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Life cycle management of concrete structures —

Part 2: Structural planning and design stage

Gestion du cycle de vie des structures en béton —

Partie 2: Etape de conception, définition du schéma structurel et calcul

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Foreword

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This document was prepared by Technical Committee ISO/TC 71, *Concrete, reinforced concrete and pre-stressed concrete*.

A list of all parts in the ISO 22040 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

A concrete structure passes through different stages during its life: from the planning, design, execution and use stages to the end-of-life stage. Due to its long life, it involves different parties at each stage. This implies that it is essential to transfer important information from one stage to another in an appropriate form. However, in reality, no appropriate system has been developed regarding the basic concept and specific methods to achieve this and manage the life cycle of the structure in a consistent manner (life cycle management).

Such lack of an appropriate system creates limitations in durability management of concrete structures, which has been recognized as a serious problem in the field of concrete technologies. This means that the prerequisites at the design stage are not managed appropriately and that execution-induced problems are not ascertained and documented. Regarding the former, there has not been a system for clarifying a long-term maintenance program based on conditions elaborated at the design stage and ensuring its continuation in an appropriate form. Regarding the latter, since a number of uncertain elements exist in the construction of a concrete structure, the quality of construction does not always match the prerequisites of design. Therefore, construction involves factors impairing the durability of the structure in quite a few cases. This suggests that confirmation of completion of the structure and documentation of the procedure to completion are essential for ensuring its performance in its life cycle. It can also become necessary to alter the design conditions of a concrete structure in the use stage. In such a case, basic information regarding the original design becomes essential, but it is often not retained in an appropriate form. As a result, it takes much work to retrieve basic information of the existing structure. Moreover, the design and execution need to be based on uncertainty to a certain extent. For appropriate management of a structure, it is therefore extremely important to keep all basic information at each stage.

Some standards, regarding the life cycle of infrastructure, have already been developed. The pertinent standards are the ISO 15686 series. The ISO 15686 series is relevant to the service life planning of new and existing buildings and cover a part of the planning process. In the ISO 15686 series, service life estimation applies principally to the estimation of residual service lives of components of a building that are already in service, and to the selection of components for, and the detailing of, repairs and new work. While a part of basic philosophy of these standards can be applied, it is difficult or rather impossible to fully apply these documents to the life cycle management of concrete structures without misunderstanding because these standards only deal with buildings with replaceable components including ancillaries. This document covers any kind of concrete structures.

A standard is, therefore, necessary regarding the basic concept and specific procedures for methods of managing concrete structures in view of the current problems, in order to rationally control concrete structures throughout their life cycle and more reliably ensure functioning of future documents. With this as a background, ISO 22040 was developed to establish the key principles, framework and procedures for appropriately implementing life cycle management (LCM) in which planning, design, execution, use and end-of-life of a structure are appropriately connected one after another. Based on it, this document focuses on the management of structural planning and design stage in details as the overall life cycle management of concrete structures.

A structure is constructed with its own purposes. It generally includes protecting people from disasters and ensuring a comfortable and safe life. A structure is required to maintain its functions and performance to achieve these purposes. The introduction of LCM for a structure contributes to all aspects of sustainability while maintaining the functions and performances to fulfil its purposes.

Sustainability is the goal of sustainable development. It refers to any state of the global system in which the needs of the present are met without compromising the ability of future generations to meet their own needs. The concept of sustainability is continually evolving. Understanding and achieving a balance between environmental, social and economic aspects, ideally in mutually supporting ways, is considered essential for making progress towards achieving sustainability. The achievement of sustainability is now recognized as one of the most important considerations in all human activities (see ISO Guide 82).

A concrete structure inherently has a planned life when it is well designed, executed and maintained under proper life cycle management based on sustainability framework.

Life cycle management of concrete structures —

Part 2:
Structural planning and design stage

1 Scope

This document applies to management conducted at the structural planning and design stages as part of the ISO 22040 series.

NOTE Basic design or conceptual design of a structure is conducted at the structural planning stage, whereas verification is conducted at the design stage to confirm that the performance requirements are satisfied, and balance of the specified sustainability indicators is ensured at the time of design.

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 2394, *General principles on reliability for structures*

ISO 16204, *Durability — Service life design of concrete structures*

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

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
life cycle
set of consecutive, interlinked stages of a structure, which comprise planning, design, execution, use and end-of-life stages

3.2
life cycle management
LCM
set of systematic and coordinated activities and practices through which a structure is appropriately managed over its *life cycle* (3.1)

3.3
life cycle management scenario
LCM scenario
plan for ensuring *performance* (3.5) of a structure throughout its *life cycle* (3.1)

3.4
maintenance
set of activities taken to check, evaluate the *performance* (3.5) of a structure and preserve/restore it so as to satisfy *performance requirements* (3.6) in service

[SOURCE: ISO 16311-1:2014, 3.8]

3.5
performance
qualitative or quantitative representation of the behaviour of a structure

3.6
performance requirement
required *performance* (3.5) determined in the structural planning stage

3.7
sustainability
ability of a structure or structural element to contribute positively to the fulfilment of the present needs of humankind with respect to social, economic and environmental aspects, without compromising the ability of future generations to meet their needs in a similar manner

3.8
sustainability indicator
indicator related to economic, environmental or social impacts

[SOURCE: ISO 21929-1:2011, 3.33]

4 Life cycle management at the structural planning stage

4.1 General

In structural planning, the designer shall establish the functions that a structure should retain throughout its service life and shall determine the performances necessary for achieving such functions. The performance requirements shall be determined by assuming changes in the behaviour and performance of the structure within the ranges of restricting conditions at each stage in consideration of the uses of the structure during its design service life and the environment of the construction spot. In designing, the structure type, structure style, materials, main dimensions and so forth shall be materialized so that the structure satisfies the performance requirements, while possessing redundancy and robustness. A life cycle management (LCM) scenario shall then be formulated to confirm that the desired balance of sustainability indicators is achieved throughout the design service life. The basic LCM scenario shall be formulated, comprehensively considering various conditions, with thorough consideration to junctures between the stages of design, execution, use, and end of life, so that work can be carried out appropriately at each stage (see Figure 1).

The results of structural planning shall be summarized as the basic LCM scenario to be surely transferred to the next stage of design.

4.2 Planning and performance requirements of structures

Structural planning shall be appropriately conducted in line with the upper-level plans for a civil structure, such as national land plans and route plans, and, for a building structure, in line with the plans for the uses and functions of the structure during its design service life. For such planning, it is necessary to clarify the limiting conditions, including laws and standards, at each stage of planning/design, execution, and use of the structure, and conduct in advance research required for establishing the structural outline.

Functions required for the structure during its design service life and performances required to achieve such functions shall be established. The materials and structural framing of an actual structure are prone to deterioration by environmental and loading actions over time, leading to degradation of its performances. Accidental actions such as earthquakes can also cause significant performance degradation. Therefore, when establishing the performance requirements for a structure, an appropriate extra margin should be added

to the requirements in consideration of the possibility of accidental actions in addition to normal actions. Performance requirements of structures shall be established in accordance with ISO 2394 and ISO 19338.

4.3 Basic LCM scenario

A basic LCM scenario shall be formulated for a structure to satisfy the performance requirements throughout its design service life.

The basic LCM scenario shall set forth the functions, design service life, and performance requirements of the structure established in the structural planning stage. It shall then present the procedure to confirm that the structure satisfies the performance requirements throughout its design service life. Periodic inspection shall generally be conducted after the structure is placed in service to ensure there is no deterioration in its construction. Based on the inspection results, the structural performance shall be evaluated, and if the performance is found to reach or fall under the limit state established for management, then measures including repair shall be taken. It is simultaneously necessary to formulate a scenario to achieve the balance of the established sustainability indicators. In the use stage, the LCM scenario shall be adjusted and updated according to the latest conditions, uses, and actions of the structure.

During the life cycle of a structure, its use or application can change. In such cases, the structure shall retain the performance to fulfil the changed required functions. If such changes are anticipated, the structure shall be capable of being reconstructed or its structural form shall be changed. The structure shall be designed to allow easy maintenance to maintain the functions during the service life, and to allow safe construction work by considering the predicted structural performance at the end of the service life and the demolishing process, so that the structure can be demolished at the end-of-life stage. In addition, reuse and recycling of used materials and structural members should be designed while considering the environmental impact.

Data of the structure necessary to perform LCM during the design service life shall be recorded and passed on over the life cycle. During the long-life cycle, unexpected damage can occur and changes in use can be necessary. In such cases, the accumulated data shall be used to newly define the functions of the structure, determine the performance required to meet those functions, and redefine the LCM scenario.

In some cases, it is expected that the structure will continue to be used without demolishing after reaching the expected service life at the time of design. Such structures shall be structurally planned so that they will retain sufficient performance even if they are used beyond their intended service life. The structure also shall be designed to allow easy maintenance of parts that are expected to deteriorate due to long-term use.

In structural planning, the following items shall be clarified and documented in the basic LCM scenario:

— purpose of the structure and functions to materialize the purpose;

— design service life;

— performance requirements;

— basic policy to satisfy the performance requirements;

— sustainability indicators to be considered and basic principle for the balance of such indicators;

— production/construction methods (construction methods, methods of obtaining materials, etc.);

— methods of management/operation (maintenance) in the use stage;

— methods of demolition/management in the end-of-life stage.

NOTE 1 The basic policy for satisfying the performance requirements includes methods of imparting redundancy and robustness.

NOTE 2 Sustainability indicators are quantified requirements established from the standpoints of the environmental, economic, and social aspects.

4.4 Determination of structural concept

At the stage of formulating the basic LCM scenario, the designer shall determine an appropriate structure style that can achieve necessary functions throughout the design service life. This includes the determination of the structure style, basic dimensions, materials, and so forth, which are necessary for designing the structure. The conditions considered for determination and the results of determination shall be documented in the basic LCM scenario, and are listed as follows:

— given conditions of design;

— actions considered in the design;

— performance indexes to materialize the performance requirements under the design actions;

— results of comparison among alternative structural concepts, structural configuration, structure style, main dimensions, materials, construction methods (procurement methods), results of investigation into the concept of sustainability indicators, maintenance items assumed necessary in the use stage, matters to be considered in the end-of-life stage, etc.;

— matters to be considered for management at each stage of design, execution, use, and end of life.

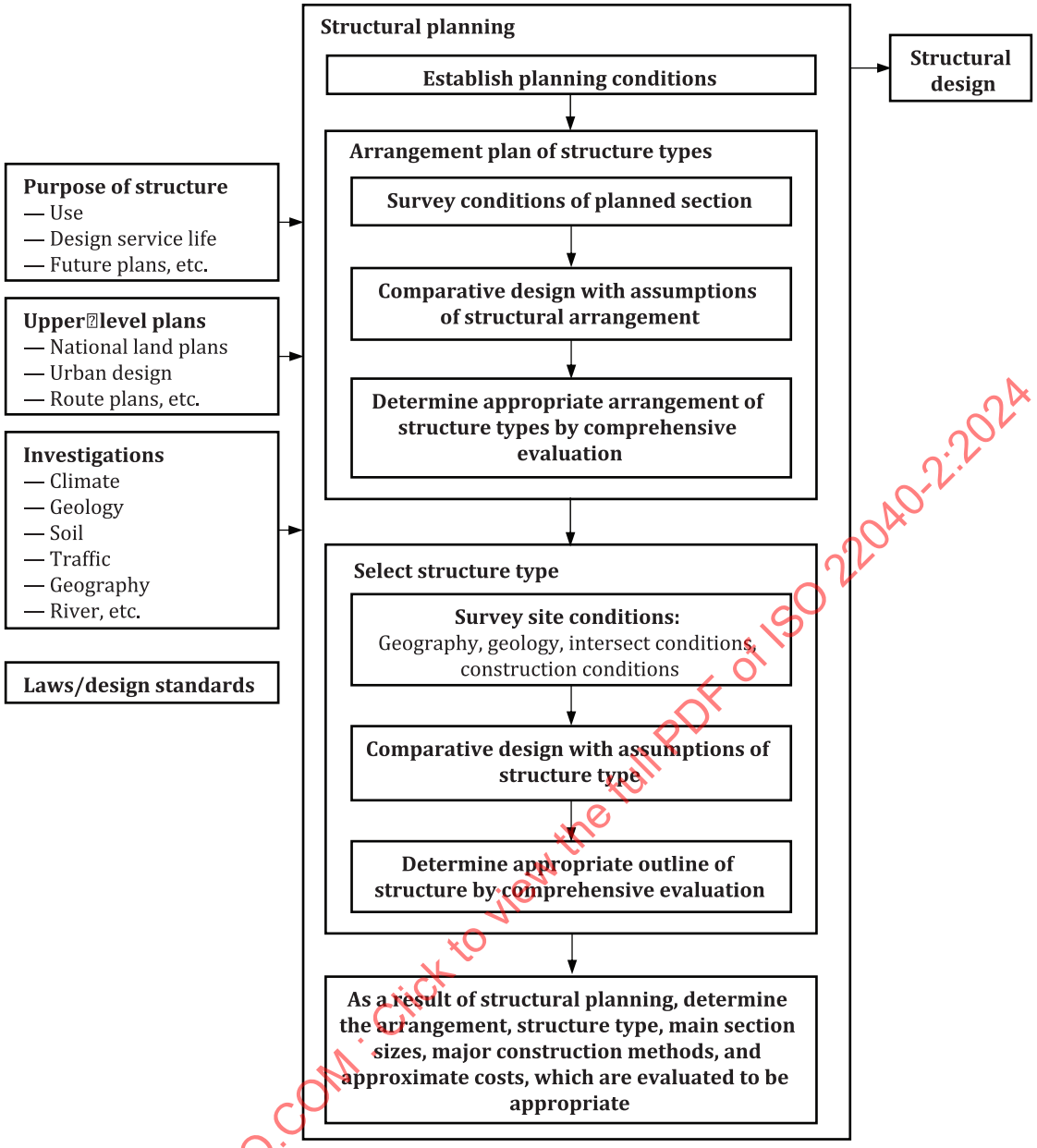

Figure 1 — Flow of structural planning

5 Life cycle management at the structural design stage

5.1 General

In the design stage, the structural specifications determined in the structural planning stage shall be verified by an objective method to confirm that the structure possesses the necessary functions and that its performance that satisfies the performance requirements is retained throughout its design service life. It shall also be confirmed that the balance of the obtained sustainability indicators is in accordance with the basic principle.

The results of management in the design stage shall be added to the basic LCM scenario and shall be transferred to the execution stage.

When it becomes clear as a result of management in the design stage that the performance requirements cannot be satisfied by the structural specifications established in the structural planning stage, it is

necessary that such results be fed back to the structural planning stage for re-formulation of a new structural plan.

5.2 Management items

5.2.1 Design actions

In the design stage, it shall be confirmed that the actions envisaged during execution, design service life, and demolition are established in appropriate combinations according to the limit states for the performance requirements. Also, since the design actions are determined by multiplying the characteristic values of actions by action factors (partial safety factors), it shall be confirmed that these values and factors are appropriately established from the aspect of the probability distribution of the actions. It shall be particularly confirmed that accidental actions are appropriately determined from the aspect of the encounter probability of relevant accidental actions during the design service life. It shall also be confirmed that environmental actions are appropriately established according to the deterioration mechanisms of assumed materials in consideration of their present and future changes within the design service life.

5.2.2 Assumptions and methods in structural analysis

In structural analysis, it shall be confirmed that the shapes, boundary conditions, and actions on the structure are appropriately considered; that modelling techniques suitable for the limit states to be verified are adopted; and that the response of the structure under the design actions is appropriately computed. In this process, it is necessary that models with preliminarily verified reliability and accuracy are used.

In structural analysis, it shall be confirmed that the method used can compute the verification indexes according to the modelling of the actions and structure. If this is difficult, then it shall be confirmed that the method used allows conversion to the verification indexes in an appropriate manner.

5.2.3 Material properties

It shall be confirmed that concrete, steel, and other materials to be used possess properties necessary for ensuring fulfilment of the performance requirements for the structure. It shall be confirmed that the concrete possesses the mechanical properties to satisfy the performance requirements and resistance to deterioration and material penetration throughout its design service life, as well as workability suitable for construction tasks. It shall also be confirmed that the steel possesses mechanical properties to satisfy the performance requirements of the structure by being used with concrete.

It shall be confirmed that the characteristic values of the mechanical properties of each material to be used for the structure are appropriately established according to the limit states to be verified. It shall also be confirmed that appropriate characteristic values and partial safety factors (material factors) are established according to the variability of the material qualities.

It shall be confirmed that test methods are established to confirm that the material properties set at the time of design are satisfied at the time of execution. It shall also be confirmed that target values for quality control are established accordingly.

5.2.4 Performance verification

In performance verification of a structure, it shall be confirmed that the limit states according to performance requirements are established for each structural member or the structure as a whole during its construction and design service life. This is to ensure that the structure or structural members having structural details including the shapes, dimensions, bar arrangement, and so forth assumed in the structural planning stage would not reach the limit state. In other words, it shall be confirmed that verification is conducted by establishing appropriate verification indexes and comparing the limit values with response values.

With regard to performances for which no quantitative verification indexes or limit values can be established, it should be confirmed that such performances are appropriately taken into consideration.