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Structural intervention of existing concrete structures using cementitious materials —

Part 1:
General principles

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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*.

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Introduction

As a repairing and strengthening method, attaching of cementitious material layer to surface of existing concrete structures has been widely accepted. Since the cementitious layer does not have enough tensile strength, tension reinforcement is generally placed in the cementitious layer. There are two types of attaching way. For the first way, the cementitious layer is attached either on top surface or bottom surface of horizontal concrete members, especially slabs, while, for the second way, the cementitious layer is attached to jacket vertical concrete members, especially columns. There has not been ISO standard on design, execution and maintenance for this method with attaching cementitious layer. This ISO 5091 serves as the first ISO standard for the intervention by attaching cementitious material layer with tension reinforcement inside.

At the same time, this ISO 5091 is the first ISO standard developed for a specific intervention method, which conforms to the umbrella code, ISO 16311 Maintenance and repair of concrete structures, especially ISO 16311-3 – Part 3: Design of repairs and prevention and ISO 16311-4 – Part 4: Execution of repairs and prevention.

ISO 5091 Structural intervention of existing concrete structures using cementitious materials consists of four parts; ISO 5091-1 – Part 1: General principles, ISO 5091-2 – Part 2: Top-surface overlaying, ISO 5091-3 – Part 3: Bottom-surface (soffit) underlaying, and ISO 5091-4 – Part 4: Jacketing. ISO 5091-1 provides the issues common to all three parts, while ISO 5091-2, 3 and 4 provide the issues specific to each attaching way of cementitious material layers.

It is expected that this ISO 5091 could serve as a practical standard for construction industry, such as client, design consultant and general contractor, to apply the structural intervention with externally attached cementitious layer. Additional technical information, which is not provided explicitly in ISO 5091, needs to be provided in each application case with consideration of the provisions of ISO 5091.

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Structural intervention of existing concrete structures using cementitious materials —

Part 1:
General principles

1 Scope

This document specifies the standards for design, construction and maintenance following completion of intervention that is to be applied for performing intervention work using cementitious materials to improve the performance of existing concrete structures. The intervention dealt with in this guideline is intended to restore, sustain or improve the mechanical performance of concrete structures. When the intervention is aimed at restoring or improving durability, reference should be made to relevant documents.

This document covers the overlaying, underlaying and jacketing methods using cementitious materials.

Assuming that the standard requirements regarding the intervention of existing structures are as set forth in ISO 16311, especially Parts 3 and 4, this document consists of Part 1: General principles specifying the common requirements not dependent on the method of performing intervention using cementitious materials and method-specific Parts 2, 3, and 4, each describing the specifics of top-surface overlaying, bottom-surface (soffit) underlaying and jacketing, respectively.

The intervention with cementitious materials shallis covered in Clause 4 Basis of maintenance and repair of ISO 16311-1.

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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 16311-1:2014, *Maintenance and repair of concrete structures — Part 1: General principles*

ISO 16311-2:2014, *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 16311-4:2014, *Maintenance and repair of concrete structures — Part 4: Execution of repairs and prevention*

ISO 19338:2014, *Performance and assessment requirements for design standards on structural concrete*

ISO 1920-8, *Testing of concrete — Part 8: Determination of drying shrinkage of concrete for samples prepared in the field or in the laboratory*

ISO 10406-2, *Fibre-reinforced polymer (FRP) reinforcement of concrete — Test methods — Part 2: FRP sheets*

ISO 10406-3, *Fibre-reinforced polymer (FRP) reinforcement of concrete — Test methods — Part 3: CFRP strips*

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ISO 12473, *General principles of cathodic protection in seawater*

ISO 13823, *General principles on the design of structures for durability*

ISO 14484, *Performance guidelines for design of concrete structures using fibre-reinforced polymer (FRP) materials*

ISO 22966, *Execution of concrete structures*

3 Terms and definitions

For the purposes of this document, the following terms and definitions 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
Top-surface overlaying
A method in which the thickness of the structural element associated with the top surface of the existing concrete members is increased using cementitious materials, which will generally be reinforced. The technique enhances the performance (e.g. strength, stiffness) of the existing concrete structure and is applicable to highway bridge decks, etc.

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3.2
Bottom-surface (soffit) underlaying
A method in which the thickness of the structural element associated with the bottom surface of the existing concrete is increased using cementitious materials, which will generally be reinforced. The technique enhances the performance (e.g. strength, stiffness) of the existing concrete structure and is applicable to highway bridge decks, tunnel linings, box culverts / waterway structures, beams, etc.

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3.3
Jacketing
A method in which additional cementitious materials and associated reinforcement are added to the periphery of the existing concrete member to increase its strength, stiffness and/or ductility (applicable to columns, bridge piers, rigid-frame pier beams, etc.)

3.4
thickening capability
ability to achieve the required application thickness of one layer of polymer hydraulic cement mortar or other mortar material

3.55
bonding product
material, such as a primer, anchor grouting material or adhesive, that is applied or grouted to bond concrete members, concrete and mortar or concrete and reinforcing material

3.6
filling material
material injected to fill the gap between a reinforcing material, such as intermediate penetrating tie, and concrete

3.7
filling property
degree of filling of cracks and adhesion of crack filling material to substrate

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3.8
intermediate penetrating tie
reinforcing member, generally made of steel or FRP, that is installed inside the drilled hole and glued into the concrete substrate to improve the ductility and shear strength of bridge piers

3.9
very high early strength cement
type of cement with a typical mix proportion that develops a compressive strength as high as 20 N/mm^2 to 30 N/mm^2 within 2 to 3 hours of placement

3.10
reinforcing material
steel or FRP reinforcing material used to sustain the performance of a structure or to restore or improve performance

3.11
polymer hydraulic cement mortar
hydraulic mortar modified by the addition of a polymer

3.12
overlaying or underlaying material
cementitious material, potentially reinforced, added to an existing concrete structure for the purpose of making an intervention to enhance the performance of that structure

Note 1 to entry: The top-surface overlay / bottom-surface (soffit) underlay shall achieve adequate bond to the existing concrete substrate.

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3.13
FRP grid
resin-impregnated FRP reinforcing materials formed into a grid shape

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3.14
design response value
value of structural response obtained by numerical analysis on design process, such as sectional force and deformation

3.15
design limit value
design value for quantified limit state on design process, such as strength of element, allowable crack width

3.16
verification index
representative items to be quantitatively verified by design response value and design limit value on design process, such as deflection, crack width and strength

3.17
cross section failure
failure which is related to cross sectional strength, such as flexure, shear and axial strength

3.18
maintainability
ability of a structure to meet service objectives with a minimum expenditure of maintenance effort under service conditions in which maintenance and repair are performed

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4 Investigation of existing structure

4.1 General

The existing structure for which intervention is to be considered shall be investigated in detail to obtain the information necessary for intervention design and construction.

4.2 Investigation

4.2.1 Investigation using documents, records, etc.

When an investigation is conducted using documents, records, etc., the climatic conditions, environmental conditions, geographical conditions and other relevant conditions of the local site shall be understood in detail from the following viewpoints:

— formulation of material and structural plans;

— formulation of a construction plan; and

— maintenance following completion of intervention.

NOTE Generally, the workability and hardening characteristics of cementitious materials greatly change depending on the construction environment, such as temperature and, therefore, it is necessary to see the climate of the local site during the period when construction is planned to be performed. Also, intervention using cementitious materials requires that the restrictions of the local site regarding the construction space as well as the carry-in and installation of materials and equipment be understood before a specific construction plan is formulated.

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4.2.2 On-site investigation

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On the site, an investigation shall be conducted to check degradation, damage and initial defects of the existing concrete structure from the following viewpoints:

— Securing of integrity between the existing parts and strengthening parts

— Prediction of durability and degradation after intervention

NOTE In obtaining the expected effect of intervention using cementitious materials, integrity between the repairing or strengthening parts and existing structure is important. Ensuring integrity requires taking necessary measures based on the understanding of degradation, such as carbonation of the surface of the existing structure, damage such as cracks, splash or leakage of water, etc.

Degradation of a concrete structure after intervention progresses at a different rate depending on the type of cause and degree of degradation. Therefore, before intervention is performed for a damaged concrete structure, it is necessary to understand the cause and degree of degradation.

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5 Intervention design

5.1 General

In intervention, a rational structural plan shall be formulated and structural details shall be established based on that plan so that the structure after intervention fulfills the required performance throughout the remaining design service life.

NOTE The intervention design involves establishing a structural plan and structural details to ensure that intervention restores the performance of the existing structure to the required level and that the structure after intervention fulfills the required performance throughout the remaining design service life. In the case of intervention using cementitious materials, increasing the stiffness of repaired or strengthened members is easy while the members become heavier as well. IThe structural plan shall be made to select an appropriate intervention method, taking into consideration the current condition of the existing intervention target structure, intervention construction conditions, maintainability after intervention and so forth.

In structural details, appropriate methods of bonding and anchoring reinforcing materials shall be selected to ensure integrity between the existing parts and strengthening parts that are necessary for the structure after the intervention to meet the specified performance requirements. Also, the load share and stress redistribution of the existing parts and strengthening parts before and after intervention shall be clarified and the sectional capacity and stiffness of the strengthened members shall be established according to the structural properties of the intervention target members, the intervention method and so forth.

In the performance verification of the structure after the intervention, partial safety factors for materials and actions shall be chosen appropriately, taking into consideration the current condition of the existing structure and the condition in which the structure is expected to be placed during the remaining design service life. When providing partial safety factor for members, construction records and actual measured values of the existing parts may be considered.

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5.2 Structural plan

In the structural plan, the intervention method shall be selected, taking into consideration the structural properties, materials, construction method, maintenance method, economy, etc., so as to ensure that the structure after intervention fulfills the required performance.

When considering the intervention method, the type of the intervention materials and the methods of bonding these materials (bonding and anchoring methods) shall be selected according to the conditions of the intervention target structure to ensure that the structure after intervention fulfills the required performance. When considering structural details, not only the design documents created at the time of new construction but also the current condition of the existing structure identified through field measurements and other activities shall be taken into consideration.

Consideration shall be given to ensure that the structure after intervention satisfies the required levels of durability, safety, serviceability and restorability throughout the design service life.

To ensure that the structure after intervention fulfills the required performance throughout the remaining design service life, it is common either to prevent reinforcing materials from degrading or changing due to environmental actions during the design service life or to design the intervention to minimize the impact of degradation such that the performance of the structure will not degrade even if degradation occurs. If a change has already occurred in the intervention target structure, it is necessary to consider an appropriate measure to prevent the progress of the change from affecting the effect of intervention. Ensuring compatibility between the existing parts and strengthening parts is particularly important for preventing the structure after intervention from experiencing early performance degradation.

The structural plan shall be made taking into consideration the restrictions on construction.

For the structure after the intervention to exhibit the required performance, structural plan needs to be made taking into full consideration the restrictions on construction. Since intervention of an existing structure is expected to face strict restrictions on the construction period, construction space, etc. due to service conditions and other factors, it is important to consider ways to ensure the required levels of

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construction accuracy and quality in the carry-in and installation of reinforcing materials as well as in the bonding work.

In the structural plan, consideration shall be given to maintenance following completion of intervention, the importance of structures, design service life, service conditions, environmental conditions, maintainability, etc.

NOTE T intervention methods and materials to be used shall be ensured that maintenance work such as inspections and performance evaluations can be efficiently conducted on the structure after intervention as well as to minimize the costs required for corrective measures. Where intervention materials are bonded, in particular, the condition of the existing parts may be difficult to check and, therefore, it is desirable to consider ways to appropriately understand changes that can occur in the structure after the intervention.

5.3 Structural details

The bonding method of reinforcing materials shall be selected appropriately to ensure that the structure after intervention achieves the required level of performance.

Generally, in the verification of the serviceability and safety of the structure after intervention, it is assumed that the existing parts and strengthening parts are integrated to resist external forces. When providing structural details, it is necessary to consider a bonding method that ensures sufficient integrity for the structure after intervention.

The reinforcing materials to be used and the structural properties of the strengthening parts shall be selected so that the structure after intervention sustains the required load-carrying capacity and stiffness.

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NOTE The type of reinforcing material and the structural properties of the strengthening parts need to be selected, taking into consideration the differences in load-carrying capacity and stiffness between the existing parts and strengthening parts, to ensure the load-carrying capacity and stiffness required for the structure after intervention. If the stiffness ratio of the existing parts and strengthening parts is large, care needs to be exercised because a sufficient strengthening effect may not be obtained depending on the bonding method. It is important to give full consideration in advance as to how to make the existing parts, bonded parts and strengthening parts are resistant to each load level, respectively. Note that there is the need to fully understand the reinforcement arrangement of the existing parts in the investigation of the existing structure, including whether round bars are used.

NOTE In the structure after intervention, the permanent action (dead load) on the existing structure is borne by the existing parts alone, and the integrated structure bears the variable action (live load and actions due to wind or earthquake, etc.) in addition to the weight of the strengthening parts. Specifically, it should be carefully examined whether the weight of the strengthening part is transferred to the existing structure or is borne by the strengthening part itself. It is important to set the stiffness ratio of the existing parts and strengthening parts appropriately and to control the load sharing ratio and resistance mechanism.

NOTE Care needs to be taken to prevent the existing parts from being damaged or integrity from being impaired by time-dependent deformation of reinforcing materials or bonding products such as creep occurring in reinforcing materials or adhesive due to the stress of permanent action. Also, there are cases in which the existing parts restrict the shrinkage of the strengthening parts and a thorough consideration of indirect actions is necessary.

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