INTERNATIONAL STANDARD

ISO 5091-4

First edition
2023-07

Structural intervention of existing concrete structures using cementitious materials —

Part 4: Jacketing

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

Partie 4: Chemisage

Reference number
ISO 5091-4:2023(E)

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Published in Switzerland

Contents

Page

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 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 any ISO standard on design, execution and maintenance for this method with attaching cementitious layer. The ISO 5091 series serves as the first ISO standard for the intervention by attaching 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 jacketing is 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 are grasped through a prior investigation and crack injection or sealing, patching repair and other measures are taken in advance as necessary.

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 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 fibre-reinforced polymer (FRP) grids around the periphery of existing concrete column or beam and jackets these members with cementitious materials.

This document specifies structural intervention of existing concrete structures using cementitious materials design and execution principles, and strategies for defects and on-going deterioration including, but not limited to:

a) mechanical actions, e.g. fatigue, impact, overloading, movement caused by settlement, blast, vibration, and seismic actions;

b) chemical and biological actions from environments, e.g. sulfate attack, alkali-aggregate reaction;

c) physical actions, e.g. freeze–thaw, thermal cracking, moisture movement, salt crystallization, fire, and erosion;

d) reinforcement corrosion;

e) original construction defects that remained unaddressed from the time of construction.

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 5091-1:2023, *Structural intervention of existing concrete structures using cementitious materials — Part 1: General principles*

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
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.

3.2
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.

3.3
filling material
material injected to fill the gap between a reinforcing material, such as intermediate penetrating tie, and concrete

3.4
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

3.5
reinforcing material
steel or FRP material used to sustain, restore or improve the mechanical performance of a structure

3.6
polymer hydraulic cement mortar
hydraulic composition made cementitious materials and fine aggregate modified by the addition of a polymer

3.7
FRP grid
resin-impregnated FRP reinforcing materials formed into a grid shape

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 ISO 5091-1:2023, Clause 4.

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.

4.2 Investigation

4.2.1 Investigation using documents, records

An investigation using documents, records, etc. shall be conducted in accordance with ISO 5091-1:2023, 4.2.1.

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.

4.2.2 On-site investigation

The on-site investigation on the existing structure shall be conducted in accordance with ISO 5091-1:2023, 4.2.2. Specifically, an earthquake-affected structure shall involve studying the status of damage caused by the earthquake in detail.

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 can 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 four levels.

— Level a: Resistance remaining intact

— Level b: Slightly degraded resistance

— Level c: Significantly degraded resistance

— Level d: No resistance

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 fulfils the required performance throughout the remaining 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 and restrictions, maintenance method, economy to ensure that the required performance is fulfilled under the environmental conditions of the structure, factoring in the structure's importance.

In the design phase, it can 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 are met.

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.

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.

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.

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.

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. Specifically, for jacketing for the seismic strengthening of an existing structure, materials shall be selected to ensure the integrity between the existing parts and jacketing parts so that the structure repaired or strengthened through jacketing fulfils the seismic performance.

6.2 Materials in existing structure

The characteristic values of material strength, design values and material factors of the materials in an existing and earthquake-affected structure shall be determined in accordance with ISO 5091-1:2023, 6.2.

When intervention is targeted at an earthquake-affected structure, the materials in the existing structure can 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 ISO 5091-1:2023, 6.3.

Table 1 shows the classification of the materials used for jacketing. In this document, 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.

Table 1 — Types of materials used for jacketing

Construction method	Cementitious materials	Reinforcing materials	Bonding products	Filling materials
Concrete jacketing	— Concrete	— Reinforcing steel — Prestressing steel — FRP reinforcing materials	— Primer — Anchor grouting material — Adhesive	— Non-shrink grout — Mortar
Mortar jacketing	— Mortar	— Reinforcing steel — FRP reinforcing materials		

6.3.2 Cementitious materials

The cementitious materials used for jacketing shall be selected in accordance with ISO 5091-1:2023, 6.3.2.

In principle, as the concrete used for concrete jacketing, high-quality materials having the required level of workability appropriate for construction through jacketing shall be selected and an appropriate mix proportion shall be established by performing trial mixing so as to minimize the change in quality over time after hardening.

When appropriate testing and analysis have confirmed that the compressive strength and other material properties of the concrete, which have been created with an appropriate mixing design through the use of materials of proven quality, will exhibit almost no change over time, the material properties at the time of verification may be used as those for intervention construction.

With the jacketing method, reinforcing materials, such as reinforcing steel, are placed on the outer surface of the existing structure. It is therefore advisable to make the reinforcement covering of the jacketing concrete sufficiently thick or, if necessary, provide the jacketing parts with surface protection so as to ensure that the reinforcing materials deteriorate as little as possible over time. When deterioration in the material properties over time can be prevented through appropriate protection, the material properties at the time of verification may be used as those for intervention construction.

As the mortar used for mortar jacketing, materials with proven quality and safety for which an appropriate mix proportion is established shall be used according to the type of spraying or trowelling work.

As the materials for dry or wet spraying, those proven to meet the quality and safety requirements for spraying mortar shall be used. Table 2 shows typical examples of the composition of the materials used in spraying mortar.

Table 2 — Typical examples of the composition of the materials used in spraying mortar

Materials		Materials for dry spraying	Materials for wet spraying
Cement		Ultrarapid hardening cement (high early strength Portland cement or normal Portland cement to be used depending on circumstances)	Portland cement, Portland blast-furnace slag cement, Portland fly ash cement and calcium-aluminate cement
Fine aggregate		Dry natural fine aggregate[a]	Dry natural fine aggregate and lightweight Aggregate
Fibre		Steel fibre and organic fibre	Mainly organic fibre
Admixture	Cement mixing polymer[b]	Polymer dispersion	Polymer dispersion and redispersible polymer powder
	Water reducing agent	-	Can be used.
	Water retention agent	-	Used in many cases.
	Accelerant	-	Can be used when thickening is required for construction in cold weather.
	Retarder	-	Can be used for construction in hot weather.
	Quick setting agent	Can be used.[c]	Can be used.
	Expansive additive	-	Used in many cases.
	Fine powder	Can be used.	Used in many cases.
Water		Tap water is used normally.	

[a] Mainly mechanically stabilized prepacked aggregate.

[b] In the case of polymer hydraulic cement mortar.

[c] When high early strength Portland cement or ordinary Portland cement is used.

6.3.3 Reinforcing materials

The reinforcing materials used for jacketing shall be selected in accordance with ISO 5091-1:2023, 6.3.3.

The reinforcing steel and FRP materials shall be checked to confirm that they possess mechanically reliable material properties including strength, elongation capacity, Young's modulus and coefficient of linear thermal expansion. Steel materials that fulfil the quality requirements set forth in the relevant national standards should be used.

The durability of an FRP reinforcing material varies depending on the types of continuous fibre and matrix resin. It is necessary to check the durability of the composite material after molding.

6.3.4 Bonding products

The bonding products used for jacketing shall be selected in accordance with ISO 5091-1:2023, 4.3.5.

A primer that meets the performance requirements shall be selected so that stress is transferred between the existing concrete and the cementitious materials of the jacketing parts.

With the mortar jacketing method, a primer is generally applied before the jacketing of mortar to ensure the transfer of stress between the existing concrete and mortar. A primer of proven quality that ensures the bonding property of the existing concrete and mortar shall be selected according to the type of mortar used.

An anchor grouting material that has the required strength and ensures the anchorage strength between the existing concrete and reinforcement shall be selected.

An adhesive having the required strength and capable of integrating the existing concrete and reinforcing materials shall be selected.

The adhesive shall also meet the quality requirements related to construction, such as the viscosity and fluidity appropriate for the construction work at the site.

6.3.5 Filling materials

A filling material having the required fluidity that reliably fills the gap between the reinforcing materials and existing concrete shall be selected.

A filling material having appropriate workability and corrosion inhibitor shall be selected considering the space between the reinforcing materials and concrete and the injection method.

6.4 Characteristic values and design values of materials

6.4.1 General

The characteristic values and design values of the materials used for jacketing shall be as set forth in ISO 5091-1:2023, 6.4.

6.4.2 Cementitious materials

The characteristic values and design values of the cementitious materials used for jacketing shall be as set forth in ISO 5091-1:2023, 6.4.2.

6.4.3 Reinforcing materials

The characteristic values and design values of the reinforcing materials used for jacketing shall be as set forth in ISO 5091-1:2023, 6.4.3.

6.4.4 Bonding products

The characteristic values and design values of the bonding products used for jacketing shall be as set forth in ISO 5091-1:2023, 6.4.4.

7 Actions

7.1 General

The actions to be considered in the performance verification of a structure repaired or strengthened using the jacketing method shall be as set forth in ISO 5091-1:2023, Clause 7.

7.2 Actions for intervention design

The actions to be considered for the intervention design shall be as set forth in ISO 5091-1:2023, 7.2.

8 Performance verification for repaired or strengthened structure

8.1 General

The items to be verified for the members repaired or strengthened through jacketing shall be established appropriately to ensure that the structure meets its performance requirements after intervention.

For members configured so that the existing concrete and jacketing parts behave as one, the verification can be performed in accordance with Clause 8. If no integrity is ensured between the existing concrete

and jacketing parts, the performance verification shall be performed by means of an appropriate method, such as analyses and experiments, in accordance with ISO 5091-1.

If the existing concrete and jacketing parts cannot be thought to be integrated or, in other words, if it is necessary to take into consideration any separation or slip at the interface between the jacketing parts and existing concrete, the performance verification needs to be performed through appropriate analyses and experiments, factoring in the effect of the separation or slip.

8.2 Calculation of response values

8.2.1 General

The response values of a structure repaired or strengthened through jacketing shall be calculated as set forth in ISO 5091-1:2023, 8.2.

8.2.2 Modelling of structure

A structure repaired or strengthened through jacketing shall be modelled in accordance with ISO 5091-1:2023, 6.2.2 according to the required performance of the structure.

Members repaired or strengthened through jacketing shall be modelled appropriately, taking into consideration the cross-sectional shape after intervention, and the range of strengthening and anchorage length shall be taken into account.

The materials of members repaired or strengthened through jacketing shall be modelled in accordance with ISO 5091-1.

A structure repaired or strengthened through jacketing shall be modelled appropriately based on inspection and diagnosis results, taking into consideration the degradation of and damage to the existing members.

8.2.3 Structural analysis

The structural analysis of a structure repaired or strengthened through jacketing shall be performed as set forth in ISO 5091-1:2023, 8.2.3.

8.2.4 Calculation of response

The response of members repaired or strengthened through jacketing shall be calculated as set forth in ISO 5091-1:2023, 8.2.4.

8.3 Durability verification

The durability of a structure repaired or strengthened through jacketing shall be verified as set forth in ISO 5091-1:2023, 8.3 in order to check that the structure is not subject to changes over time, such as steel corrosion due to environmental actions and degradation of the existing concrete and the cementitious materials of the jacketing parts, or that the degree of such change remains minor.

8.4 Safety verification

8.4.1 General

In general, the safety of a structure repaired or strengthened through jacketing shall be verified by establishing a limit state for cross-sectional failure.

8.4.2 Verification related to failure

8.4.2.1 General

The verification related to failure shall be generally performed with respect to bending moment, axial force, shear capacity and torsion.

8.4.2.2 Verification related to bending moment and axial force

The safety verification related to bending moment and axial force shall be performed taking into consideration the state of failure appropriately.

The strength can be calculated assuming that the existing and jacketing parts are integrated as one and that multiple layers of reinforcing materials are placed.

When strength is calculated in a verification such as the verification related to the limit state of failure of a member subject to bending moment, as well as to bending moment and axial force, the model can be used for the stress-strain curve of concrete.

When the physical properties of the concrete of the jacketing parts can be deemed to be identical to those of the existing concrete, the stress-strain curve of the existing concrete may be assumed.

The stress-strain curve of the cementitious materials used for the jacketing parts shall be as set forth in ISO 5091-1:2023, 6.4.2.

When strength is calculated in a verification such as the verification related to the limit state of failure, the impact on the cross-section shall be taken into consideration and, if the cementitious materials can be deemed to be the same as the existing concrete, the stress-strain curve of the existing concrete can be assumed.

When strength is calculated in a verification such as the verification related to the limit state of failure, the model can be used for the stress-strain relationship of steel.

The stress-strain curve of FRP reinforcing materials shall be as set forth in ISO 5091-1:2023, 6.4.3.

8.4.2.3 Verification related to shear force

In principle, the safety verification related to shear force shall be performed with respect to the design shear capacity V_{yd} and design diagonal compressive failure strength of the web concrete V_{wcd}, respectively, taking into consideration the state of failure appropriately. The calculation example is shown in Annex A. The safety of members that are modelled as simple beams or cantilever beams shall be verified with respect to both design shear capacity and design diagonal compressive failure strength. If the shear span to depth ratio is small, however, the safety shall be verified with respect to design diagonal compressive failure strength.

As for the shear reinforcement of the jacketing parts, only that wrapped around the entire periphery of the existing members is taken into consideration in principle.

When not wrapped around the entire periphery, the shear reinforcement of the jacketing parts is not anchored completely and may fail to function effectively. Therefore, only the shear reinforcement wrapped around the entire periphery of the existing members shall be taken into consideration in principle.

8.4.2.4 Verification related to torsional moment

If the action of the torsional moment is not negligible, a safety study shall be performed by means of an appropriate method.

If the action of torsional moment is substantial and its impact on the safety of the structure cannot be ignored, a safety verification shall be performed with respect to torsion. The impact on the cementitious

materials and reinforcing materials of the jacketing parts should be checked through appropriate analyses, experiments or other means.

8.5 Serviceability verification

8.5.1 General

The serviceability verification for a structure repaired or strengthened through jacketing shall involve a verification related to appearance, a verification related to vibration and verification related to displacement and deformation if necessary.

8.5.2 Verification related to appearance

The appearance of a structure repaired or strengthened through jacketing shall be verified as set forth in ISO 5091-1:2023, 8.5.3.

8.5.3 Verification related to vibration

The verification related to vibration for a structure repaired or strengthened through jacketing shall be performed as set forth in ISO 5091-1:2023, 8.5.4 and involve checking by means of an appropriate method that the vibration of the repaired or strengthened structure does not affect the comfort in use of the structure itself or any surrounding structure.

8.5.4 Verification related to displacement and deformation

The verification related to displacement and deformation shall involve checking by means of an appropriate method that the comfort in use is not affected by the displacement or deformation that occurs in a structure repaired or strengthened through jacketing.

8.6 Seismic performance verification

When a seismic performance verification is performed for members repaired or strengthened through jacketing, a level of seismic performance and a limit value of damage corresponding to that seismic performance level shall be established in advance.

Establishing the seismic performance of a structure shall involve taking into consideration the response properties of the structure corresponding to the assumed earthquake scale. In addition to the behaviour during an earthquake, the impact of the damage of the structure on human lives and assets, secondary disaster prevention efforts, daily livelihoods and economic activities in the local community after the earthquake, difficulty in restoration and construction costs shall be considered comprehensively to establish seismic performance.

A limit value shall be established according to the seismic performance, taking into consideration the topographical, geological and geotechnical features as well as the location among others. The limit value for seismic performance 2 shall be established within a range beyond the yield displacement or yield rotation angle of members up to the ultimate displacement or ultimate rotation angle.

8.7 Structural details

8.7.1 Arrangement of reinforcing materials and spacing of reinforcing steel

The arrangement of reinforcing materials and spacing of reinforcing steel shall be determined taking into consideration the property of bonding between cementitious materials and reinforcing materials, the crack dispersion performance and the constructability of cementitious materials.

When the crack dispersion performance is taken into consideration, the arrangement spacing of reinforcing materials should be kept below 200 to 300 mm, although it depends on the diameter of the reinforcing steel. In the case of FRP grids, the spacing should be kept below 200 mm.

Also, depending on the type of cementitious material, the construction method, such as placing, spraying or trowelling, and the aggregate size differ. The arrangement of reinforcing materials and spacing of reinforcing steel shall be determined so that the specified bonding property is achieved without honeycombs forming around the reinforcing steel as a result of construction work.

8.7.2 Covering and jacketing thickness of reinforcing materials

The covering and jacketing thickness of reinforcing materials of the jacketing parts shall be sufficient to ensure the performance of the repaired or strengthened structure with constructability taken into consideration.

Care shall be taken if the structure is in an extremely saline environment or requires fire resistance. Since the properties differ depending on the material used, it is necessary to consider the material type when determining the covering.

FRP reinforcing materials have high corrosion inhibition and, therefore, the covering can be made thinner. Taking the bonding property into consideration, it is necessary to check the required covering through experiments.

8.7.3 Joints for lateral reinforcing materials

When reinforcing steel is used as the lateral reinforcing material, joints that directly bond reinforcing steel shall be employed. Lap splice shall not be used in principle.

When an FRP reinforcing material is used as the lateral reinforcing material, a method whose performance has been proven through experiments or other appropriate means shall be used.

Joints used in the range subject to plasticization, such as the bridge pier base, shall have a structure, length and arrangement whose performance has been proven through experiments or other means.

8.7.4 Anchorage of longitudinal reinforcement to footings

The post-installed anchors used for the anchorage of longitudinal reinforcement to footings shall be anchored in a way that ensures the yield strength of longitudinal reinforcement.

8.7.5 Intermediate penetrating tie

Considering the aspect ratio of existing members, intermediate penetrating tie shall be placed as necessary.

Intermediate penetrating tie should be placed when strengthening bridge piers having a cross-sectional shape whose aspect ratio was below 1/3.

With the concrete jacketing method, it is standard to place intermediate penetrating tie at intervals not exceeding the bridge axial cross-sectional width after intervention in the horizontal direction and at intervals of 300 mm or so in the height direction. In principle, when reinforcing steel is used as the intermediate penetrating tie, the steel shall be anchored with hooks. Possible alternative methods to be employed if the use of reinforcing steel is impractical to include using prestressing steel and shaped steel and anchoring them with bolts, as well as using aramid FRP rods as an FRP reinforcing material to introduce tensioning force.

9 Construction

9.1 General

The construction for intervention with the jacketing method shall be in principle performed in accordance with Clause 9 and ISO 5091-1:2023, Clause 9.

Methods of jacketing are roughly divided into concrete jacketing and mortar jacketing, and there are two mortar jacketing methods: spraying and trowelling. Furthermore, two spraying methods are available: wet spraying and dry spraying. An example of the construction procedure for jacketing is shown in Annex A.

Engineers with sufficient knowledge and experience in the construction using the jacketing method shall be assigned to the site and the construction work shall be performed under the direction of those engineers. It is therefore desirable to assign engineers qualified through spraying managing engineer qualification systems run by relevant organizations or qualified spraying technicians.

9.2 Prior investigation and construction plan

A prior investigation shall be conducted before construction to grasp the condition of the existing structure to be repaired or strengthened through jacketing.

It is also required to grasp the status of cracking in the existing members, whether free lime and rust staining is present or not, the status of steel corrosion and the level of damage such as concrete flaking and spalling, as well as to fill cracks, remove degraded parts, perform patching repair and take other measures as necessary before construction using the jacketing method. The prior investigation and measures shall be as set forth in the relevant standard for maintenance.

An appropriate construction plan shall be formulated, and a construction plan document shall be created, taking into consideration the construction and environmental conditions, to construct the repaired or strengthened structure shown in design documents.

It is therefore necessary to formulate a construction plan appropriate for the conditions of the local site while reflecting the results of the prior investigation. The construction plan shall be formulated by reflecting the prior investigation results, comprehensively taking into consideration the securing of quality, the safety, economy and period of construction work and the environmental burden. When formulating a construction plan, care shall be taken to ensure:

— a reasonable process plan is created taking into consideration the time zones during which work can be done;

— a sufficient workspace is secured;

— the necessary amounts of materials of proven quality are procured;

— constructing parties with necessary skills and sufficient experience are assigned.

Also, in order to perform construction safely, care shall be taken to ensure:

— measures to provide safety for constructing parties are specified;

— measures to provide safety for third parties are specified;

— measures to prevent the destruction of additive and other related facilities;

— a system is in place to respond to accidents swiftly;

— a waste disposal method is specified.

Formulating the construction plan shall involve considering the actual work methods and the management methods to ensure the implementation of those methods. The construction procedure for jacketing consists of the processes mentioned below. When formulating a construction plan, the actual work methods and management methods in the individual work processes shall be clearly defined as follows:

a) Concrete jacketing

   1) Surface treatment

2) Assembly of reinforcing materials

3) Mold setup

4) Execution of concrete jacketing

5) Curing

6) Mold removal

b) Mortar jacketing

1) Surface treatment

2) Assembly of reinforcing materials

3) Surface preparation

4) Storage, mixing and transportation of jacketing materials

5) Execution of mortar jacketing (spraying (wet or dry) or trowelling)

6) Curing

Considering the restrictions such as the work environment of the construction site and work time, a quality control method shall be specified to ensure the processes corresponding to the construction items and the required performance in the design. If any change in construction work becomes necessary during construction, the construction plan shall be changed to ensure that the relevant requirements, such as the construction requirements and the performance requirements of the structure, are met. If the construction plan is changed, the construction plan document shall be changed accordingly.

9.3 Surface treatment

In surface treatment for jacketing, dirt such as oil and grease on the surface of the existing members and vulnerable layers shall be removed so that the existing concrete and jacketing parts are integrated. Also, harmful cracks, floating, spalling and water leaks shall be treated appropriately.

If the surface of the existing members has construction defects such as honeycombs, noticeable degradation, cracks, water leaks, etc., the existing members shall be repaired using an appropriate method such as patching repair, crack injection, crack sealing or water leak prevention.

9.4 Assembly of reinforcing materials

The reinforcing materials used for jacketing shall be placed at the specified positions precisely.

If epoxy-coated reinforcing steel bars are used in a saline environment, due care shall be taken so that the epoxy coating is not damaged during assembly. In the case of concrete jacketing, the relevant standard for execution of concrete structures shall apply.

The reinforcing materials used for mortar jacketing shall be securely anchored to existing members using concrete anchors using metal fittings or other tools appropriate for the individual reinforcing materials so that there will be no space between the existing members and reinforcing materials. Other methods may be used in which reinforcing materials are embedded in grooves on the surface of the existing members and fastened with adhesive.

The positions of the joints of reinforcing materials and the jointing method shall be in principle as specified in design documents. To joint reinforcing materials, an appropriate method shall be selected according to the type of reinforcing material, cross-sectional dimension, stress status, joint positions, joint performance requirements and so on. In the design phase, therefore, the joint positions and jointing method are specified in design documents giving due consideration to these factors. For this reason, the joint positions and jointing method shall be in principle as specified in design documents.

When intermediate penetrating tie are used, they shall be placed at the specified positions according to design documents such that they do not damage the steel in the existing members. When holes are bored in existing members by means of core boring or some other technique in order to place intermediate penetrating tie, the positions of reinforcing steel shall be checked in advance through a radar survey not to damage the existing reinforcing steel.

9.5 Execution of concrete jacketing

Mold setup, concrete placement, curing and mold removal for concrete jacketing shall be performed by means of appropriate methods. Since the concrete placed for jacketing is structurally prone to cracking, an appropriate mixing design shall be considered. Also, a sufficient amount of water shall be sprayed over existing members immediately before the placement of concrete in order to prevent hardening failure that may occur as the moisture in the concrete is absorbed in the existing members.

9.6 Execution of mortar jacketing

9.6.1 Surface preparation

For the work of surface preparation, bonding products appropriate for the mortar materials used shall be selected.

9.6.2 Storage, mixing and transportation of jacketing materials

Mortar materials shall be stored properly.

Mortar shall be mixed using the specified mix proportion, which is determined for each material, in the specified order of material entry at the specified mixer capacity in the specified mixing time.

For the transportation of mortar, a method shall be selected that ensures that the required amount of mortar can be transported with the required level of quality. The pump capacity, pipe diameter and length and spraying equipment appropriate for the jacketing method and the selected mortar shall be selected.

9.6.3 Execution of mortar jacketing

For mortar jacketing, mortar shall be applied using the method determined for each material.

If the jacketing thickness is large, the material shall be divided into an appropriate number of layers according to the thickness when applied.

NOTE The allowable spray thickness per layer differs depending on the spraying method and spraying direction. In general, when the material is sprayed horizontally, the maximum allowable spray thickness is 50 mm or so for the wet spraying method and 200 mm or so for the dry spraying method. When the material is sprayed upwardly, the maximum allowable spray thickness is 30 mm or so for the wet spraying method and 100 mm or so for the dry spraying method.

When the spray surface is finished, the jacketing material shall be sprayed up to the finished surface and the surface shall be smoothed with a metal trowel.

During construction, temperature management shall be accomplished using a thermometer installed at the construction site. Before performing construction work, the average daytime temperature shall be checked. If the temperature is outside acceptable ranges, construction shall be performed in accordance with ISO 22966.

9.6.4 Curing

The mortar applied for jacketing shall be cured such that it is not subject to sudden temperature changes, drying or other detrimental action appropriately until it achieves the specified strength.

9.7 Surface protection

After the construction of the jacketing parts is complete, surface protection work against carbonation and salt attack as well as against other types of damage shall be performed as necessary.

9.8 Quality control

Quality control shall be implemented for specified items in each phase of construction so as to check that the structure repaired or strengthened through jacketing has the required level of quality. Quality control shall involve not only controlling the quality of reinforcing materials but, in the case of mortar jacketing, managing the mixing of mortar and accomplishing mix proportion management.

a) Quality control of reinforcing materials

b) Mixing management

c) Mix proportion management

d) Strength management

9.9 Inspection

A structure constructed using the jacketing method shall be in principle inspected according to an inspection plan under the responsibility of the ordering party of the structure. Particularly, since the covering thickness is small, an inspection shall be conducted to ensure that the thickness is appropriate.

10 Records

Information concerning the intervention of a structure shall be recorded by means of an appropriate method and retained for a necessary period. The method of recording shall be as set forth in ISO 5091-1:2023, Clause 10.

11 Maintenance

The maintenance of a structure repaired or strengthened through jacketing shall be as set forth in ISO 5091-1:2023, Clause 11.

Structures repaired or strengthened through jacketing, such as bridge piers, can be located in extremely corrosive environment such as in rivers and along with seaside areas. In such cases, concrete surface protection or some other measure can be necessary to sustain the required durability and commonly the concrete surface protection work involves treatment such as periodical repainting. Therefore, a maintenance plan is formulated by incorporating the basic policy on the treatment required to sustain durability during the service life after the intervention as well as on when such treatment is to be given.

In the case of a structure built in a river, driftwood and other objects can collide with the structure during a flood, possibly damaging the covering parts of concrete or mortar that have been placed. Therefore, an inspection needs to be performed after a flood and, upon discovery of the damage, appropriate treatment will be given.

Annex A
(informative)

Examples of design and execution

A.1 Verification related shear force

The design shear capacity V_{yd} can be calculated using Formula (A.1) below.

$$V_{yd} = V_{cd} + V_{sd} + V_{asd} \tag{A.1}$$

where V_{cd} is the design shear capacity of beam or column that do not use shear reinforcing steel, which is calculated using Formula (A.2).

$$V_{cd} = \beta_{dr} \cdot \beta_{pr} \cdot (f_{vcd} \cdot b_w + f_{avcd} \cdot b_{aw}) \cdot d_r / \gamma_b \tag{A.2}$$

$f_{vcd} = 0{,}20\sqrt[3]{f'_{cd}}$ (N/mm^2) where $f_{vcd} \leq 0{,}72$ (N/mm^2)

$\beta_{dr} = \sqrt[4]{1\,000 / d_r}$ (d_r : mm) but when $\beta_{dr} > 1{,}5$, it needs to be set to 1,5.

$\beta_{pr} = \sqrt[3]{100 p_{vr}}$ but when $\beta_{pr} > 1{,}5$, it needs to be set to 1,5.

b_w is the web breadth of the existing concrete (mm);

d_r is the effective height after strengthening

distance from the extreme compression fibre of the concrete to the centroid of tensile reinforcement bars of reinforced concrete members of the existing and jacketing parts (mm)

$p_{vr} = A_{sr} / \{(b_w + b_{aw}) \cdot d_r\}$

A_{sr} is the cross-sectional area of the tensile reinforcement (mm^2);

f'_{cd} is the design compressive strength of the existing concrete (N/mm^2);

f_{avcd} is the average shear strength of cementitious materials of the jacketing part (N/mm^2);

b_{aw} is the web breadth of the jacketing part (mm);

γ_b is the partial safety factor for member, which is generally set to 1,3;

V_{sd} is the design shear capacity supported by the shear reinforcement of the existing members, which is calculated using Formula (A.3).

$$V_{sd} = \left[A_w f_{wyd} (\sin\alpha_s + \cos\alpha_s) / s_s \right] z_r / \gamma_b \tag{A.3}$$

A_w is the total cross-sectional area of the shear reinforcement in interval s_s (mm^2);

f_{wyd} is the design yield strength of the shear reinforcement. The upper limit is $25 f'_{cd}$ (N/mm^2) or 800 N/mm^2 (whichever is the smaller value);

α_s is the angle formed by the shear reinforcement and member axis;

s_s is the shear reinforcement spacing (mm);

z_r is the distance from the position at which the force resulting from compressive stress is applied after strengthening to the centroid of tensile steel, which can be generally set to $d_r / 1{,}15$;

γ_b is the partial safety factor for member, which is generally set to 1,1;

V_{asd} is the design shear capacity supported by the shear reinforcement of the jacketing part, which is calculated using Formula (A.4).

$$V_{asd} = \left[A_{aw} f_{awyd} (\sin\alpha_{as} + \cos\alpha_{as}) / s_{as} \right] z_r / \gamma_b \quad \text{(A.4)}$$

A_{aw} is the total cross-sectional area of the shear reinforcement in interval s_{as} of the jacketing part (mm^2);

f_{awyd} is the design yield strength of the shear reinforcement of the jacketing part. Future experimental or analytical verification is needed if design yield strength is more than 345 N/mm^2;

α_{as} is the angle formed by the shear reinforcement of the jacketing part and member axis;

s_{as} is the shear reinforcement spacing in the jacketing part (mm);

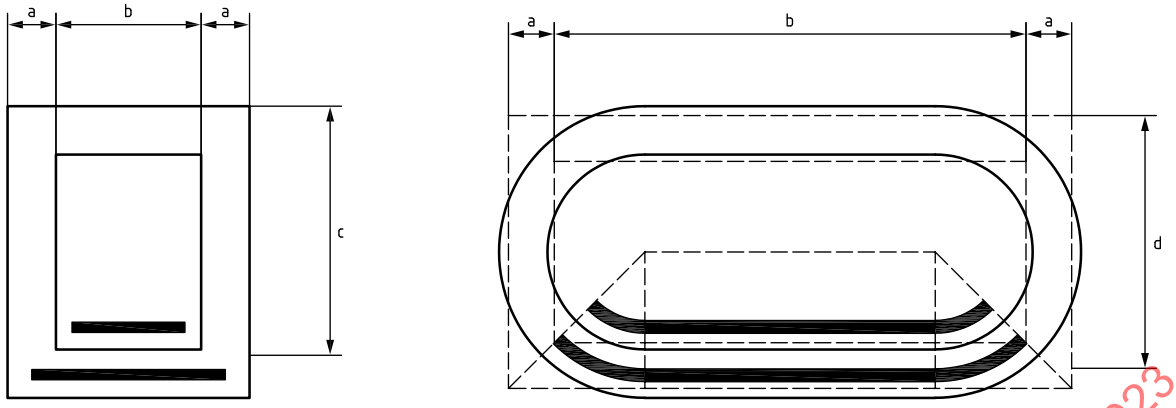
γ_b is the partial safety factor for member, which is generally set to 1,1.

Assuming that the existing concrete and jacketing parts are integrated, the design shear capacity of beam or column needs to be expressed as the sum of the contribution of capacity of the cementitious materials of the existing and jacketing parts, the contribution of capacity of the shear reinforcing steel of the existing parts and the contribution of capacity of the shear reinforcement of the jacketing parts. The design shear capacity of beam or column that do not use shear reinforcing steel need to be calculated from the shear strength of the existing concrete and the average shear strength of the cementitious materials of the jacketing parts, and it has been decided that the effective height needs to be up to the centroid of the reinforcement of the existing and jacketing parts.

In jacketing, the web width needs to be twice the jacketing thickness of the jacketing parts. In the case of a circular or elliptical cross-section, its size needs to be calculated after being converted to that of a rectangular shape (see Figure A.1).

When FRP reinforcing materials are used as shear reinforcement, the contribution of capacity of the shear reinforcement needs to be calculated, and its Young's modulus and effective strain need to be evaluated appropriately.

It has been decided that the upper limit of the design yield strength of the shear reinforcement of the jacketing part needs to be specified. Because Formula (A.4) was formulated based on the experiment using general rebars. When high-strength reinforcement is used, this need to be verified through experiments or other means.



a Half of web breadth of the jacketing part (mm) $b_{aw}/2$

b Web breadth of the existing concrete (mm) b_w

c Effective height after strengthening (mm) d_r

d Effective height after strengthening considering equivalent cross section (mm) d

Figure A.1 — Determining the web width in jacketing

The design diagonal compressive failure strength of the web concrete against shear V_{wcd} can be calculated using Formula (A.5) below.

$$V_{wcd} = f_{wcd} \cdot (b_w + b_{aw}) \cdot d_r / \gamma_b \tag{A.5}$$

where

$f_{wcd} = 1{,}25\sqrt{f'_{cd}}$ but $f_{wcd} \leq 9{,}8$ (N/mm^2);

γ_b is the partial safety factor for member, which is generally set to 1,3.

A.2 Anchorage of longitudinal reinforcement to footings

Generally, the centre-to-centre space between anchors is 300 mm. Anchors need to be placed at intervals of 250 to 500 mm, avoiding the main reinforcement on top of the footings. Epoxy resin and non-shrink mortar are used as anchor grouting materials. Since the minimum anchorage length differs depending on the type of grouting material, a test-proven value needs to be adopted.

The anchorage length of the reinforcement is calculated by Formula (A.6). For example, the minimum anchorage length of epoxy resin is said to be 20 times the diameter of reinforcing steel. The anchorage length of epoxy resin, which is shorter, is often used as the standard.

$$L = \alpha \frac{f_{yd}}{4 f_{bod}} \varphi \tag{A.6}$$

where

φ is the diameter of reinforcing steel;

f_{yd} is the design tensile yield strength of reinforcing steel;

f_{bod} is the design bond strength of concrete. Considering that γ_c is 1,3,