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Structural intervention of existing concrete structures using cementitious materials —

Part 4:
Jacketing

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Contents

Page

Foreword

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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 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.

Structural intervention of existing concrete structures using cementitious materials —

Part 4: Jacketing

1 Scope

This document specifies the standard requirements regarding design, construction and maintenance to be applied for structural intervention using the jacketing method, which places reinforcing materials such as reinforcing steel or FRP grids around the periphery of existing concrete column or beam and jackets these members with cementitious materials. The requirements not mentioned in the Jacketing shall be as set forth in ISO / NP 5091-1.

NOTE Jacketing is a construction method that restores or improves mechanical performance, such as flexural load-carrying capacity, shear capacity and ductility, as well as durability and other performance properties, by placing reinforcing steel or FRP grids around existing concrete members or in the grooves on the concrete surface and jacketing the entire periphery of the members with cementitious materials, such as concrete or polymer hydraulic cement mortar, so that the materials integrate with the existing concrete members. Generally, when concrete is used as the jacketing material, the concrete jacketing method is adopted whereby concrete is placed in set up molds, or when polymer hydraulic cement mortar or other types of mortar is used as the jacketing material, the mortar jacketing method is adopted whereby the thickness of members is increased by spraying or trowelling. Jacketing is often employed for seismic strengthening mainly of column members such as bridge piers and beam members of rigid-frame piers. The Jacketing specifies the standard requirements regarding design, construction and maintenance to be applied for structural intervention of existing concrete structures using the jacketing method. The requirements not mentioned in the Jacketing shall be as set forth in ISO / NP 5091-1.

NOTE The Jacketing also covers cases of intervention in which the jacketing method is used to repair or strengthen concrete structures such as reinforced concrete bridge piers damaged by seismic actions. When a damaged concrete structure is repaired or strengthened using the jacketing method, the status of damage such as concrete cracking and spalling shall be grasped through a prior investigation and crack injection or sealing, patching repair and other measures shall be taken in advance as necessary

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 22966:2009, *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 General

The definitions of the terms used in the Jacketing shall be as defined in Clause 3 of ISO / NP 5091-1.

4 Investigation of existing structure

4.1 General

The investigation of the existing structure for which to consider intervention using the jacketing method shall be conducted as set forth in Clause 4 of ISO / NP 5091-1.

When an earthquake-affected structure is repaired or strengthened using the jacketing method, the status of damage to that structure shall be studied in detail.

NOTE Jacketing is often employed for seismic strengthening of vertical members such as reinforced concrete bridge piers. In some cases, it is also used for intervention of earthquake-affected structures. An earthquake-affected structure may have been suffered from ~~with~~ different types of damage including cracking of concrete, spalling of cover concrete, crushing of concrete, buckling and rupture of reinforcing steel and so on. Depending on the status of damage, it may be necessary to take measures such as crack injection or sealing, patching repair, restoration of deformation of reinforcement and replacement of reinforcement before intervention using the jacketing method. These types of damage may significantly impact the mechanical performance of the existing structure and the repaired or strengthened structure. Therefore, when an earthquake-affected structure is repaired or strengthened using the jacketing method, it is necessary to grasp the status of damage through an investigation, evaluate the impact that these types of damage have on the performance of the structure by means of an appropriate method and ensure that the intervention design and construction plan reflect the evaluation results.

4.2 Investigation

4.2.1 Investigation using documents, records, etc.

A investigation using documents, records, etc. shall be conducted in accordance with 4.2.1 of ISO / NP 5091-1.

Details of the materials used in the target existing structure and the structural specifications shall be understood from the design documents created at the time of construction, the design documents for the intervention work performed before the consideration of intervention.

NOTE The structural specifications mean the cross-sectional dimensions and reinforcement arrangement. These are necessary for evaluating the performance of the existing structure and verifying the performance of the repaired or strengthened structure.

4.2.2 On-site investigation

The on-site investigation on the existing structure shall be conducted in accordance with 4.2.2 of ISO / NP 5091-1.

NOTE Obtaining the expected effect of intervention through the use of the jacketing method requires ensuring the integrity between the existing structure and the jacketing parts. It is therefore advisable to grasp the status of degradation and damage on the surface and inside of the existing structure through the on-site investigation.

The on-site investigation on an earthquake-affected structure shall involve studying the status of damage caused by the earthquake in detail.

NOTE An earthquake-affected structure may have been suffered from different types of damage including cracking of concrete, spalling of cover concrete, crushing of concrete, buckling and rupture of reinforcing steel and so on. Therefore, when an earthquake-affected structure is repaired or strengthened using the jacketing method, the status of damage shall be studied in detail by means of an appropriate method. The methods commonly used in the on-site investigation are visual inspection and tapping inspection.

NOTE It is advisable to grade the changes in the appearance, taking into consideration the degree of damage to the concrete, steel, etc. and changes in the mechanical performance, and evaluate the structural performance according to the grading of the appearance changes. In the structural performance evaluation based on the appearance changes, the grades of structural performance shall be established on mechanical grounds taking into full consideration the degree of each graded appearance change and the impact of the changed region on structural performance. Appearance changes may be classified into the following three grades.

— Grade I: No or minor damage

— Grade II: Moderate damage

— Grade III: Severe damage

The mechanical resistance of the change region should be classified into the following 4 levels.

— Level a: Resistance remaining intact

— Level b: Slightly degraded resistance

— Level c: Significantly degraded resistance

— Level d: No resistance

NOTE As for reinforced concrete bridge piers damaged by an earthquake, the methods of inspecting the damaged bridge piers and determining the degree of damage should be set properly. In the case of reinforced concrete bridge piers, both the position and degree of damage are important. It is, therefore, necessary to investigate each bridge pier to determine whether it is damaged at its base or in its middle part (where the main reinforcement is cut off). This investigation needs to be conducted in both the bridge longitudinal direction and transverse direction. The damage process in reinforced concrete bridge piers differs between bending failure and shear failure. In general, damage progresses as described below, respectively.

— Bending failure
  a. Concrete cracking (horizontal cracking)
  b. Cover concrete spalling
  c. Buckling of longitudinal reinforcement
  d. rupture of longitudinal reinforcement or crushing of core concrete

— Shear failure
  a. Concrete cracking (horizontal or diagonal cracking)
  b. Spread of concrete cracking
  c. Cover concrete spalling

d. Exposure of longitudinal reinforcement

e. rupture of tie reinforcement or crushing of core concrete

NOTE In order to grasp the degree of damage, therefore, it is important to investigate the actual damage to reinforced concrete bridge piers to determine which of the above-mentioned stages corresponds to the damage.

5 Intervention design

5.1 General

In the intervention design using the jacketing method, 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 There are cases in which repairing or strengthening a structural member using the jacketing method may induce damage to other members in the event of an earthquake. When planning the intervention, therefore, consideration shall be given to ensure that the entire structure fulfills the performance.

NOTE If the intervention target structure is already damaged, the damage may affect the performance of the repaired or strengthened structure. Therefore, the impact of the existing damage of the structure shall be evaluated, based on the results of the investigation of the existing structure set forth in Clause 2, and then practical measures shall be planned according to circumstances in which the structure is placed, to ensure that the target structural performance is achieved throughout the design service life. When an earthquake-affected structure is repaired or strengthened using the jacketing method, it is necessary to take appropriate measures for the members damaged by the earthquake first. The intervention plan shall be considered.

5.2 Structural plan

In the intervention plan using the jacketing method, 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 required performance is fulfilled under the environmental conditions of the structure.

NOTE There are two methods to achieve intervention by jacketing members with cementitious materials: concrete jacketing and mortar jacketing. Generally, the concrete jacketing method is more economical and has been in wider use. In the case of a structure installed in a river, however, the impediment ratio of river flow, which is identified as the reduction of the cross-sectional area of the river channel caused by the jacketing work, needs to be taken into consideration and there may be restrictions such as a severe clearance limit due to a narrow space from the adjacent structure. In such a case, if the concrete jacketing method is used for which the standard jacketing thickness is 250 mm or so, the cross-sectional dimensions of members become large, potentially making it impossible to meet the restrictions on construction or service. By contrast, the standard jacketing thickness of the mortar jacketing method is 100 mm or less and the change in the cross-sectional dimensions of strengthened members can be reduced. Therefore, the mortar jacketing method may be selected to meet the restrictions such as those mentioned above. Among the mortar materials used for jacketing, polymer hydraulic cement mortar is highly durable with a low diffusion coefficient of chloride ions, a low carbonation rate, etc. and is used in an environment such as a coastal or seaside area. As mentioned above, a specific intervention method shall be selected, taking into consideration the structural properties, materials, construction method, maintenance method, economy, etc., so as to ensure that the required performance is fulfilled under the environmental conditions of the structure

NOTE In the design phase, the public safety in the surrounding area that may be impacted by an accident such as the spalling of the cover concrete of the concrete members repaired or strengthened using the jacketing method shall be verified in principle with established limit states assuming that such concrete spalling off does not occur. If it is feared that this assumption may be exceeded, measures should be taken to prevent a public disaster from happening. There are two possible cases of spalling of the jacketing part: spalling off of the surface of the jacketing part (the covering of the reinforcing material of the jacketing part); and spalling off of the jacketing part due to the separation at the interface between the jacketing part and the existing part. In the design phase, it may be considered that the public safety requirements regarding the spalling off of the jacketing part and other public disaster risks for users of the structure, third parties, etc. are met if the requirements set forth in 8.3 “Durability Verification” are met.

The intervention plan using the jacketing method shall take into consideration the restrictions on construction.

NOTE In intervention, the impact of the location and environmental conditions of the target structure on the construction work and the impact of the construction work on the surrounding environment are both significant. In the case of the intervention of a structure installed in a river, for example, it is necessary to take into consideration the environmental impacts on animals, plants, water quality and so forth. When the structure subject to intervention is located in a steep valley, it is uneconomical to carry in large construction machines. Construction work in a cold region requires care about the handling of cementitious materials, such as cold weather concrete measures in the winter and hot weather concrete measures in the summer. Given these factors, the intervention plan shall take into consideration the restrictions on construction.

In the intervention plan using the jacketing method, consideration shall be given to facilitate the maintenance of the repaired or strengthened structure, factoring in the structure's importance, design service life, service conditions, environmental conditions, maintainability, etc.

NOTE There are cases in which it is difficult to ensure durability for the structure that is to be repaired or strengthened using the jacketing method, as with a structure in a river that may become submerged underwater or a structure close to the sea. In order to ensure that the repaired or strengthened structure achieves and sustains its expected performance, it is necessary to take measures to prevent re-degradation while taking into consideration the maintenance following completion of intervention. In the design phase, therefore, a method that facilitates maintenance following completion of remedial action shall be selected, factoring in the structure's importance, design service life, service conditions, environmental conditions, maintainability, etc.

5.3 Structural details

In intervention using the jacketing method, structural details shall be determined so as to ensure the integrity between the existing members and jacketing parts.

NOTE In order to ensure that the seismic performance and other performance requirements of a structure are fulfilled by performing intervention using the jacketing method, it is important that the existing parts and jacketing parts function as an integrated structure. Therefore, the materials, construction method and cross-sectional structure that enable the integrity of these parts need to be selected.

The members to be repaired or strengthened using the jacketing method, the range of intervention, the arrangement of reinforcing materials around the periphery of the existing members, the thicknesses of reinforcing material covering and jacketing material, etc. shall be established appropriately so that the performance requirements of the structure are met.

NOTE The members to be jacketed and the range of jacketing shall be selected appropriately so that the seismic performance and other performance requirements of the structure are met. Also, to ensure the required shear capacity, flexural load-carrying capacity and ductility, reinforcing materials such as longitudinal reinforcement or lateral confinement reinforcement shall be placed around the periphery of the existing members. In addition, based on the environment in which the existing structure is placed, the thicknesses of reinforcing material covering and jacketing material of the jacketing parts shall be determined taking into consideration durability and constructability.

If the flexural load-carrying capacity needs to be improved, the reinforcement placed around the periphery shall be anchored securely enough to the existing parts.

NOTE If the flexural load-carrying capacity of the existing structure needs to be improved, the jacketing shall be such that the placed reinforcement can be anchored appropriately to the existing structure. When the column members of bridge piers or the like are strengthened through jacketing, longitudinal reinforcement needs to be anchored appropriately to the footings.

If the ductility needs to be improved, it is advisable to consider placing intermediate penetrating tie according to the cross-sectional shape of the existing structure.

NOTE If the cross-sectional shape of the members subject to intervention is flat with an aspect ratio of smaller than 1/33:1, as with wall-type piers, placing intermediate penetrating tie is effective in improving the ductility of the strengthened members. It is therefore advisable to consider placing intermediate penetrating tie as necessary, taking into account the cross-sectional shape, size and other factors of the existing structure.

6 Materials

6.1 General

The materials used for jacketing shall be of proven quality to ensure that the required performance is fulfilled for a necessary period.

NOTE The jacketing method is often used to improve the seismic performance of an existing structure. In such a case, materials need to be selected to ensure the integrity between the existing parts and jacketing parts so that the structure repaired or strengthened through jacketing fulfills the seismic performance and other performance requirements for a necessary period.

6.2 Materials in existing structure

The characteristic values of material strength, design values and material factors of the materials in an existing structure shall be determined in accordance with 6.2 of ISO / NP 5091-1.

NOTE The characteristic values of material strength, design values and material factors of the materials in an earthquake-affected structure shall be determined appropriately taking into consideration the degree of the existing damage, the type of measures taken for the damage, etc.

NOTE When intervention is targeted at an earthquake-affected structure, the materials in the existing structure may have incurred severe damage, such as yielding or buckling of reinforcing steel, cracking of concrete or crushing of core concrete, and the impact of that damage shall be evaluated appropriately. If any measure such as cracking repair or patching repair has been taken for such damage prior to intervention through jacketing, the characteristic values, design values and material factors of the materials in the existing part shall be determined, appropriately taking into consideration the influence of that measure as necessary.

6.3 Materials used in repairing or strengthening parts

6.3.1 General

The quality of the materials used in the parts repaired or strengthened through jacketing shall be as set forth in 6.3 of ISO / NP 5091-1.

NOTE Jacketing is a construction method to improve the mechanical performance of members by integrating the reinforcing materials placed around the periphery of the existing structure and the cementitious materials placed for jacketing. As the materials used for jacketing, therefore, it is required to select those proven not only to achieve the specified mechanical properties but also to meet the quality requirements in terms of the bonding property required to ensure the integrity between the existing concrete and jacketing parts, workability for jacketing and so forth.

NOTE Table 1 shows the classification of the materials used for jacketing. The cementitious materials are divided into concrete used for concrete jacketing and mortar, such as polymer hydraulic cement mortar, used for mortar jacketing. As reinforcing materials, FRP reinforcing materials such as reinforcing steel, prestressing steel and FRP grids are used. The bonding products are applied or grouted to bond concrete members, concrete and mortar or concrete and reinforcing materials. Here, they refer to the following materials.

— Primer used to improve the bond strength of the existing concrete and mortar

— Anchor grouting material used to anchor longitudinal reinforcement or other reinforcing materials to footings

— Adhesive used to bond reinforcing materials and existing concrete. It is mainly used for a construction method that requires a bond for reinforcing materials placed in grooves on existing concrete cover or for bonding intermediate penetrating tie.

NOTE The filling materials are grouted to fill the gap between reinforcing materials, such as intermediate penetrating steel, and concrete in order to prevent steel corrosion without expecting the intermediate penetrating tie to be bonded.