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Maintenance and repair of concrete structures —

Part 4: Execution of repairs

Entretien et réparation des structures en béton —

Partie 4: Exécution des réparations

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 71, *Concrete, reinforced concrete and pre-stressed concrete*, Subcommittee SC 7, *Maintenance and repair of concrete structures*.

This second edition cancels and replaces the first edition (ISO 16311-4:2014) which has been technically revised.

The main changes are as follows:

- the title has been changed due to clarification of the definition of the term;
- some relevant reference standards have been clarified;
- some editorial corrections have been made.

A list of all parts in the ISO 16311 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document defines and specifies site application of products and systems and quality control of repairs. The execution of maintenance and repair of concrete structures is an important and integral part of the complex process of repair, and this document specifies how it is carried out. This document incorporates rules for the use of maintenance and repair materials and systems. Maintenance and repair methods applying traditional concrete construction work are listed in this document. Maintenance and repair methods applying electrochemical methods, e.g. cathodic protection, re-alkalisation of carbonated concrete, and chloride extraction, are listed in this document.

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Maintenance and repair of concrete structures —

Part 4: Execution of repairs

1 Scope

This document provides requirements for substrate condition before and during application, including structural stability, storage of materials, the preparation, and application of products and systems for repair of concrete structures, including quality control and qualifications of personnel, maintenance, health and safety, and the environment.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 1920-2, *Testing of concrete — Part 2: Properties of fresh concrete*

ISO 1920-3, *Testing of concrete — Part 3: Making and curing test specimens*

ISO 1920-4, *Testing of concrete — Part 4: Strength of hardened concrete*

ISO 1920-5, *Testing of concrete — Part 5: Properties of hardened concrete other than strength*

ISO 1920-6, *Testing of concrete — Part 6: Sampling, preparing and testing of concrete cores*

ISO 1920-7, *Testing of concrete — Part 7: Non-destructive tests on hardened concrete*

ISO 2394, *General principles on reliability for structures*

ISO 2409, *Paints and varnishes — Cross-cut test*

ISO 2808:2019, *Paints and varnishes — Determination of film thickness*

ISO 3274, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Nominal characteristics of contact (stylus) instruments*

ISO 4624, *Paints and varnishes — Pull-off test for adhesion*

ISO 4628-1, *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 1: General introduction and designation system*

ISO 4628-2, *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 2: Assessment of degree of blistering*

ISO 4628-3, *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 3: Assessment of degree of rusting*

ISO 4628-4, *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 4: Assessment of degree of cracking*

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ISO 4628-5, *Paints and varnishes — Evaluation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 5: Assessment of degree of flaking*

ISO 4628-6, *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 6: Assessment of degree of chalking by tape method*

ISO 5091 (all parts), *Structural intervention of existing concrete structures using cementitious materials — Part 1: General principles*

ISO 6935-2, *Steel for the reinforcement of concrete — Part 2: Ribbed bars*

ISO 8501-1, *Preparation of steel substrates before application of paints and related products — Visual assessment of surface cleanliness — Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings*

ISO 8502-2, *Preparation of steel substrates before application of paints and related products — Tests for the assessment of surface cleanliness — Part 2: Laboratory determination of chloride on cleaned surfaces*

ISO 8502-3, *Preparation of steel substrates before application of paints and related products — Tests for the assessment of surface cleanliness — Part 3: Assessment of dust on steel surfaces prepared for painting (pressure-sensitive tape method)*

ISO 8502-4, *Preparation of steel substrates before application of paints and related products — Tests for the assessment of surface cleanliness — Part 4: Guidance on the estimation of the probability of condensation prior to paint application*

ISO 13822, *Bases for design of structures — Assessment of existing structures*

ISO 14654, *Epoxy-coated steel for the reinforcement of concrete*

ISO 14657, *Zinc-coated steel for the reinforcement of concrete*

ISO 16311-1, *Maintenance and repair of concrete structures — Part 1: General principles*

ISO 16311-2, *Maintenance and repair of concrete structures — Part 2: Assessment of existing concrete structures*

ISO 16311-3:2014, *Maintenance and repair of concrete structures — Part 3: Design of repairs and prevention*

ISO 19338, *Performance and assessment requirements for design standards on structural concrete*

ISO 21920-3, *Geometrical product specifications (GPS) — Surface texture: Profile — Part 3: Specification operators*

ISO 22965-1, *Concrete — Part 1: Methods of specifying and guidance for the specifier*

ISO 22965-2, *Concrete — Part 2: Specification of constituent materials, production of concrete and compliance of concrete*

ISO 22966, *Execution of concrete structures*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 16311-1, ISO 2394, ISO 13822 and ISO 19338 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at <https://www.iso.org/obp>

— IEC Electropedia: available at <https://www.electropedia.org/>

3.1

bond

adhesion of the applied product or system to the substrate

Note 1 to entry: The bond requirements for a given repair can range from negligible to firmly adherent.

3.2

cement grout

mixture of cement, water, and, in some cases, admixtures

3.3

cementitious repair products and systems

hydraulic or polymer hydraulic mortars, concretes and grouts

3.4

dew point

temperature at which water vapour condenses

3.5

mortars

concrete

hydraulic, polymer hydraulic, and polymer mortar and concrete

3.6

pre-formed hole

hole or slot formed or cut in concrete into which reinforcement or other fixing is to be anchored

3.7

quality plan

programme to ensure that the activities of a process are undertaken to comply with the intended design

3.8

sprayed mortar or concrete

mortar or concrete applied under pressure through a nozzle delivered through pipes

3.9

wet on wet

application of a cementitious mortar or concrete onto the surface of a similar material which has set but not hardened

4 Structural stability during execution of repairs

Safety and stability before, during and after repair shall be maintained in accordance with ISO 16311-3.

Any period required for gain of strength of the repair products and systems shall be a part of the duration of the repair.

5 General requirements

Consideration shall be given to the chemical, electrochemical and physical condition of the substrate and any contaminants, the ability of the structure to accept loading, movement and vibration during repair, ambient conditions and the characteristics of the materials contained in the structure and those of repair products and systems.

The following requirements shall be met.

- The achievement of the required condition of the substrate regarding cleanliness, roughness, cracking, tensile and compressive strength, chloride or other contaminant and their penetration, depth of carbonation, moisture content, temperature, and degree of corrosion of reinforcement.
- The achievement of the compatibility of the original concrete and reinforcement with repair products and systems and compatibility between any different products and systems, including avoiding the risk of creating conditions which can cause corrosion.
- The achievement of the specified properties of products and systems when applied and in their hardened condition regarding the fulfilment of their purpose for repair of the structure.
- The achievement of the required storage and application conditions regarding ambient temperature, humidity and dew point, wind force and precipitation, and any temporary protection which is needed.

6 Methods of repair

The remedies and methods of repair, given in ISO 16311-3:2014, Table 1, are described below, excluding those methods specified in standards valid in the place of use.

The preparation of substrate, application of products and systems, quality control, and maintenance for each method shall comply with [Clauses 7, 8, 9](#) and [10](#).

The relevant subclauses are given in [Table 1](#) for each method together with any deviations, additions, necessary precautions and limitations.

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Table 1 — Table for each method together with any deviations, additions, necessary precautions and limitations

Repair remedies and methods		Preparation See subclauses	Application See subclauses	Quality control See subclauses
Method	Methods to satisfy remedy 1 – Protection against ingress The following methods satisfy the remedy of reducing or preventing the ingress of adverse agents, e.g. water, other liquids, vapour gas such as carbon dioxide, chemicals such as chlorides and biological agents.			
1.1	Hydrophobic impregnation This method applies a product to prevent or reduce the passage of water by lining the surface pores with material with hydrophobic properties.	7.1, 7.2.1, 7.2.2	8.1, 8.2.7	9.1, 9.2
1.2	Impregnation This method is to apply liquid products which penetrate the concrete and block the pore system.	7.1, 7.2.1, 7.2.2	8.1, 8.2.7	9.1, 9.2
1.3	Coating This method applies a product to the surface of the concrete to prevent the passage of agents.	7.1, 7.2.1, 7.2.2	8.1, 8.2.1, 8.2.7	9.1, 9.2
1.4	Surface bandaging of cracks The method seals cracks in the concrete to prevent the passage of deleterious agents. Refer to A.5 .	7.1, 7.2.1, 7.2.2	^a 8.1, 8.2.1, 8.2.2, 8.2.5, 8.2.6	9.1, 9.2
1.5	Filling of cracks This method fills cracks to protect against ingress.	7.1, 7.2.1, 7.2.2	^a 8.1, 8.2.1, 8.2.2, 8.2.5, 8.2.6	9.1, 9.2
1.6	Transforming cracks into joints This method makes use of existing cracks as an integral part of the structure. Refer to A.5 .	7.1, 7.2.1, 7.2.2	8.1, 8.2.1, 8.2.6	9.1, 9.2
1.7	Erecting external panels This method installs barrier panels to protect or encapsulate the deteriorating substrate.	System dependent	System dependent	System dependent
1.8	Applying membranes This method installs proprietary systems to protect or encapsulate the concrete substrate.	System dependent	System dependent	System dependent
Method	Methods to satisfy remedy 2 – Moisture control The following methods satisfy the remedy of adjusting and maintaining the moisture content in the concrete between a specified range of values.			
2.1	Hydrophobic impregnation This method applies a product to reduce the penetration of water and other agents into the treated concrete by lining the surface pores with materials with hydrophobic properties.	7.1, 7.2.1, 7.2.2	8.1, 8.2.7	9.1, 9.2
2.2	Impregnation This method applies liquid products which penetrate the concrete and block the pore system.	7.1, 7.2.1, 7.2.2	8.1, 8.2.7	9.1, 9.2
2.3	Coating This method applies a product to the surface of the concrete to prevent the passage of water or water vapour.	7.1, 7.2.1, 7.2.2	8.1, 8.2.1, 8.2.7	9.1, 9.2
2.4	Erecting external panels (refer to method 1.7) Concrete at the edges of cracks shall be prepared and repaired in accordance with Clauses 7 and 8 . Subclauses 8.2.2 and 8.2.5 apply only to cementitious grouts.	System dependent	System dependent	System dependent
	^b Subclauses 8.2.1 and 8.2.5 apply only to cementitious grouts.			
	^c Coating to concrete which prevents repassivation shall be removed and the concrete shall be cleaned, roughened and removed where necessary.			
	^d Concrete shall be removed only to the depth to which it has been cracked or loosened. Embedded reinforcement shall be cleaned in accordance to 7.3.1 and 7.3.2 .			
	^e Hydraulic mortar or concrete shall be used.			

Table 1 (continued)

Repair remedies and methods		Preparation See subclauses	Application See subclauses	Quality control See subclauses
2.5	Electrochemical treatment This method applies an electro-osmotic pulse to reduce water content of the concrete. Refer to A.5 .	System dependent	System dependent	System dependent
Method	Methods to satisfy remedy 3 – Concrete restoration The following methods satisfy the remedy of restoring the original concrete of a member of the structure to the originally specified shape and function. Restoring the concrete structure by replacing part of it.			
3.1	Hand-applied localized patches	7.1, 7.2.1, 7.2.2, 7.2.3, 7.2.4	8.1, 8.2.1, 8.2.2, 8.2.5	9.1, 9.2
3.2	Recasting components with concrete or mortar	7.1, 7.2.1, 7.2.2, 7.2.3, 7.2.4 and ISO 22966	8.1, 8.2.1, 8.2.2, 8.2.5 , ISO 22965-1, ISO 22965-2 and ISO 22966	9.1, 9.2
3.3	Spraying concrete or mortar	7.1, 7.2.1, 7.2.2, 7.2.3, 7.2.4 and ISO 22966	8.1, 8.2.1, 8.2.2, 8.2.5 and ISO 22966	9.1, 9.2
3.4	Replacing structural members	ISO 2394	ISO 22966	9.1, 9.2
Method	Methods to satisfy remedy 4 – Structural strengthening The following methods satisfy the remedy of increasing or restoring the structural load bearing capacity of a member of the concrete structure.			
4.1	Adding or replacing embedded or external reinforcing bars	7.1, 7.3.1, 7.3.2, 8.2.1, 8.3.2	8.1, 8.2.8, 8.3.1, 8.3.3 and ISO 22966	9.1, 9.2
4.2	Adding reinforcement anchored in pre-formed or drilled holes	7.1, 7.2.1, 7.2.2	8.1, 8.2.1, 8.2.8, 8.3.1, 8.3.3	9.1, 9.2
4.3	Bonding plate reinforcement This method bonds the strengthening plates externally to a member of the concrete structure.	7.1, 7.2.1, 7.2.2, 7.2.3, 7.2.4	8.1, 8.2.1, 8.2.6, 8.2.9	9.1, 9.2
4.4	Adding mortar or concrete This method bonds additional mortar or concrete to the concrete structure.	7.1, 7.2.1, 7.2.2, 7.2.3, 7.2.4	8.1, 8.2.1, 8.2.2, 8.2.3, 8.2.4, 8.2.5	9.1, 9.2
4.5	Injecting cracks, voids or interstices This method injects the concrete with appropriate fluid.	7.1, 7.2.1, 7.2.2	8.1, 8.2.1, 8.2.2, 8.2.5, 8.2.6	9.1, 9.2
4.6	Filling cracks, voids, or interstices	7.1, 7.2.1, 7.2.2	8.1, 8.2.1, 8.2.2, 8.2.5, 8.2.6	9.1, 9.2
4.7	Prestressing (post-tensioning) or FRP strengthening	ISO 2394	ISO 22966	9.1, 9.2
Method	Methods to satisfy remedy 5 – Increasing physical resistance The following methods satisfy the remedy of increasing resistance to physical or mechanical attack.			
5.1	Coating This method increases the physical resistance with a coating.	7.1, 7.2.1, 7.2.2	8.1, 8.2.1, 8.2.7	9.1, 9.2
a	Concrete at the edges of cracks shall be prepared and repaired in accordance with Clauses 7 and 8 , Subclauses 8.2.2 and 8.2.5 apply only to cementitious grouts.			
b	Subclauses 8.2.1 and 8.2.5 apply only to cementitious grouts.			
c	Coating to concrete which prevents repassivation shall be removed and the concrete shall be cleaned, roughened and removed where necessary.			
d	Concrete shall be removed only to the depth to which it has been cracked or loosened. Embedded reinforcement shall be cleaned in accordance to 7.3.1 and 7.3.2 .			
e	Hydraulic mortar or concrete shall be used.			

Table 1 (continued)

	Repair remedies and methods	Preparation See subclauses	Application See subclauses	Quality control See subclauses
5.2	Impregnation This method applies liquid products which penetrate the concrete.	7.1, 7.2.1, 7.2.2	8.1, 8.2.7	9.1, 9.2
5.3	Adding mortar or concrete This method bonds additional mortar or concrete to the concrete structure.	7.1, 7.2.1, 7.2.2, 7.2.3, 7.2.4	8.1, 8.2.1, 8.2.2, 8.2.3, 8.2.4, 8.2.5	9.1, 9.2
5.4	Applying membranes This method installs proprietary systems to protect or encapsulate the concrete substrate.	System dependent	System dependent	System dependent
Method	Methods to satisfy remedy 6 – Increasing resistance to chemicals The following methods increase the resistance of the concrete surface to deterioration by reducing the penetration of chemical agents.			
6.1	Coating This method increases the physical resistance with a coating.	7.1, 7.2.1, 7.2.2	8.1, 8.2.1, 8.2.7	9.1, 9.2
6.2	Impregnation This method applies liquid products that penetrate the concrete.	7.1, 7.2.1, 7.2.2	8.1, 8.2.7	9.1, 9.2
6.3	Adding mortar or concrete This method bonds additional mortar or concrete to the concrete structure.	7.1, 7.2.1, 7.2.2, 7.2.3, 7.2.4	8.1, 8.2.1, 8.2.2, 8.2.3, 8.2.4, 8.2.5	9.1, 9.2
Method	Methods to satisfy remedy 7 – Preserving or restoring passivity The following methods satisfy the remedy of creating chemical conditions in which the surface of the reinforcement is maintained at or is returned to a passive condition.			
7.1	Increasing cover to reinforcement with additional cementitious mortar or concrete, or applying coatings These methods increase cover or provide surface coatings to prevent penetration of the de-passivating agents: — Concrete or mortar overlays — Coatings	7.1, 7.2.1, 7.2.2, 7.2.3, 7.2.4 7.1, 7.2.1, 7.2.2	8.1, 8.2.1, 8.2.2, 8.2.3, 8.2.4, 8.2.5 8.1, 8.2.1, 8.2.7	9.1, 9.2 9.1, 9.2
7.2	Replacing contaminated or carbonated concrete This method replaces carbonate concrete with uncontaminated mortar or concrete.	7.1, 7.2.1, 7.2.2, 7.2.3, 7.2.4	8.1, 8.2.1, 8.2.2, 8.2.5	9.1, 9.2
7.3	Electrochemical re-alkalisation of carbonated concrete	System dependent	System dependent	9.1, 9.2
7.4	Re-alkalisation of carbonated concrete by diffusion	c, d 7.1, 7.2.1, 7.2.2, 7.2.3, 7.2.4	e 8.1, 8.2.1, 8.2.2, 8.2.3, 8.2.4, 8.2.5	9.1, 9.2
7.5	Electrochemical chloride extraction	System dependent	System dependent	System dependent and 9.1, 9.2
a	Concrete at the edges of cracks shall be prepared and repaired in accordance with Clauses 7 and 8 , Subclauses 8.2.2 and 8.2.5 apply only to cementitious grouts.			
b	Subclauses 8.2.1 and 8.2.5 apply only to cementitious grouts.			
c	Coating to concrete which prevents re-passivation shall be removed and the concrete shall be cleaned, roughened and removed where necessary.			
d	Concrete shall be removed only to the depth to which it has been cracked or loosened. Embedded reinforcement shall be cleaned in accordance to 7.3.1 and 7.3.2 .			
e	Hydraulic mortar or concrete shall be used.			

Table 1 (continued)

Repair remedies and methods		Preparation See subclauses	Application See subclauses	Quality control See subclauses
7.6	Applying membranes (preserving passivity only) This method installs proprietary systems to protect or encapsulate the concrete substrate, thereby maintaining passivity.	System dependent	System dependent	System dependent
Method	Methods to satisfy remedy 8 – Increasing resistivity The following method satisfies the remedy of increasing the electrical resistivity of the concrete by limiting moisture content.			
8.1	Hydrophobic impregnation This is a method to reduce water content and as a result increase the electrical resistance of concrete.	7.1, 7.2.1, 7.2.2	8.1, 8.2.7	9.1, 9.2
8.2	Impregnation This method applies liquid products that penetrate the concrete.	7.1, 7.2.1, 7.2.2	8.1, 8.2.7	9.1, 9.2
8.3	Coating This method increases the physical resistance with a coating.	7.1, 7.2.1, 7.2.2	8.1, 8.2.1, 8.2.7	9.1, 9.2
Method	Methods to satisfy remedy 9 – Cathodic control The following methods satisfy the remedy of creating conditions in which potentially cathodic areas of reinforcement are unable to drive an anodic reaction.			
9.1	Limiting oxygen content (at the cathode) by saturation or surface coating Saturation. Surface coating.	7.1, 7.2.1, 7.2.2 7.1, 7.2.1, 7.2.2	The concrete shall be continuously saturated with water. 8.1, 8.2.1, 8.2.7	9.1, 9.2 9.1, 9.2
Method	Method to satisfy remedy 10 – Cathodic protection			
10.1	Applying an electrical current to achieve a protective electrochemical potential			9.1, 9.2
Method	Methods to satisfy remedy 11 – Control of anodic areas The following methods satisfy the remedy of creating conditions in which potentially anodic areas of reinforcement are unable to take part in the corrosion reaction.			
11.1	Active coating of the reinforcement This is a method which provides either: — coatings to provide an alkaline environment; — coatings which function as inhibitors of electrochemical action; — coatings provide sacrificial galvanic reaction.	7.1, 7.3.1, 7.3.2	8.1, 8.3.1	9.1, 9.2
11.2	Barrier coating of the reinforcement This is a method providing a barrier to prevent pore water containing chlorides or other contaminants from reaching the reinforcement.	7.1, 7.3.1, 7.3.2	8.1, 8.3.1	9.1, 9.2
a	Concrete at the edges of cracks shall be prepared and repaired in accordance with Clauses 7 and 8 , Subclauses 8.2.2 and 8.2.5 apply only to cementitious grouts.			
b	Subclauses 8.2.1 and 8.2.5 apply only to cementitious grouts.			
c	Coating to concrete which prevents repassivation shall be removed and the concrete shall be cleaned, roughened and removed where necessary.			
d	Concrete shall be removed only to the depth to which it has been cracked or loosened. Embedded reinforcement shall be cleaned in accordance to 7.3.1 and 7.3.2 .			
e	Hydraulic mortar or concrete shall be used.			