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Transport Infrastructure Ireland

TII Publications



The Protection and Repair of Concrete Road Structures

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NRA DMRB and MCDRW References

For all documents that existed within the NRA DMRB or the NRA MCDRW prior to the launch of TII Publications, the NRA document reference used previously is listed above under 'historical reference'. The TII Publication Number also shown above now supersedes this historical reference. All historical references within this document are deemed to be replaced by the TII Publication Number. For the equivalent TII Publication Number for all other historical references contained within this document, please refer to the TII Publications website.

The Protection and Repair of Concrete Road Structures

January 2016

Summary:

This Standard sets out the principles for the protection and repair of concrete road structures that have suffered damage or deterioration. It contains the basic information necessary to establish a route to achieving an acceptable level of concrete repair.

**VOLUME 3 ROAD STRUCTURES:
INSPECTION AND
MAINTENANCE**

SECTION 3 REPAIR

PART 2

NRA BD 27/16

**THE PROTECTION AND
REPAIR OF CONCRETE ROAD
STRUCTURES**

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1. INTRODUCTION

General

- 1.1 For concrete repairs to be successful it is necessary to use appropriate materials and techniques. Failure to do so will result in a recurring maintenance problem. Concrete repair is a specialist activity requiring fully trained and competent personnel at all stages of the process. This Standard sets out the principles for the protection and repair of concrete road structures that have suffered damage or deterioration.
- 1.2 This Standard contains information necessary to establish a route to achieving an acceptable level of concrete repair.
- 1.3 This Standard is consistent with IS EN 1504 – Products and Systems for the Protection and Repair of Concrete Structures – Definitions, requirements, quality control and evaluation of conformity.
- 1.4 The various parts of IS EN 1504 are comprehensive and provide information and guidance to those involved in the concrete repair process. IS EN 1504 is divided into 10 parts, see Table 1, and it addresses all stages of the repair process.

IS EN 1504 Part No.	Document Title
Part 1	Definitions
Part 2	Surface protection systems for concrete
Part 3	Structural and non-structural repair
Part 4	Structural Bonding
Part 5	Concrete Injection
Part 6	Anchoring of reinforcing bars
Part 7	Reinforcement corrosion protection
Part 8	Quality control and evaluation of conformity
Part 9	General principles for the use of products and systems
Part 10	Site application of products and systems and quality control of the works

Table 1: List of IS EN 1504 Parts

Scope

- 1.5 This Standard does not cover the specification of concrete repairs. Further information on the specification of concrete repairs can be found in NRA MCDRW Series 5500.

Definition

1.6 For the purpose of this Standard the following definitions apply:

- i) Structural Assessment Engineer: Engineer with recognised University degree to Level 8 or equivalent with a minimum 7 years post graduate experience in the design and assessment of bridge structures, with experience in concrete and reinforced concrete deterioration and repair.
- ii) Specialist Repair Contractor: Shall have a proven track record in the field of concrete repair with a minimum of 10 years' experience working on bridge structures. Shall be ISO 9001 and IS EN 14001 accredited.

2. DETERIORATION

General

- 2.1 There are several potential causes of deterioration in concrete structures. For example, the largest single cause of deterioration in reinforced concrete is corrosion of the reinforcement. In addition, there are a number of deterioration processes that attack the concrete matrix as well as defects caused by inadequate design, specification or use of unsuitable construction materials.
- 2.2 With any concrete repair it is essential that a thorough investigation of the nature and extent of any concrete deterioration is undertaken prior to any remedial works so that the cause of the problem is adequately established. This investigation shall be conducted by a Structural Assessment Engineer as defined in 1.6. The main objective shall be to address the cause of the concrete deterioration and not just tackling the symptoms.

Common Causes of Deterioration

- 2.3 Some common causes of defects, damage and decay in concrete structures are given below in Figures 1a and 1b. More detailed information can be found in Concrete Society Technical Report No. 54, 'Diagnosis of Deterioration in Concrete Structures'⁽¹⁾.

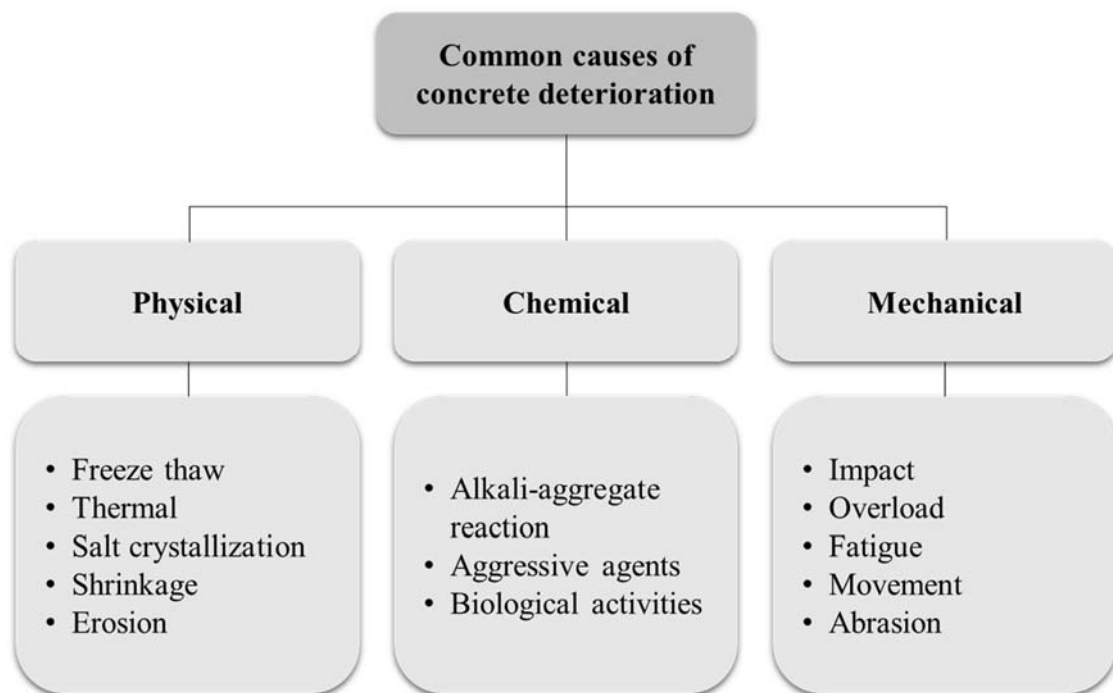


Figure 1a: Common Causes of Concrete Matrix Deterioration

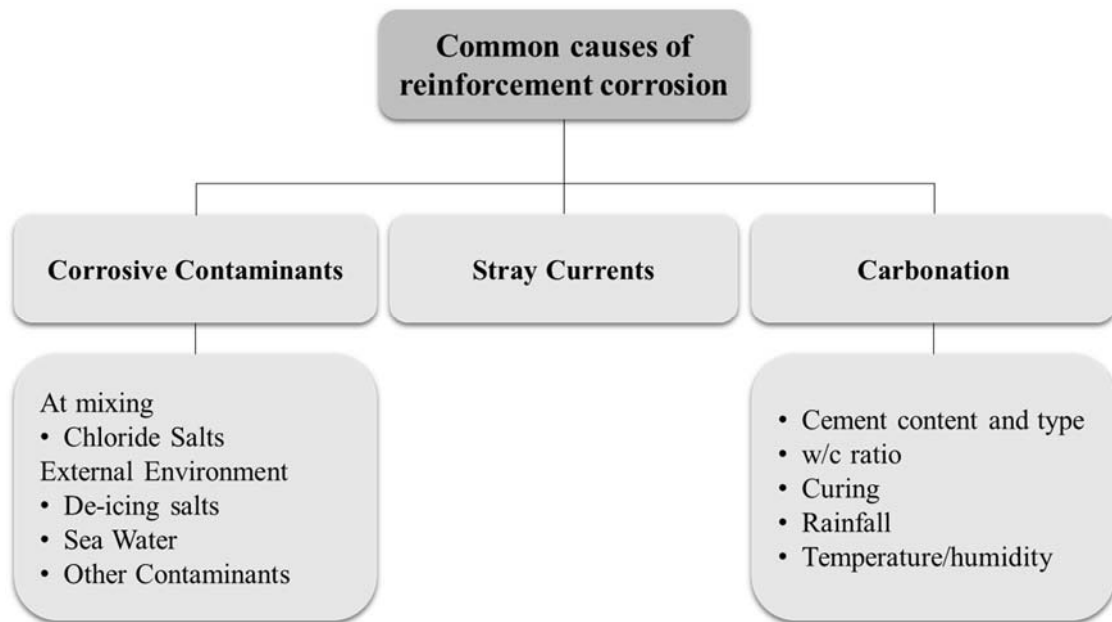


Figure 1b: Common Causes of Reinforcement Corrosion

2.4 The nature and causes of defects, including combination of causes shall be identified and recorded prior to any concrete repair in accordance with NRA BD 02.

3. KEY STEPS IN THE REPAIR PROCESS

- 3.1 The general approaches to concrete repair are set out in IS EN 1504-9, ‘General Principles for the use of products and systems.’
- 3.2 Having identified the need for some form of remediation of a structure, IS EN 1504-9 is the initial document that the Structural Assessment Engineer shall consult. It provides a structured approach to defect investigation and the identification of the cause of deterioration and outlines principles of remedial action using products and systems compatible with European Standards.
- 3.3 All repairs to concrete structures shall follow a logical number of key steps as illustrated below in Figure 2⁽²⁾, considering options and selecting principles aimed at achieving value based on whole life costing.



Figure 2: Key Steps in the Repair Process

3.4 The key steps may be summarised as follows:

3.4.1 **Assess structure:** It is essential that a formal assessment of a structure's condition is undertaken by a Structural Assessment Engineer, prior to any decision on repair being made, in order to accurately determine the causes of deterioration (e.g. salt exposure; under-design; concrete defects, etc.).

3.4.2 **Choose options:** Once the deterioration problem has been identified and the current and likely future deterioration is estimated, the options for repair, along with their potential costs and timescales shall be assessed.

The following options should be taken into account in deciding the most appropriate action to meet the future requirements and the desired residual service life of the structure. These can be used singly but are more commonly used in combination:

- Do nothing for a certain time, but monitor the structure;
- Analyse the structural capacity of the weakened element;
- Prevent or reduce further deterioration;
- Improve, strengthen or refurbish all or part of the structure;
- Replace all or part of the structure;
- Demolish, completely or partially.

3.4.3 **Select repair principles:** Select the appropriate principles as given in Chapter 4.

3.4.4 **Choose repair methods:** Choose methods which are appropriate to the selected repair principles. Refer to Chapter 4.

3.4.5 **Specify material performance:** Repair materials should be selected with the performance characteristics required for the chosen application.

3.4.6 **Carry out repair:** Repair shall be carried out by a Specialist Repair Contractor with appropriate experience in concrete repair methods. The work shall be supervised by the Employer's Site Representative to ensure consistency and quality of the repair.

3.4.7 **Set out on-going requirements:** Develop instructions on inspection and maintenance for the residual life of the structure.

3.5 All repair proposals shall be documented in accordance with NRA BD 02 and shall be approved by the Structures Section of Transport Infrastructure Ireland prior to any works being carried out.

4. PRINCIPLES AND METHODS FOR PROTECTION AND REPAIR OF CONCRETE STRUCTURES

General

- 4.1 The protection and repair of concrete structures requires complex design work. IS EN 1504-9 defines the basic principles that shall be used to protect and repair concrete structures which have suffered or may suffer damage or deterioration and gives guidance on the selection of products and systems which are appropriate for a particular intended use.
- 4.2 The scope of IS EN 1504-9 does not specifically cover structures containing tensioned reinforcement (pre-tensioned or post-tensioned). However, there is no reason why the principles of Part 9 and the associated product performance Standards (Parts 2-6) and site application (Part 10) would not apply to these repair situations providing careful consideration is given to the behaviour of the structure. All proposed repair work on structures containing tensioned reinforcement shall be agreed with the Structures Section of Transport Infrastructure Ireland prior to any work taking place.
- 4.3 It should be noted that the repair of historical structures may have project-specific requirements such as minimising the removal of original material or aesthetics which modify the application of the repair principles. Specialist advice should be sought before undertaking any work on an historical structure. Refer to NRA BD 89, 'The Conservation of Road Structures,' for further guidance.

Principles of Repair

- 4.4 The principles of protection and repair are based on chemical, electrochemical and physical principles that can be used to prevent or stabilise the deterioration of concrete, electrochemical corrosion on the steel reinforcement surface or to strengthen the concrete structure as a whole.
- 4.5 For the protection and repair of concrete structures, different principles have been defined separately for defects in concrete and damages induced by reinforcement corrosion. There are 11 Principles of Remedial Action, six relate to defects in concrete and five relate to reinforcement corrosion. These principles are listed and defined in Table 2.

Principle No.	Principle Definition
Principles related to degradation of the concrete matrix	
Principle 1 [PI]	Protection against ingress Reducing or preventing the ingress of adverse agents
Principle 2 [MC]	Moisture control Adjusting and maintaining the moisture content in the concrete within a specified range of values
Principle 3 [CR]	Concrete restoration Restoring the original concrete of an element of the structure to the originally specified shape and function Restoring the concrete structure by replacing part of it
Principle 4 [SS]	Structural strengthening Increasing or restoring the structural load bearing capacity of an element of the concrete structure
Principle 5 [PR]	Physical resistance Increasing resistance of the concrete surface to deterioration by chemical attack
Principle 6 [RC]	Resistance to chemicals Increasing resistance of the concrete surface to deterioration by chemical attack
Principles related to reinforcement corrosion	
Principle 8 [IR]	Increasing resistivity Increasing the electrical resistivity of the concrete
Principle 9 [CC]	Cathodic control Creating conditions in which potentially cathodic areas of reinforcement are unable to drive an anodic reaction.
Principle 10 [CP]	Cathodic Protection A technique to control the corrosion of reinforcement by making it work as a cathode of an electrochemical cell
Principle 11 [CA]	Control of anodic areas Creating conditions in which potentially anodic reactions of reinforcement are unable to take part in the corrosion reaction

Table 2: IS EN 1504 Principles of Repair

- 4.6 Table 3 contains examples of protection and repair methods which apply the above principles. Only methods which comply with the principles of Table 2 shall be selected for protection and repair of concrete structures, taking into account any possible undesirable consequence of applying a particular method or combination of methods under the specific conditions of the individual repair. All repair methods must be agreed prior to use with the Structures Section of Transport Infrastructure Ireland.

Principles	Examples of methods based on the principles	Relevant part of IS EN 1504 (where applicable)
1. Protection against ingress	1.1 Hydrophobic impregnation	2
	1.2 Impregnation	2
	1.3 Coating	2
	1.4 Surface bandaging of cracks	
	1.5 Filling of cracks	5
	1.6 Transferring cracks into joints	
	1.7 Erecting external panels ^a	
	1.8 Applying membranes ^a	
2. Moisture Control	2.1 Hydrophobic impregnation ^a	2
	2.2 Impregnation	2
	2.3 Coating	2
	2.4 Erecting external panels	
	2.5 Electrochemical treatment	
3. Concrete Restoration	3.1 Hand-applied mortar	3
	3.2 Recasting with concrete or mortar	3
	3.3 Spraying concrete or mortar	3
	3.4 Replacing elements	
4. Structural strengthening	4.1 Adding or replacing embedded or external reinforcing bars	
	4.2 Adding reinforcement anchored in pre-formed or drilled holes	6
	4.3 Bonding plate reinforcement	4
	4.4 Adding mortar or concrete	3, 4
	4.5 Injecting cracks, voids or interstices	5
	4.6 Filling cracks, voids or interstices	5
	4.7 Prestressing – (post tensioning)	
5. Physical resistance	5.1 Coating	2
	5.2 Impregnation	2
	5.3 Adding mortar or concrete	3
6. Resistance to chemicals	6.1 Coating	2
	6.2 Impregnation	2
	6.3 Adding mortar or concrete	3
7. Preserving or restoring passivity	7.1 Increasing cover with additional mortar or concrete	3
	7.2 Replacing contaminated or carbonated concrete	3
	7.3 Electrochemical re-alkalisation of carbonated concrete	
	7.4 Re-alkalisation of carbonated concrete by diffusion	
	7.5 Electrochemical chloride extraction	
8. Increasing resistivity	8.1 Hydrophobic Impregnation	2
	8.2 Impregnation	2
	8.3 Coating	2
9. Cathodic control	9.1 Limiting oxygen content (at the cathode) by saturation or surface coating	
10. Cathodic protection	10.1 Applying an electrical potential	
11. Control of anodic areas	11.1 Active coating of the reinforcement	7
	11.2 Barrier coating of the reinforcement	7
	11.3 Applying corrosion inhibitors in or to the concrete	

^a These methods may also be applicable to other principles

Note: Not all methods are within the scope of products and systems covered by parts of IS EN 1504.

Table 3: Methods for protection and repair of concrete structures

- 4.7 Details of the different product types for use in repair are discussed in IS EN 1504 Parts 2-7.
- 4.8 Guidance on site application and associated quality control are covered in IS EN 1504-10. However the guidance does not provide sufficient information to enable the Structural Assessment Engineer to draw up a detailed specification. For advice and guidance on how best to carry out the works on site, guidance should be sought from the product manufacturer.
- 4.9 All repair products shall have CE marking or equivalent certificate and shall be used for the correct purposes and applied in accordance with their associated data sheet.

5. SUCCESSFUL CONCRETE REPAIR

5.1 A repair has the best chance of being effective if;

- the underlying causes of deterioration are correctly diagnosed;
- the repair method is correctly selected to counteract the causes of deterioration and the structure is reinstated in line with the needs of Transport Infrastructure Ireland;
- thorough surface preparation of the concrete substrate and reinforcing steel is carried out;
- the chosen repair products meet the performance requirements of the selected repair principle and method, and if these products are correctly applied by properly trained and experienced personnel;
- the health, safety and environmental issues are properly considered and any mitigation measures are adhered to before and during the application of the repair method.

The Essential Steps

5.2 IS EN 1504 covers the essential steps that need to be followed or considered before, during and after carrying out a concrete repair.

5.3 It is necessary to ensure that each of the steps listed below is seriously considered by the Structural Assessment Engineer in order to ensure a successful repair.

Health, Safety & Environment

5.4 These aspects shall be considered together, throughout the repair process. They are major factors in the management of a successful concrete repair project.

Definition of the Client's objectives

5.5 IS EN 1504 states that any repair project must identify the goals and objectives of the structure owners before any work commences. This includes life expectancy, future use and budget constraints. Short, medium and long term options should always be considered, based on whole life costs. This will enable the most cost-effective repair solution to be agreed with the Structures Section of Transport Infrastructure Ireland.

Assessment of damage or deterioration and diagnosis of its cause

5.6 A thorough investigation of the nature and extent of the damage/deterioration to be repaired shall be carried out by the Structural Assessment Engineer or Specialist Repair Contractor. The assessment shall also include the analysis of the current condition of the structure including visible and latent deterioration. Further information on the inspection and testing procedures to assist the Structural Assessment Engineer in forming an accurate diagnosis can be found in Concrete Society Technical Report No. 54, 'Diagnosis of Deterioration in Concrete Structures' ⁽¹⁾.

Selection of the repair work

5.7 All repair works shall be specified by the Structural Assessment Engineer. The following shall be considered when selecting the final repair method:

- Health and Safety considerations;
- Environmental effects of repair work (e.g. dust, noise etc.);
- Structural considerations;
- Preventing or slowing continuing deterioration;
- Appearance of repaired concrete;
- Durability of chosen repair method.

In all cases, materials for the repair shall be properly selected and the repair method shall be fully compliant with IS EN 1504.

Preparation of the specification

5.8 The specification shall be prepared in accordance with NRA MCDRW Series 5500. The specification should be detailed and cover all aspects of the work including progressive investigation and testing; surface cleaning; preparatory work and the precise nature and sequence of the repair operation. It should specify the repair methods and materials as well as any additional aspects such as weather precautions, material thicknesses and curing procedures.

Contractor selection

5.9 All works on site shall be carried out by suitably qualified Specialist Repair Contractors with experience in concrete repairs of a similar nature to those being addressed.

Supervision of the work

5.10 All works shall be supervised by the Employer's Representative to ensure the use of the correct Standards and consistency of the quality of the works carried out.

Post-repair management of the structure

5.11 A monitoring programme shall be agreed to ensure that the repaired area and adjoining structural elements have at least the same residual service life.

6. REFERENCES

National Roads Authority Publications

NRA Manual of Contract Documents for Road Works, Series 5500, Concrete Repairs

Other Publications

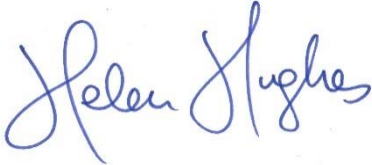
Concrete Society Technical Report No. 54, 'Diagnosis of Deterioration in Concrete Structures.'

Concrete Society Technical Report No. 69, 'Repair of Concrete Structures with Reference to BS EN 1504.'

7. ENQUIRIES


7.1 All technical enquiries or comments on this document or any of the documents listed as forming part of the NRA DMRB should be sent by e-mail to infoDMRB@tii.ie, addressed to the following:

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