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Maintenance and repair of concrete structures —

Part 1: **General principles**

Entretien et réparation des structures en béton —

Partie 1: Principes généraux

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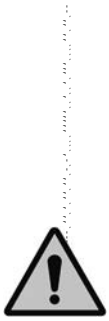

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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 documents 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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 71, *Concrete, reinforced concrete and pre-stressed concrete*, Subcommittee SC 7, *Maintenance and repair of concrete structures*.

ISO 16311 consists of the following parts, under the general title *Maintenance and repair of concrete structures:*

— *Part 1: General principles*

— *Part 2: Assessment of existing concrete structures*

— *Part 3: Design of repairs and prevention*

— *Part 4: Execution of repair and prevention*

Introduction

In the context of this part of ISO 16311, maintenance and repair are two closely related activities aimed at securing that a concrete structure (hereinafter referred to as "structure") is retained in a state in which it can perform its required functions, while in an acceptable and safe condition. Maintenance will be used as a general term that also covers repair as a distinct activity to restore worn, damaged, or deteriorated parts. For a well-designed and well-executed concrete structure with proper maintenance, repair should not be necessary within the service life of the structure.

This part of ISO 16311 covers the activities necessary to retain the performance of the structure above the required levels during its service life, such as:

— maintenance planning for existing structures;

— assessment of structure including inspection/investigation and evaluation of the performance of structure;

— planning and designing repair in case it is required due to damage, deterioration, or wear;

— execution of repair including preparation, execution, and documentation.

The main scope of this part of ISO 16311 is the maintenance and repair of existing structures. The goal of maintenance and repair strategies is to plan and execute systematic routines that minimize degradation of performance and serviceability of a structure during its service life in the most cost-effective manner.

This part of ISO 16311 does not address newly built structures for which it is recommended that a maintenance plan should be established at the design stage. However, a so called "birth certificate" for newly built structures will be useful in later planning of maintenance and repair. Reference is given to ISO 16204, where this is covered.

"*Part 1: General principles*" provides the framework of maintenance activities for all structures or their components and gives general principles of each activity. As shown in Figure 1, this part of ISO 16311 is the first of four parts dealing with maintenance and repair of concrete structures. The subsequent three parts, namely "Assessment of existing structures", "Design of repairs and prevention", and "Execution of repairs and prevention" are the operational parts of this set of International Standards giving detailed requirements and guidelines (an extended hierarchy of the parts and other related International Standards are shown in Annex A).

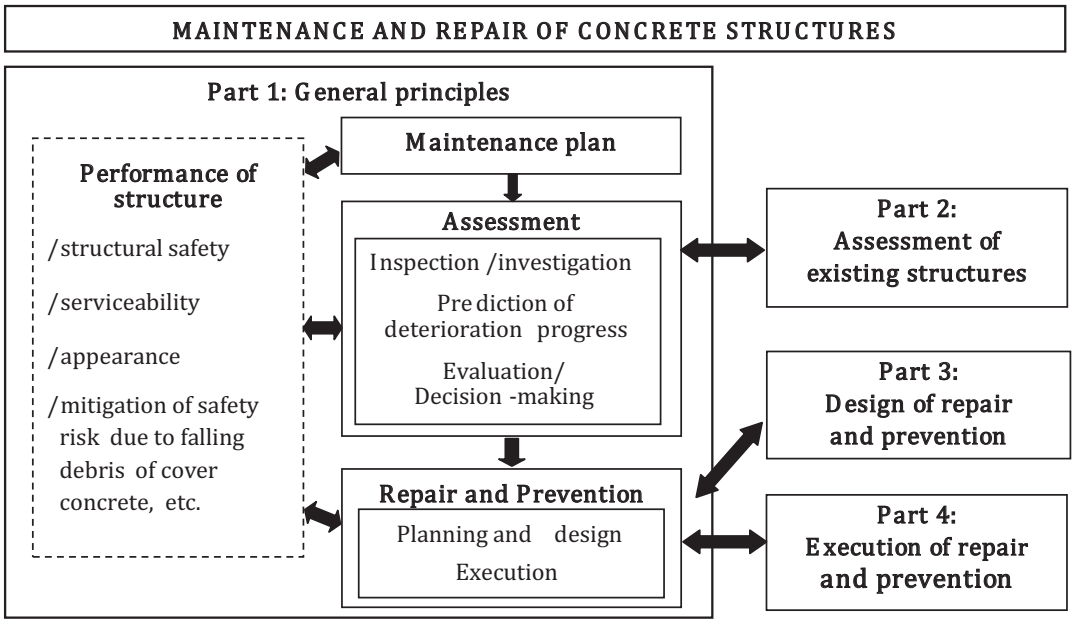


Figure 1 — Relationship between each part of this International Standard

Maintenance and repair of concrete structures —

Part 1:
General principles

1 Scope

This part of ISO 16311 presents the framework and general principles for maintenance and repair of all kinds of existing concrete structures — un-reinforced and reinforced concrete, prestressed concrete and steel-concrete composite structures, or their structural members.

In this part of ISO 16311, deterioration is clearly distinguished from damage occurring in a short period and not developing over subsequent time, such as cracking and scaling due to earthquakes or impact loading, etc. Deterioration is mainly dealt with as a target for the maintenance activities.

This part of ISO 16311 also provides the basic concept of repair and preventions carried out to restore structural performance of existing structures.

This part of ISO 16311 does not cover those aspects of maintenance and repair that are related to serviceability and esthetics without direct impact on durability and service life, e.g. cleaning of drains, removal of vegetation, refreshment of paint, etc.

This International Standard also does not cover repair of defects during execution of new structures.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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, *Maintenance and repair of concrete structures — Part 4: Execution of repairs and prevention*

ISO 19338:2007, *Performance and assessment requirements for design standards on structural concrete*

3 Terms and definitions

For the purpose of this International Standard, the following terms and definitions shall apply with those in ISO 19338.

3.1
assessment
set of activities performed in order to verify the reliability of an existing structure for future use

[SOURCE: ISO 13822:2010]

3.2
amended service life
revised service life period of a structure-in-service during which it meets prescribed performance requirements for duration specified by the owner, possibly representing an amendment of the original design service life

Note 1 to entry: A change from the original design service life can arise from changing owner requirements, accelerated deterioration of a structure or its components such that they do not meet prescribed performance requirements, a usage change affecting performance requirements, or the owner's selection of maintenance and repair scenarios that might shorten or extend the original design service life period.

Note 2 to entry: See Figure 2.

3.3
design service life
period of time specified in design of structure for which a structure or its members is to be used for its intended purpose without major repair being necessary

Note 1 to entry: See Figure 2.

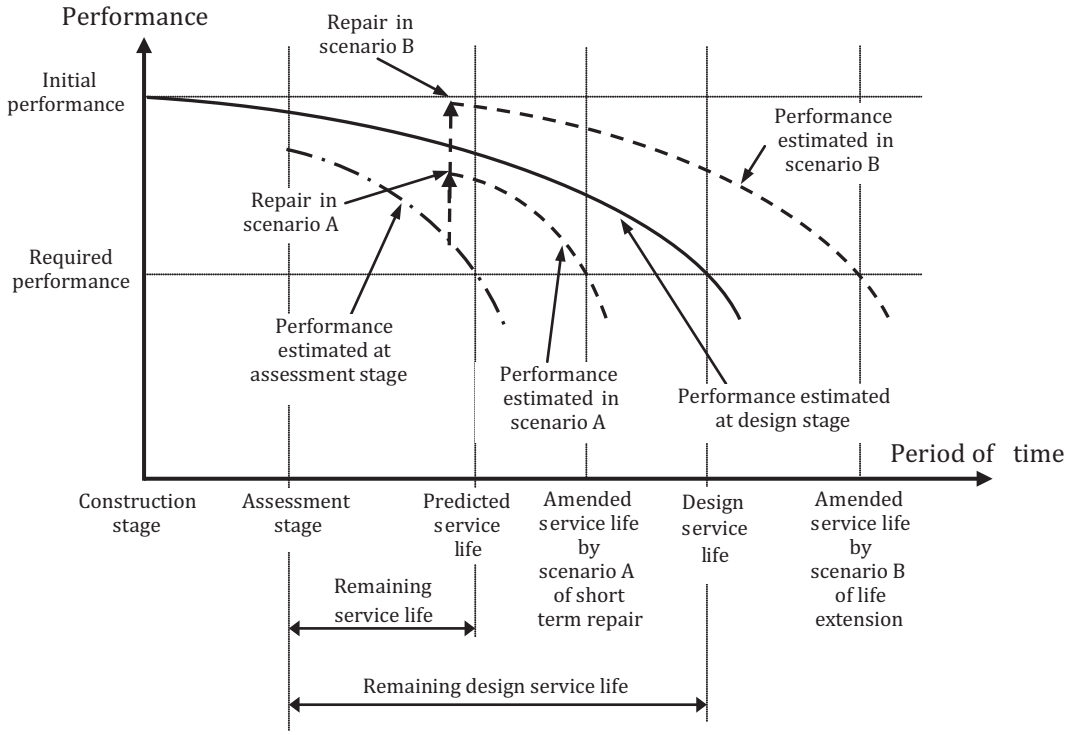


Figure 2 — Definitions of service life

3.4
deterioration
process that adversely affects the performance of a structure, including reliability over time due to defects and damages caused by

— naturally occurring chemical, physical, biological, or other environmental actions,

— repeated mechanical actions such as those causing fatigue,

— wear due to use, abuse, and others, and

— improper operation and maintenance of the structure

[SOURCE: ISO 13822:2010]

3.5
durability
capability of a structure or any of its members to satisfy, with planned maintenance, the required performance over a specified period of time under the influence of the environmental action

[SOURCE: ISO 13823:2008]

Note 1 to entry: "durability" is often used as qualitative term to express condition in which structure maintains its required performance, such as structural safety, serviceability, and appearance, during the service life.

3.6
inspection
conformity evaluation by observation and judgment accompanied as appropriate by measurement, testing, or gauging

[SOURCE: ISO 16311-2]

Note 1 to entry: For structures, this evaluation consists of actions collecting information on the current state of a structure through observation and simplified non-destructive or destructive testing supplemented with materials and structural testing, as required.

3.7
investigation
collection of information through inspection, document search, load testing, and other testing

3.8
maintenance
set of activities taken to check, evaluate the performance of a structure, and preserve/restore it so as to satisfy performance requirements in service

3.9
maintenance category
class of maintenance depending on importance, service life, environmental conditions, maintainability of the structures, etc

3.10
maintenance plan
plan realizing maintenance strategy in order to ensure that the structure retain the performance within the specified tolerances throughout its service life

Note 1 to entry: This includes planning not only for assessment but also for repair or other remedial actions.

3.11
monitoring
frequent or continuous, normally long-term, observation or measurement with recording of appropriate data for deterioration and/or performance of structure using appropriate equipment

3.12
predicted service life
period of time estimated based on activities of assessment, such as recorded performance, previous experience, tests, or modeling

Note 1 to entry: See Figure 2.

3.13
prevention
remedial action to prevent or slow down the further deterioration of a structure or structural member and to reduce the possibility of damage to the user or any third party, inhibiting the progress of deterioration, and proactively preventing deterioration

3.14
rehabilitation
work required to repair and possibly upgrade an existing structure

[SOURCE: ISO 13822:2010]

3.15
remaining design service life
period from the time of a given inspection of a structure till the end of its design service life

Note 1 to entry: See Figure 2.

3.16
remaining service life
period from the time of a given assessment of a structure until the end of its predicted service life

Note 1 to entry: See Figure 2.

3.17
remedial action
action carried out with the objective of arresting or slowing down the deterioration process, restoring or improving the performance of structure, or reducing the danger of damage or injury to the user or any third party

3.18
repair
restoration of a structure or its components to an acceptable condition by the renewal or replacement of worn, damaged, or deteriorated components

[SOURCE: ISO 13823:2008]

Note 1 to entry: Repair is adopted to restore structural performance and to mitigate safety risks up to the initially required design level and to achieve the intended service life.

3.19
repair plan
plan for establishing the method and level of repair, determining the materials, sectional dimensions, and execution methods, specifying the control items during execution in consideration of the policy and level of repair

3.20
safety risks due to falling debris
hazards of damage and/or injury caused by concrete fragments and surface coating (finishing) materials, etc. falling from a deteriorated structure

3.21
service life
actual period during which a structure meets the prescribed performance requirement

3.22
strengthening
measures taken to improve structural performance relating to load bearing capacity and deformation of an existing structure and/or its members

4 Basis of maintenance and repair

4.1 General

A concrete structure shall retain the required performance for its service life by providing necessary maintenance and repair activities, such that its performance is always above the required performance

level with adequate reliability under an appropriate maintenance plan. A qualified person (design professional, engineer, etc.) shall develop a proper maintenance plan that could permit a structure to retain its required performance

4.2 Procedure of maintenance and repair

A general flow of maintenance procedure is shown in Figure 3. The overall maintenance activities shall encompass the maintenance plan, assessment (including investigation/inspection, prediction of progress of deterioration, and evaluation of structural integrity/decision-making), and shall be followed by repair, prevention, or other remedial actions (if required). Results of these activities shall be recorded with an easily accessible format.

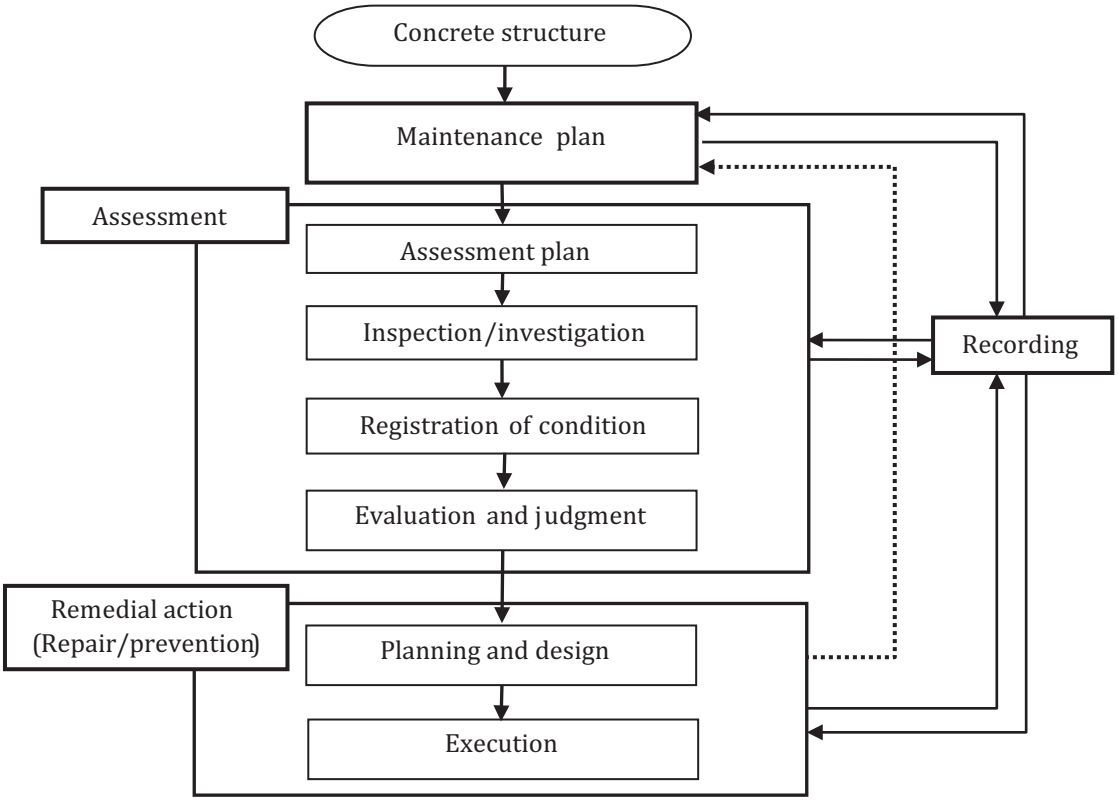


Figure 3 — General maintenance procedure

4.3 Competence of personnel

All activities of maintenance and repair shall be carried out by a team of qualified persons having the adequate knowledge of design, construction, maintenance, and repair of concrete structures.

NOTE In some countries, there are special requirements regarding the level of knowledge, training, and experience of persons involved in the different tasks.

5 Maintenance plan

5.1 General

For accomplishing overall maintenance activities, an adequate maintenance plan shall be formulated taking into account the maintenance category selected provisionally in accordance with 5.3, remaining service life, life-cycle cost, and other considerations particular to the structure.

The following shall be specified in the maintenance plan:

— performance requirements which a structure should retain for the remaining service life;

— methods and timing of assessment composed of investigation and prediction of deterioration of the structure or its structural members, performance evaluation for structure, and decision of the need of remedial actions;

— basic consideration concerning repair and/or other remedial actions for the expected deterioration/performance degradation of structure.

5.2 Timing of maintenance planning for structure

An appropriate maintenance plan shall be formulated before starting maintenance actions.

NOTE During the life of a structure, there are the following three stages where a maintenance plan should be formulated:

— at the design stage by choosing structural type and materials that satisfies maintainability;

— under service conditions when some maintenance activity is considered to be required;

— after a large repair project is carried out.

The last two stages are only covered in this part of ISO 16311 for the timing of formulating a maintenance plans.

5.3 Selection of maintenance category

In the maintenance plan, a suitable maintenance category shall be provisionally selected to carry out the maintenance work as effectively as possible in consideration of such factors as the importance of the structure, remaining service life, safety concerns, environmental conditions, and ease of maintenance (see Annex C).

When structural members have differences in their importance, environmental condition, safety concerns, ease of maintenance, etc., different maintenance categories should be selected on each member even in the same structure.

5.4 Final determination of maintenance plan

When the results of initial assessment prescribed in 6.2.2 suggest that the maintenance category provisionally selected is not suitable, it shall be revised. Consequently, the maintenance plan shall be determined in accordance with the finally selected maintenance category.

6 Assessment

6.1 General

Assessment of a structure shall be carried out to verify its reliability after due considering structural performance and durability.

An appropriate assessment plan, which includes planning of methods and procedures for investigation, prediction of deterioration progress, evaluation of actual structure condition, decision-making for necessity of remedial action, and record, shall be established after due considering the actual condition of the structure.

NOTE Assessment of existing concrete structures is covered in detail in ISO 16311-2.

6.2 Assessment plan

6.2.1 Preparation of assessment plan

To identify probably critical situations for the structure, the expected condition of the structure during its remaining service life should be specified appropriately prior to the assessment planning. The preparation of an assessment plan, therefore, may begin with the documentation of relevant performance criteria such that areas of concern that would compromise the structure meeting or exceeding its design service life are identified.

To carry out the assessment on a structure rationally and economically, the category and the level of assessment should be decided appropriately in the assessment plan prior to the execution of the assessment procedure. The selected category and level of assessment depend on the assessment objectives, timing of assessments, and other specific circumstances such as availability of the design and construction document, observation of damage, use of the structure.

6.2.2 Category of assessment

Assessment performed in maintenance activities for a structure throughout its service life is categorized suitably on the basis of the timing of assessment and the type of information desired.

In general, the assessment is classified in the following three categories.

— Initial assessment: an assessment carried out for evaluating the initial condition of a structure before initiating into routine/regular maintenance activities.

NOTE Examples of initial assessment are

— first assessment of existing structures when no repair is necessary but a maintenance plan is recommended,

— assessment of an existing structure that has undergone large scale remedial actions, and

— "birth certificate" of newly constructed structures.

— Periodic assessment: assessment carried out routinely or regularly at certain intervals prescribed in the maintenance plan.

NOTE When some kinds of visual sign of deterioration are observed or when there is a suspicion that some kind of deterioration is going on, the assessment is carried out spontaneously in spite of the routine or regular interval.

— Extraordinary assessment: assessment carried out after a structure has been subjected to an accidental action, such as earthquake, storm, flood, fire, and impact by a vehicle or ship.

6.2.3 Level of assessment

An appropriate assessment level shall be selected depending upon the purpose and scope of the category of assessment.

In general, two levels of assessment are defined as follows.

— Preliminary level: assessment to collect the basic information on structural condition by using simple inspection/investigation methods complied with a maintenance plan, such as a visual inspection and simple non-destructive test.

— Detailed level: assessment to obtain detailed and specific information regarding deterioration and performance degradation of the structure. It is used when the assessment in the preliminary level is insufficient for identifying the deterioration and/or performance degradation or anytime when it is required.

6.3 Investigation

Investigation in assessment shall be carried out with the objectives of detecting deterioration and/or change in performance of the structure. Such investigation shall be carried out by inspection visually or with the help of appropriate methods and techniques, document search, load testing and other testing, etc., at appropriate intervals depending on the importance of the structure, the category of maintenance, the category and level of assessment, and the expected mechanism and the rate of deterioration.

As deterioration and/or change in performance of the structure are affected by environmental influence and/or physical actions such as loading, investigations shall also be conducted by an appropriate method to identify the characteristics of the environment in which the structure has been placed.

When commencing investigation, it is necessary to make an adequate implementation plan, which includes selection of items and method, identification of location, frequencies, etc. based on the expected deterioration prediction and past maintenance records.

NOTE Details of site and laboratory investigation are given in ISO 16311-2.

6.4 Registration of condition

To carry out appropriate prediction of deterioration occurring on the structure and/or its structural member under consideration, the mechanism of deterioration shall be provisionally identified. In general, deterioration mechanism should be identified in consideration of the deterioration factors specified and any signs of deterioration detected in the inspection and/or other tests in investigation.

NOTE Deterioration factors are classified as:

— external factors, i.e. those related to an external condition, such as environmental, weather, and external force conditions affecting the concrete structure under consideration;

— internal factors, i.e. those related to the internal conditions of the structure and linked to the design and construction processes.

A structure and/or structural members are often subjected to more than one deterioration mechanism. In this case, the combined effects of those mechanisms shall be considered.

According to the identified deterioration mechanism, current condition/consequence level, and deterioration rate on the structure and/or its members shall be determined using appropriate analysis models established on the basis of the environmental conditions and any other useful information obtained from investigation.

The degradation in structural performance and its progress shall be also properly predicted by appropriate models, which are formulated based on the predicted current condition of the structure/member's performance and the rate of deterioration.

NOTE Methods to register the condition of structure or its members is covered in detail in ISO 16311-2.

6.5 Evaluation and judgment

For evaluating structure/members condition, the structural performance possessed during remaining service life shall be verified with reference to the threshold of requirements. The verification, in principle, should be carried out respectively for one or more of required performance.

NOTE The threshold of required performance of the structure is determined in accordance with requirements from government (e.g. standards, codes), owner, designer, user, etc.

Depending on the importance of the structure, category of maintenance, intended remaining service life, life-cycle cost, and other considerations, as well as the overall results of the structural performance

evaluation, judgement shall be made appropriately to give recommended actions in the preliminary and detailed levels of assessment, respectively.

NOTE Methods to evaluate and judge the condition of structure or its members are covered in detail in ISO 16311-2.

7 Repair including prevention

7.1 General

The procedure of repair including prevention (here-in-after shown as "repair/prevention") mainly consists of planning, design, execution, and completion inspection.

Planning and design for the repair/prevention action shall be formulated on the basis of the extent of deterioration, remaining service life, remaining and desired structural performance for safety, such as load bearing capacity, importance of the structure, the conservation level, and previous repair/prevention taken.

NOTE 1 When fatal defect, damage of urgency, or unsafe conditions are observed during assessment, it is subjected to emergency measures because leaving such a defect or damage untreated subsequently leads to a serious accident, or a serious economic disadvantage.

NOTE 2 The results of the completed assessment are valid when the repair/prevention is planned, designed, and carried out. However, if, as a result of passage of time, or for any other reason, there are doubts about the validity of the assessment, a new assessment shall be made.

Before execution of the remedial action, a detailed execution plan should be formulated in consideration of the execution environment, time of execution, and execution period.

The repair/prevention shall be carried out with minimum disturbance to the surrounding environment and the service condition of the structure.

After the repair/prevention is taken, the performance of the structure shall be evaluated by the completion inspection. When the prescribed performance of the structure is upheld, a revised maintenance plan shall be developed.

7.2 Planning and design

7.2.1 General

Planning of repair/prevention shall be carried out on the basis of the results and evaluation of the assessment, and the owner's need and expectations for the structure. At least, the following should be considered to examine in the planning:

— options of actions;

— factors to consider;

— choice of appropriate strategies;

— choice of appropriate methods;

— properties of materials, products and systems;

— other remedial actions.

A design of the repair/prevention should be executed after selecting the repair method, the materials to be used, and the level of repair. In the repair design, the types and combinations of repair materials, execution methods, and repair area or portion, should be determined.

NOTE Planning and design of repair and prevention of concrete structures is covered in details by ISO 16311-3.

7.2.2 Option of actions

The following alternatives shall be considered in deciding the appropriate action to meet the future requirements for the life of the structure:

— do nothing for a certain time while monitoring the structure;

— re-analyses the structural capacity, possibly leading to a downgrade in function;

— prevent or reduce further deterioration;

— strengthen or repair and protect all or part of the concrete structure;

— reconstruct all or part of the concrete structure;

— demolish all or part of the concrete structure.

NOTE Some of these alternatives will not result in prevention/repair of the structure. Those alternatives are mentioned further in 7.2.7.

7.2.3 Factors to consider

A suitable repair method shall be selected based on, but not limited to the following items:

— the assessment results relating deterioration condition and future development;

— the structural integrity and stability;

— the environmental exposure condition and its aggressiveness;

— the category of maintenance;

— the intended use and remaining service life;

— easiness of maintenance including cost efficiency;

— potential advantage of an earlier action from the aspect of life-cycle cost;

— the likely service life of the repair/prevention;

— the number and cost of repair cycles accepted during the remaining design life;

— importance of the structure;

— the appearance of the repaired structure;

— health and safety aspects.

Formulating a repair plan refers to establishing the required repair level and selecting a repair method, repair materials, sectional dimensions after repair, and the execution methods.

7.2.4 Choice of appropriate strategies

The choice of strategy for the structure shall be based on the assessment of the structure, client requirements, and relevant provisions (e.g. safety requirements) valid in the place of execution.

A repair/prevention principle or principles shall be chosen based on the appropriate type, cause, or combination of causes of deterioration, to the extent of the defects, and on the appropriate future service conditions.

Control of load bearing capacity shall be based on information from the assessment, the planned future use of the structure and normally on design standards valid at the time of prevention/repair.

An appropriate repair level shall be set considering the maintenance category, the importance of the structure, intended remaining service life, cost effectiveness, and the post-repair maintenance plan.

NOTE For instance, the repair level is simply classified into the following three categories:

— repair level expected to restore performance during remaining service life of structure by only one cycle of repair activity;

— repair level expected to restore structural performance during remaining service life of structure by a few cycles of repair activity;

— repair level expected to restore structural performance by the several cycles of repair activities, or to restore the performance for a short period only.

7.2.5 Choice of appropriate methods

Within each of the remedies, one or more methods are available. Some of the methods are listed under more than one remedial action(s).

The method for repair shall be adequately chosen based on deterioration mechanism, remaining service life, the importance and maintenance level of the structure.

NOTE Care is taken, as the method of restoring the performance may vary depending on the deterioration mechanism, even if the level of performance degradation is the same.

The absence from this part of ISO 16311 of a specific method, or the application of a method to a new situation, shall not be taken to mean that such a method or application is necessarily unsatisfactory. The application of methods to situations unforeseen in this part of ISO 16311, or the use of methods which do not have a substantial history of successful performance, and are not specified in this part of ISO 16311, may be satisfactory in appropriate circumstances.

NOTE Typical remedies are detailed in ISO 16311-3.

7.2.6 Properties of materials, products, and systems

The materials, products, and systems for repair, shall be adequately chosen based on the chosen remedial action, the deterioration mechanism, remaining service life, the importance, and maintenance level of the structure.

Properties of materials, products, and systems should be based on requirements in International Standards, Regional Standards, National Standards, Technical Approvals or Approvals according to project specification.

The properties should be documented by test methods valid in the place of use, and specified in the project specification.

7.2.7 Other remedial actions

Some of the options listed in 7.2.2, will not result in protection or repair of the structure, and they are not covered by this part of ISO 16311.

Such options are as follows:

— strengthening;

— intensified inspection;

— restriction in service;

— dismantling/removal.

Strengthening of a structure refers to the remedial action taken to upgrade structural performance to a level which is higher than that possessed at the original design. An appropriate strengthening plan shall be formulated based on the target level of performance, then methods and materials for strengthening shall be selected, considering the degradation condition of structural performance, deterioration mechanism, and maintenance after strengthening.

NOTE Strengthening includes (a) increase in the cross-sectional area of concrete and/or reinforcement, (b) addition of members, (c) increase in the supporting points, (d) addition of strengthening members, (e) application of pre-stress, etc.

Intensified inspection refers to the remedial action carried out by increasing the inspection frequency, number of inspection items and/or location for inspection, without any improvement of the condition, or performance of structure in cases where repair or retrofit cannot be implemented immediately or where it is only required to keep the structure in present state.

When intensifying inspection, the maintenance plan should be reviewed, considering the results of performance evaluation, remaining service life, importance of structure, cost for maintenance, etc. After this, appropriate inspection frequencies and items should be determined.

Restriction in service may be effective for reducing damage to the structure. This may be achieved by imposing restrictions on the use, such as limiting the maximum live load that the structure may carry. The degree and method of the restriction imposed on the use shall be determined, depending on the level of deterioration observed, so that such a restriction shall be implemented after carrying out a detailed assessment.

Dismantling and removal of a severely deteriorated structure/member, shall be carried out based on an implementation plan for the selected method which is formulated in consideration of threat posed to the environment, public safety, and disposal of debris.

7.3 Execution

7.3.1 General

Before execution of repair/prevention, a detailed execution plan should be formulated on the basis of the design procedure, the execution environment, time of execution and execution period. At least, the following should be considered to examine in the planning:

— general requirements;

— structural stability before, under and after execution;

— preparation of concrete substrate and reinforcement;

— application of materials, products and systems;

— quality control of the work;

— maintenance following completion of repair/prevention.

NOTE Execution of repair and prevention, and completion inspection are covered in details by ISO 16311-4.

7.3.2 General requirements

To keep minimum disturbance to the surrounding environment and the service condition of the structure, consideration shall be given to the chemical, electrochemical, and physical condition of the substrate and any contaminants, the ability of the structure to accept loading, movement, and vibration during repair/prevention, ambient conditions, and the characteristics of the materials contained in the structure and those of the repair/prevention products and systems.

The cleanness, roughness, etc. of the substrate, the compatibility between substrate and repair materials and systems, the hardened properties of the repair materials and systems, and the required storage and application condition also must be considered.

7.3.3 Structural stability before, under and after execution

Where a structure is considered to be unsafe to the environment, its users or any third parties, appropriate action shall be immediately implemented to make it safe before, under, and after repair or other preservation work is taken. In this process, any additional risks that may arise from the repair work itself also shall be taken into account. Such actions may include local repair/prevention, the installation of support or other temporary work, partial, or even complete demolition.

7.3.4 Preparation of concrete substrate and reinforcement

The preparation of the substrate of concrete and reinforcement shall be suitable for the required condition of the substrate and the structural status of the structure, so that the products and systems can be properly applied.

7.3.5 Application of materials, products, and systems

The application of products and systems shall be suitable for the substrate and the structure to which they are applied, and to produce repair/prevention which is in accordance with the project specification and the relating standards.

7.3.6 Quality control

The effectiveness of repair/prevention is strongly affected by the quality of execution. Therefore, the execution of repair/prevention shall be carried out under the sufficient quality control based on the prescribed execution plan.

During the execution of repair/prevention, necessary tests shall be carried out on the materials and other related control items.

Detailed quality control records during the execution of repair/prevention shall be maintained for future reference.

7.3.7 Maintenance following completion of repair and prevention

After repair/prevention, completion investigation shall be carried out to examine the condition of materials and products, and the execution methods carried out, thereby confirming that repair/prevention was executed in accordance with the repair plan, so that quality assurance shall be performed on all repairs to critical structural members.

Unless otherwise agreed, documentation relating the execution and quality control records, and instructions on inspection and maintenance undertaken during the remaining design service life of the repaired structure/members shall be provided to the owner or owner's representative.

8 Recording

8.1 General

Details concerning maintenance and repair shall be recorded. Such records as well as drawings and related documents shall be preserved by the owner for safe-keeping and future references.

8.2 Period of preservation

The maintenance records of a structure shall be preserved by the owner while the structure is in service. It is also desirable that such records should be preserved for a period as required for reference purposes in the design, construction, and maintenance of other similar structures.

NOTE It is expected that analysis of records can contribute to progress in maintenance technologies by clarifying problems and needed improvements in design and construction.

8.3 Method of recording

8.3.1 Format of records and its accessibility

The records shall be preserved in an easily understandable format so that they can easily be referred to. Since the record is preserved for a long time, much attention should be paid to make it accessible even when the data recording and storing system is changed.

8.3.2 Items included in records

The records shall include the following items:

— basic data concerning immediate and nearby environment, details of structure, the methods and results of deterioration prediction and investigation carried out, the result of evaluation/judgment of the structure and photographs;

— names of the persons responsible for maintenance;

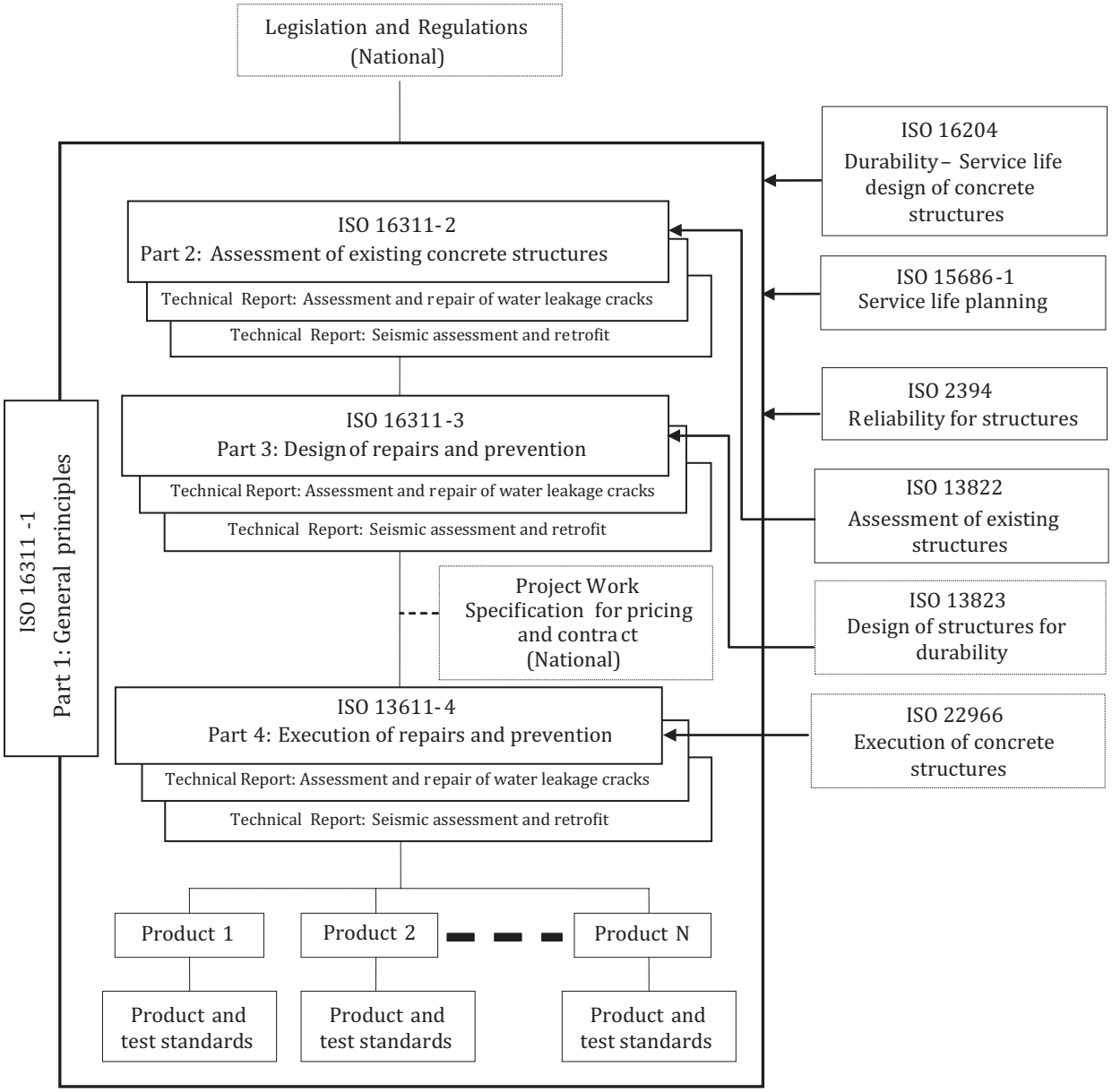
— design drawings and specifications of construction.

8.3.3 Records concerning repair and prevention

When repair/prevention is taken, records of the method used and details of execution shall be recorded together with the names of persons responsible for design, execution, and quality control of remedial actions.

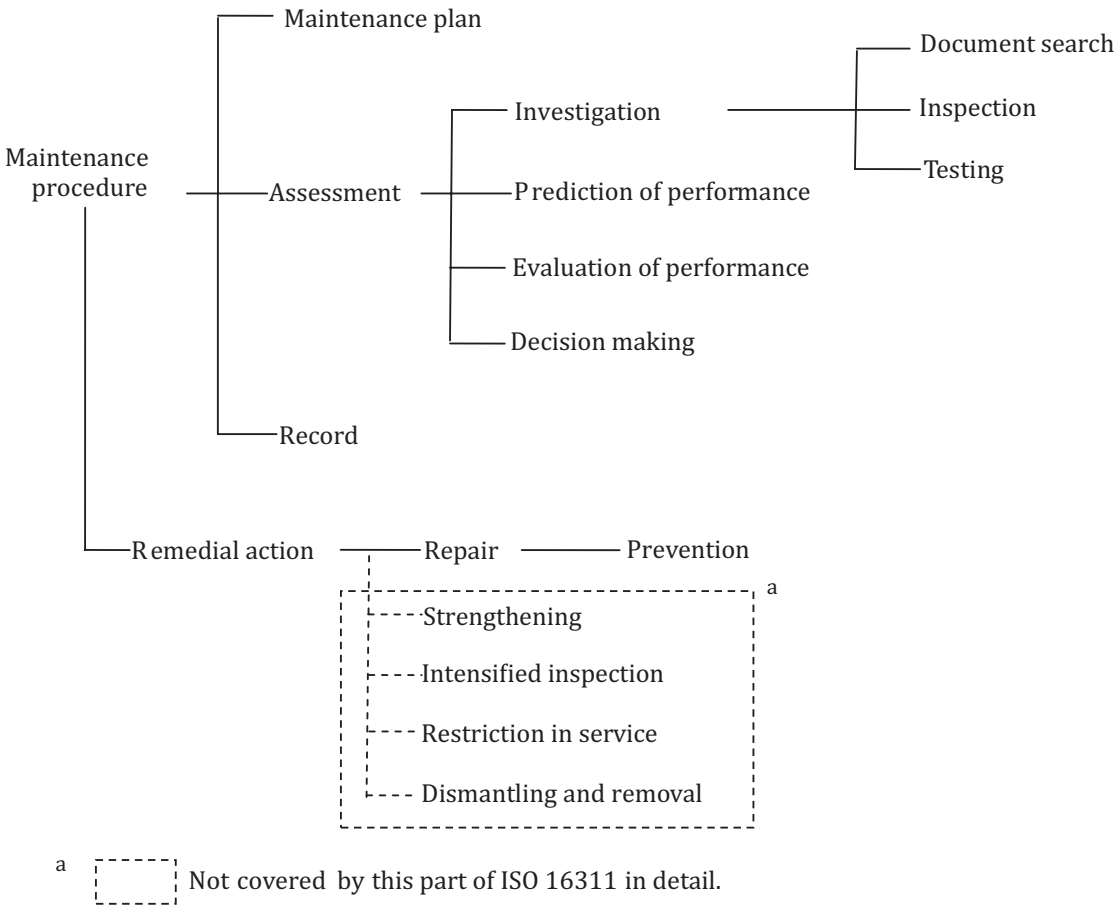
Annex A
(informative)

Extended hierarchy of "Standards for maintenance and repair of concrete structures" with national legislation and other related International Standards



Annex B
(informative)

Hierarchy of terms



a Not covered by this part of ISO 16311 in detail.

Annex C
(informative)

Category of maintenance

C.1 General

Maintenance actions should be classified into different categories depending on factors such as the importance of the structure, design service life, safety risks concerns, environmental conditions, ease of maintenance, and cost. For example, important structures such as dams and nuclear power plants have a long service life, and structures situated in very harsh environments (e.g. marine environment) may fall into a higher priority category than common structures such as multi-story buildings. Similarly, criteria for classifying structures into other priority levels need to be developed. Certain structures for any special maintenance action (e.g. underground structures) may be classified separately.

Maintenance actions are classified as: preventive maintenance, corrective maintenance, and observational maintenance.

C.2 Preventive maintenance

Maintenance is conducted based on preventive preservation. Structures in this category generally have a high degree of importance, requiring monitoring in many cases. Examples of structures requiring preventive maintenance are:

— structures for which remedial measures are difficult economically and/or technically to be taken after deterioration becomes apparent;

— structures whose deterioration must not be apparent, such as monuments;

— structures having a long intended remaining service life.

C.3 Corrective maintenance

Maintenance is conducted based on corrective preservation. In this category, maintenance is conducted to restore deterioration level and/or reduce deterioration rate so as to make structural performance satisfactory in the intended remaining service life. Examples of structures requiring corrective maintenance are:

— structures for which remedial measures can be taken after deterioration becomes apparent;

— structures for which apparent deterioration poses no immediate concern to the violation of performance requirements.

C.4 Observational maintenance

In this category, only visual inspections are conducted; no remedial action is undertaken regardless of the deterioration level. Maintenance activities for structures requiring observational maintenance are economically and/or technically difficult to perform. Examples of structures requiring observational maintenance are:

— structures for use as long as usable without any remedial actions except for the action to ensure safety from risks due to falling debris and so on;

— structures such as foundations, for which direct inspection is economically and/or technically difficult. The assessment and judgment can be made based on indirect inspection, such as land surveying, ground settlement measurement, and leakage detection, etc. Another option is constructing such structures in a way that a “maintenance free” condition is achieved.

Bibliography

[1] ISO 2394:1998, *General principles on reliability for structures*

[2] ISO 13822:2010, *Bases for design of structures — Assessment of existing structures*

[3] ISO 13823:2008, *General principles on the design of structures for durability*

[4] ISO 15686-1:2000, *Buildings and constructed assets — Service life planning — Part 1: General principles*

[5] ISO 16204:2012, *Durability — Service life design of concrete structures*

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