INTERNATIONAL STANDARD

ISO 5091-1

First edition
2023-07

Structural intervention of existing concrete structures using cementitious materials —

Part 1: General principles

Intervention structurelle sur les structures en béton existantes utilisant des matériaux cimentaires —

Partie 1: Principes généraux

Reference number
ISO 5091-1:2023(E)

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Published in Switzerland

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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*.

A list of all parts in the ISO 5091 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

As a repairing and strengthening method, attaching of a 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. For the first way, the cementitious layer is attached either on the 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 any ISO standard on design, execution and maintenance for this method with attaching a cementitious layer. The ISO 5091 series serves as the first ISO standard for the intervention by attaching a cementitious material layer with tension reinforcement inside.

At the same time, the ISO 5091 series is the first ISO standard developed for a specific intervention method, which conforms to the umbrella code, ISO 16311, especially ISO 16311-3 and ISO 16311-4.

The ISO 5091 series consists of four parts. 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.

The ISO 5091 series can 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 the ISO 5091 series, needs to be provided in each application case with consideration of the provisions of the ISO 5091 series.

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 to be applied for performing intervention work using cementitious materials to improve the performance of existing concrete structures. The intervention dealt with in this document 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.

The intervention with cementitious materials is covered in ISO 16311-1, Clause 4.

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

ISO 16311-3, *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, *Performance and assessment requirements for design standards on structural concrete*

ISO 10406-1, *Fibre-reinforced polymer (FRP) reinforcement of concrete — Test methods — Part 1: FRP bars and grids*

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*

ISO 22966, *Execution of concrete structures*

ISO 679, *Cement — Test methods — Determination of strength*

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
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

Note 1 to entry: The technique enhances the performance (e.g. strength, stiffness) of the existing concrete structure and is applicable to highway bridge decks, etc.

3.2
bottom-surface (soffit) underlaying
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

Note 1 to entry: 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.

3.3
jacketing
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

Note 1 to entry: It is applicable to columns, bridge piers, rigid-frame pier beams, etc.

3.4
bonding product
material, such as a primer or adhesive, that is applied to bond concrete and mortar

Note 1 to entry: The grouting material for bonding concrete and reinforcing material is also included in this term.

3.5
filling material
material injected to fill the gap between a reinforcing material, such as intermediate penetrating tie, and concrete

3.6
intermediate penetrating tie
reinforcing member, generally made of steel or fibre-reinforced polymer (FRP), that is installed inside the drilled hole and glued into the concrete substrate to improve the ductility and shear strength of bridge piers

3.7
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 h to 3 h of placement

3.8
reinforcing material
steel or FRP material used to sustain, restore or improve the mechanical performance of a structure

3.9
polymer hydraulic cement mortar
hydraulic composition made cementitious materials and fine aggregate modified by the addition of a polymer

3.10
overlaying material
cementitious material, potentially reinforced, added on the top surface of an existing concrete structure for the purpose of making an intervention to enhance the performance of that structure

3.11
underlaying material
cementitious material, potentially reinforced, added on the bottom surface (soffit) of an existing concrete structure for the purpose of making an intervention to enhance the performance of that structure

3.12
design response value
value of structural response obtained by numerical analysis on design process, such as sectional force and deformation

3.13
design limit value
design value for quantified limit state on design process, such as strength of element, allowable crack width

3.14
cross section failure
loss or decrease of load carrying capacity of structural member due to the excessive action more than which is more than cross sectional strength, such as flexure, shear and axial strength

3.15
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

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. The necessary information for intervention is additional to and/or different from the information obtained from assessment of existing structure as maintenance activities, which shall be obtained from ISO 13822 and ISO 16311-1 and ISO 16311-2.

4.2 Investigation

4.2.1 Investigation using documents, records

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;

— maintenance following completion of intervention.

Generally, the workability and hardening characteristics of cementitious materials greatly change depending on the construction environment, such as temperature. It is therefore necessary to take into account the climate of the local site during the period when construction is planned to be performed. Also, for intervention using cementitious materials, the restrictions of the local site regarding the

construction space as well as the carry-in and installation of materials and equipment needs to be understood before a specific construction plan is formulated.

4.2.2 On-site investigation

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.

In obtaining the expected effect of intervention using cementitious materials, integrity between the repairing or strengthening parts and existing structure is important. For ensuring integrity, it is necessary to take 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.

5 Intervention design

5.1 General

In intervention design, a rational structural plan shall be formulated, and structural details shall be established based on that plan so that intervention restores the performance of the existing structure to the required level and that the structure after intervention fulfils the required performance throughout the remaining design service life. The required performance shall be determined according to ISO 19338.

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 fulfils the required performance throughout the design service life.

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.

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 intervention methods and materials are selected to ensure that maintenance work such as inspections and performance evaluations can be efficiently conducted on the structure after intervention. The costs required for corrective measures shall be minimized through the selection. Changes that can occur in the structure after the intervention need be detected.

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.

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. A bonding method that ensures sufficient integrity for the structure after intervention should be considered.

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.

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.

Care shall 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.

6 Materials

6.1 General

The materials used for intervention shall be of proven quality.

The quality of the materials used for intervention shall be checked using an appropriate method according to their method of use and combination. The quality of the materials used for the existing structure, as well as the quality of the materials used for intervention, and the design values of these materials shall be determined as set forth in Clause 6. The properties of the materials in the existing structure subject to intervention can be different from those assumed in the design phase at the time of new construction due to the various factors in the construction phase as well as the load and environmental actions during the service life. In strengthening design, the characteristic values of the material properties and partial safety factors for materials of the existing concrete members shall be determined appropriately considering this fact. Materials not specified herein may be used as long as they fulfil the required performance in accordance with the intent of Clause 6.

6.2 Materials in existing structure

The design values of the materials in the existing structure shall be determined based on the results of inspections.

The characteristic values of the physical properties of the materials in the existing structure shall take into consideration the variations in measured values obtained through inspections and ensure that most of the measured values do not fall below them. If the values of the material physical properties can be determined based on the results of inspections separately from the characteristic values of the material physical properties, those values may be used. In general, however, there are few sample test values from inspections, which make it difficult to identify the distribution of test values. In this case, therefore, an overall judgment of inspections is made to estimate the characteristic values of material physical properties.

While the characteristic value of the tensile strength of steel is not thought to be dependent on time, the tensile property changes as the cross-sectional area decrease. Here, it has been decided to reflect this in design by taking into consideration the changes in the cross-sectional area of the steel used in the existing structure. The other characteristic values related to steel need to be determined according to the condition of corrosion, the history of previously applied stresses and so forth. If the steel has been subjected to considerable corrosion or stresses exceeding the yield strength, it is noted that the bond property, fatigue property, elongation characteristics, etc. have altered.

The partial safety factors for materials of the materials in the existing structure shall be determined in accordance with the relevant standard which was applied for the design of existing structure when it was constructed. However, if the properties of the materials in the existing structure are different from those assumed at the time of new construction or the service conditions after intervention are different, the partial safety factors for materials may be determined appropriately taking into consideration the environmental conditions and other factors.

The characteristic value of the concrete in the existing structure is known from inspections, thus resulting in less uncertainty. By considering this, the partial safety factors for materials can be reduced.

6.3 Materials used in repairing or strengthening parts

6.3.1 General

The quality of the materials used in repairing or strengthening parts can be indicated by the compressive strength or tensile strength, as well as by other strength properties, Young's modulus and other deformation properties and material properties such as thermal properties, durability and water-tightness, as required for the performance verification. As for the strength properties and deformation properties, the effect of the loading rate shall be taken into consideration as necessary. Table 1 provides examples of types of materials used for intervention.

Table 1 — Examples of the types of materials used for intervention

Cementitious materials	Reinforcing materials	Filling materials	Bonding products
— Normal-strength concrete — High-strength concrete — Fibre-reinforced mortar/concrete — Plasticized concrete — High-fluidity concrete — Expansive concrete — Polymer hydraulic cement mortar/concrete	— Reinforcing steel — Prestressing steel — FRP reinforcing materials	— Non-shrink grout — Non-shrink mortar — Expansive concrete	— Primer — Adhesive (resin-based, cement-based) — Anchor — Anchor grouting material

6.3.2 Cementitious materials

The quality of cementitious materials can be indicated by the compressive strength or tensile strength required for the repaired or strengthened structure to exhibit its performance, as well as by other strength properties, Young's modulus and other deformation properties and material properties such as thermophysical properties and water-tightness. Particularly, consideration shall be given to the integrity with the existing concrete members as well as to the property of bonding with reinforcing materials and durability.

The quality requirements for these cementitious materials vary depending on the type and level of performance required for the repaired or strengthened structure. Currently, the materials used for overlaying, underlaying or jacketing differ depending on the target method, and the materials of the appropriate types and quality are used.

It is necessary that cementitious materials shrink little, attain design strength quickly and have excellent cracking resistance, flexural property and shear property. Also, they shall have excellent fatigue resistance when used with top-surface overlaying or bottom-surface (soffit) underlaying employed to strengthen bridge decks. With bottom-surface (soffit) underlaying, whereby cementitious