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Life cycle management of concrete structures

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National foreword

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**Life cycle management of
concrete structures**

Gestion du cycle de vie des structures en béton



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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*.

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Introduction

A concrete structure passes through different stages during its life: from the planning, design, execution and use to the end-of-life stages. 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, it was decided to establish in this document 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 the other. It is worth noting that this document also serves as a guideline for other ISO standards. [Table 1](#) lists the relationship between this document and other ISO standards.

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 (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.

Table 1 — Relationship between this document and other ISO standards

Planning	Design	Execution	Use	End-of-life
ISO 22040 , Life cycle management of concrete structures				
—		[Test method] ISO 1920 series ISO 10406 ISO 17785 ISO 19044 ISO 20290 series		—
—	ISO 14484 ISO 15673 ISO 16204 ISO 19338 ISO 28841 ISO 28842	ISO 12439 ISO 14824 ISO 19595 ISO 22965 ISO 22966	ISO 16311 ISO 16711 ISO/TR 16475 ISO/TS 16774	—
—		ISO 14484 (FRP) ISO 18319 (FRP)		—
ISO 13315 series (Environmental management)				

Life cycle management of concrete structures

1 Scope

This document provides the principles for implementing life cycle management (LCM) of concrete structures throughout the stages of planning, design, execution, use and end-of-life, as well as the framework and procedures for LCM.

This document is applicable not only to new structures but also existing structures. It is also applicable to the entire life cycle and each one or more stages composing the life cycle of a structure.

NOTE Details in the procedures and specific methodologies for management in each stage of structure's life cycle based on this document is established separately.

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 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 terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://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]

the assumptions. Predictions shall be updated based on newly acquired data, and the LCM scenario shall be re-formulated if necessary, to enable appropriate management at subsequent stages.

5.3 Indicators for life cycle management

5.3.1 General

In the LCM, appropriate indicators necessary for the assessment of the LCM scenario shall be set for sustainability factors regarding social, environmental and economic aspects. These indicators shall be calculated with respect to the period of LCM.

5.3.2 Social aspect

Social aspects shall be assessed with indicators objectively expressing performance of the structure in the use stage, safety of construction work and safety of users of the structure under conceivable conditions. Even when it is difficult to set and quantify indicators for such qualities as adaptability, comfort, cultural values and social contribution, these shall be considered in a social-scientific manner.

NOTE Social indicators include health and safety, satisfaction, population and community and cultural heritage.

5.3.3 Environmental aspect

Appropriate indicators shall be set for environmental impacts in the execution and use stages of the structure, such as resources consumption, greenhouse gas emissions and impacts on the ambient environment.

NOTE See the ISO 13315 series for details of the environmental management of concrete structures.

5.3.4 Economic aspect

All the direct and indirect costs during the life cycle of the structure, as well as the benefits and values provided by the structure, shall be set as indicators.

NOTE 1 [ISO 15686-5](#) serves as a reference for details of calculating life cycle cost.

NOTE 2 Direct costs are directly attributable to managing of a structure, for example, the costs of materials, labour, equipment, etc., and all efforts or expenses directly involved. Indirect costs are not directly attributable to managing a structure and can include social inconvenience.

NOTE 3 Maintenance, repair, upgrade and adaptation at the use stage are sometimes costly.

6 Procedures of life cycle management

The basic flow of life cycle management is presented in [Figure 1](#).

A new structure shall be thoroughly managed based on the LCM concept during its life cycle. The basic LCM scenario shall be formulated at the planning stage of the structure. Design work shall be carried out to satisfy the plan and the scenario. When the design outputs do not satisfy the initially formulated LCM scenario, either:

- the LCM scenario shall be modified to be consistent with design outputs; or
- the plan and/or design shall be carried out again.

After the execution, initial assessment shall be carried out to check the state of the structure. When any defect is found from the assessment, remedial measures shall be taken as required. Then, it shall be assessed whether the basic LCM scenario is suitable for the subsequent life cycle of the structure. If modification is deemed necessary, the basic LCM scenario shall be updated. At the following

assessment, the conditions of the structure shall be re-assessed. Also, the LCM scenario shall be updated as necessary. If the sustainability evaluation shows that no remedial measures are necessary, the structure shall go to the end-of-life stage.

For an existing structure that has not been managed so far but is decided to be managed based on the LCM concept, the LCM shall start with the first assessment of its performance at the use stage. The basic LCM scenario shall be formulated by using all available assessment data and design and execution documents. If the assessment results indicate that no remedial measures are necessary, the structure shall go to the end-of-life stage. Otherwise, the same procedure as that for a new structure shall be followed.

When the basic LCM scenario is updated, subsequent management shall be carried out according to the updated scenario.

For the LCM, the appropriate scenario shall be selected from several basic LCM scenarios set at each stage of the structure's life cycle, considering the balance between the sustainability indicators in 5.3.

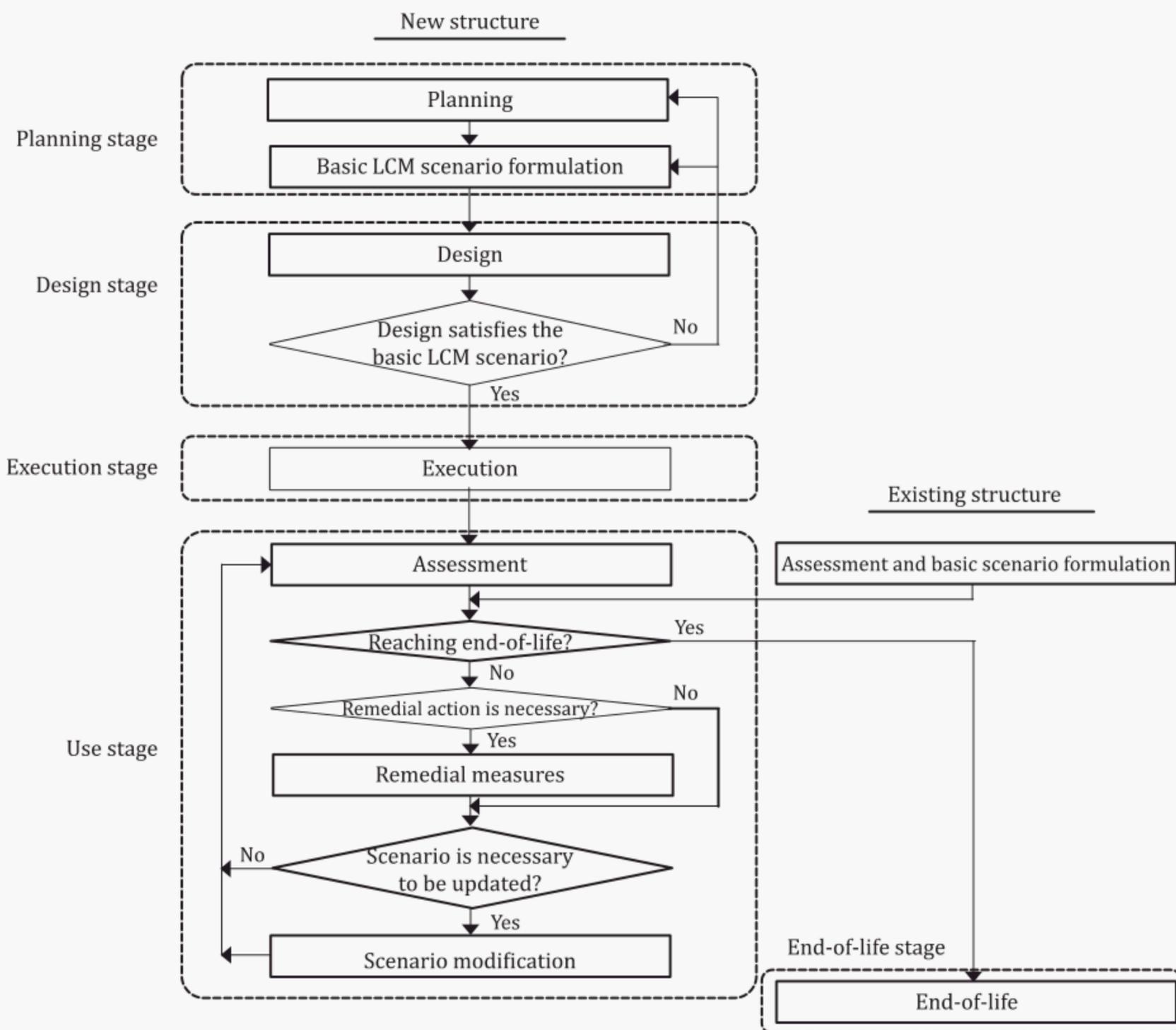


Figure 1 — Flow of LCM

7 Management for each life cycle stage

7.1 General

At each stage of the structure's life cycle, the set performance requirements shall be verified. The risk of performance degradation of the structure during its use, as well as its impact on the sustainability, shall be considered and reflected in the formulation of the basic LCM scenario.

NOTE See ISO 2394 for the fundamentals of risk assessment for structures.

At each stage of the structure's life cycle, a detailed LCM scenario shall also be formulated for management based on the basic LCM scenario. Also, these detailed LCM scenarios shall be repeatedly modified as required during operation at respective stages, so that the performance of the structure is fully ensured at each stage.

7.2 Management in planning and design stages

At the planning and design stages, the performance requirements of the structure shall be set, and the structural forms, materials and dimensional data shall be specified so that the structure can satisfy the performance requirements during the design service life. The designed performance of the structure shall be verified according to the corresponding requirements. Structural forms and materials shall be selected, and structural dimensions shall be determined, so that execution and maintenance can be carried out appropriately during the execution and use stages. The methods of execution and planned cycles of maintenance and repair shall also be predetermined. Information shall be transferred from the planning and design stages to the execution stage.

NOTE 1 Refer to local design standards conforming to [ISO 19338](#) for performance verification of the structure.

NOTE 2 See ISO 16204 for durability design of the structure.

7.3 Management in execution stage

A structure shall be constructed so as to fully ensure the performance set at the design stage. Information acquired during the execution stage shall be recorded as as-built information, including materials used and their corresponding properties, construction details, environmental data and quality control records, which are necessary for future LCM. Information shall be transferred from the execution stage to the use stage.

NOTE See ISO 22965-2 and ISO 22966 for execution of the structure.

7.4 Management in use stage

At the beginning of the use of a new structure, confirmation or first assessment shall be made as to whether the matters set at the design stage are materialized and whether the construction was carried out appropriately. If any defect is found, repair shall be made as required. Subsequent LCM scenarios shall also be revised at this point.

For an existing structure, the LCM scenario shall be formulated according to past records of the structure as well as the result of the first assessment in which necessary data shall be acquired. Once the LCM scenario is formulated, the use stage management starts and the following procedures are almost the same as those for a new structure.

In the use stage of a structure, periodic inspection/diagnosis shall be conducted so as to confirm the retained performance of the structure. If any defect is found, repair shall be made as required. Subsequent LCM scenarios shall also be revised at this point. Subsequent performance degradation shall also be predicted as required, to investigate appropriate remedial measures. The investigation of countermeasures shall not include only physical measures including repair/upgrading. It shall also include operational measures, including use restrictions or the possibility of termination of use.

The structure can fail to meet the performance requirements during its use not due to performance degradation but to an increase in the performance requirement level (through a revision of the pertinent design standard or other reasons). In such a case, the above-mentioned countermeasures shall be taken as required.

The following information shall be transferred to the party responsible for maintenance:

- information acquired from inspection/diagnosis during the use stage;
- information related to applied measures; and
- information on performance recovery.

Information acquired during the use stage shall be securely recorded and utilized for subsequent LCM.

NOTE 1 See ISO 16311-1 for the general principles for maintenance and repair during the use of the structure.

NOTE 2 See ISO 16311-2 for assessment of existing structures.

NOTE 3 See ISO 16311-3 and ISO 16311-4 for repair and prevention of an existing structure.

7.5 Management in end-of-life stage

When time to the end of use specified by the LCM implementation plan has elapsed, decision shall be taken as to whether the use of the structure should be continued or terminated considering various conditions. Termination shall be decided when recovery from these various conditions is not considered reasonable based on the sustainability indicators.

The end-of-life stage shall occur and be managed with sustainability concepts when termination of use of the structure is preferred.

NOTE Major factors that can lead to the end-of-life of a structure include insufficient functions and obsolescence due to changes of the social environment and failure to meet the performance requirements for any reason.

At the end-of-life stage, where demolition of the structure, diversion or change of use of the whole or part of the structure or members is investigated, consideration shall be given to reducing the amount of waste and promoting reuse/recycling of materials and members. The results of such investigation and consideration shall be recorded as information to be utilized for LCM of similar structures in the future.

8 Information transfer among management stages

Information accumulated at each stage of the structure's life cycle shall be transferred within and across the stages. Necessary information on decision making shall also be transferred. For appropriate management of each stage, information transfer shall include the basic philosophy of implementation of LCM for a target concrete structure as well as basic data at each stage. The information shall include the basic and important items for LCM as well.

The accurate information collected at each stage shall be retained in a form readily understandable at subsequent stages. Necessary information shall be made accessible as reference data for LCM.

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