5717.9]*

6 (02/20) Inspection category if not BS EN 14487 Part 1, Category 3. *[5717.21]*

7 (02/20) Alternative requirements for formation of construction joints. *[5717.24]*

8 (02/20) Description and specification of alternative to as-sprayed concrete finish. *[5715.26]*

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(02/20) NG SAMPLE CONTRACT SPECIFIC APPENDIX 57/5: CONCRETE INJECTION

[Note to compiler: Include here the following contract specific requirements and details:]

1 (02/20) Required concrete crack repair method for each structural element reference BS EN 1504 Part 9 (Principle 1, method 1.5, Principle 4, method 4.5 or Principle 4, method 4.6). *[5702.1]*

2 (02/20) Schedule of characteristics for each crack or group of similar cracks to be injected (structure identification, element reference, location, length, minimum thickness). Example shown below. *[5703.5, 5720.3, Table 57/6]*

Structure ID	Structural element type	Location	No of crack defects	Range of crack length (mm)	Minimum width of crack (mm)	Maximum width of crack (mm)
e.g. Bridge A	*Beam 4*	*East end*	*3*	*300 – 600*	*0.25*	*0.75*

3 (02/20) The function each injection product should perform – force transmitting filling, ductile filling or swelling-fitted filling in accordance with BS EN 1504 Part 5 should be tabulated for each defect to be treated under references for individual defects or set of defects grouped under a structural element reference number. Example is shown in the table below. *[5703.2 (iii), 5720.3, 5720.4, Table 57/6, Table 57/7, Table 57/8]*

Function of injection product				Force transmitting filling (F)	Ductile filling (D)	Swelling fitted filling (S)
Performance requirement				(Basic characteristic) Adhesion by tensile bond strength * (F1 or F2)	(Basic characteristic) Adhesion strength ** (N/mm^2)	(Workability characteristic) Expansion ratio ** (%)
Structure ID	Structural element type	Location	No of crack defects			
e.g. Bridge A	*Beam 2*	*North end*	*3*	*F2*	–	–
e.g. Culvert B	*Soffit*	*Middle*	*6*	–		*10*
e.g. Retaining wall C	*Stem*	*Every 10m*	*4*	–	*3.0*	–

[Notes to compiler. Notes should be removed from contract specific appendices:

* *required for hydraulic and polymer based products.*

** *required for polymer based products.*

(i) delete injection product function columns if not required.

(ii) remaining performance characteristics are in tables 57/7, 57/8 and 57/9 of the Specification.]

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4 (02/20) Additional performance requirements of essential characteristics (reference BS EN 1504 Part 5, Tables 1, 2 or 3) for certain intended uses of injection products (reference BS EN 1504 Part 5, Tables 6, 7 or 8) appropriate to the specified function classification. *[5720.4]*

Function of injection product	Force transmitting filling (F)			Ductile filling (D)		Swelling fitted filling (S)
Performance requirement Structure ID/ element type/ location	Adhesion by slant shear strength * (N/mm^2)	Glass transition temp.** (°C)	Chloride content *** (%)	Watertightness**	Glass transition temp. ** (°C)	Corrosion behaviour **

[Notes to compiler. Notes should be removed from contract specific appendices:

* *required for hydraulic and polymer based products.*

** *required for polymer based products.*

*** *required for hydraulic based products.*

(i) Delete injection product function columns if not required.

(ii) See BS EN 1504 Part 5 tables 6, 7 and 8 for recommended requirement.]

5 (02/20) Requirement for survey of cracks with the Overseeing Organisation to confirm extent of crack treatment. *[5720.5]*

6 (02/20) Distribution of cores through filled/injected cracks to demonstrate crack filling and bond strength of interface. *[5721.9]*

7 (02/20) Acceptable minimum percentage filling by volume of crack exposed in core if different from 80%. *[5721.17]*

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(02/20) NG SAMPLE CONTRACT SPECIFIC APPENDIX 57/6: CONTRACTOR INVESTIGATION OF CONCRETE CONDITION

[Note to compiler: Include here the following contract specific requirements and details:]

1 (02/20) The location of required investigation.

2 (02/20) Requirements for concrete investigation by the Contractor including:

i) Physical investigation:

(a) The type of defects to be recorded.

(b) Extent of concrete sounding to detect delamination

ii) Survey by instrument:

(a) Reinforcement cover survey.

(b) Electrical potential mapping.

(c) Concrete resistivity.

iii) Intrusive investigation:

(a) Location, number, diameter, depth of cores.

(b) Location, number, size, depth of trial pits.

iv) Laboratory testing:

(a) Chloride penetration.

(b) Carbonation penetration.

(c) Cement content.

(d) Other tests.

3 (02/20) Requirements for reporting:

i) Factual only report.

ii) Factual and interpretive report. *[5706.1]*

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(02/20) NG SAMPLE CONTRACT SPECIFIC APPENDIX 57/7: REQUIREMENTS FOR GALVANIC ANODES

[Note to compiler: Include here the following contract specific requirements and details:]

1 (02/20) Requirements for Contractor to design galvanic anode installation. *[5712.10]*

2 (02/20) Required service life of galvanic anodes if different from 10 years. *[5712.11]*

3 (02/20) Requirements of reference electrodes for monitoring:

(i) Type, size, material.

(ii) Location. *[5712.12, 5712.18, 5712.36]*

4 (02/20) Required spacing of galvanic anodes around the perimeter of repair, if not specified on the drawings. *[5712.24]*

5 (02/20) Requirements for monitoring of galvanic anode installation including:

(i) Connections.

(ii) Junction boxes.

(iii) Control boxes.

(iv) Terminals for local or remote monitoring. *[5712.29]*

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