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Environmental management for concrete and concrete structures —

Part 4: Environmental design of concrete structures

Management environnemental du béton et des structures en béton —

Partie 4: Conception environnementale des structures en béton

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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 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).

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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

The committee responsible for this document is Technical Committee ISO/TC 71, *Concrete, reinforced concrete and pre-stressed concrete*, Subcommittee SC 8, *Environmental management for concrete and concrete structures*.

A list of all the parts in the ISO 13315 series can be found on the ISO website.

Introduction

Environmental management is essential for properly estimating the negative and positive environmental impacts brought about by a construction project in order to reduce the environmental burden and create environmental benefits. Environmental considerations for a structure, in particular, are to be carried out at the design stage and be integrated with conventional structural design and durability design. To this end, standardization of the design procedure for environmental design becomes a necessity.

ISO 14040 stipulates the principles and framework of lifecycle assessment (LCA) for the environmental management of products and services. However, it is somewhat difficult to apply this to structures with extremely long lifecycles, such as infrastructures and building structures.

The use of concrete, a key construction material, accounts for a particularly large part of the environmental impacts related to construction projects. If the environmental impacts related to a concrete structure are accurately dealt with to achieve environmental design, this can enable a dramatic reduction in the environmental burden for the construction project as a whole and increase the environmental benefits. Therefore, a method of environmental design specifically for concrete structures is essential and led to the development of this document.

In the environmental design of a concrete structure, appropriate specifications for materials and structural details are established based on LCA. ISO 13315-1 stipulates the principles of environmental consideration for concrete and concrete structures while ISO 13315-2 stipulates the system boundaries necessary for carrying out LCA and the inventory data to be acquired.

Environmental management for concrete and concrete structures —

Part 4:
Environmental design of concrete structures

1 Scope

This document provides the general framework, principles and requirements for carrying out an environmental design of concrete structures, based on a lifecycle assessment (LCA) method or other appropriate methods.

This document is applicable to single concrete structures, as well as concrete structure complexes.

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 13315-2, *Environmental management for concrete and concrete structures — Part 2: System boundary and inventory data*

ISO 14040, *Environmental management — Life cycle assessment — Principles and framework*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 13315-1, ISO 13315-2, ISO 14040 and ISO 14050, and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
client briefing
document which specifies at any point in time the relevant needs, aims and resources of the client and user, the context of the project and any appropriate design requirements

3.2
durability design
design of a structure in which durability is considered

3.3
environmental design
design of a structure in which environmental impacts are considered

[SOURCE: ISO 13315-1:2012, 3.6]

3.4
structural design
design of a structure in which structural performances including safety, serviceability, restorability, structural integrity and robustness are considered

4 Framework of environmental design

Figure 1 illustrates the positioning of environmental design in the entire design of concrete structures.

The environmental design of a concrete structure shall be carried out integrally with structural design and durability design and be in harmony with the landscape and surrounding environment.

Environmental design includes client briefing, setting of environmental performance requirements, design, estimation of retained environmental performances, verification and documentation.

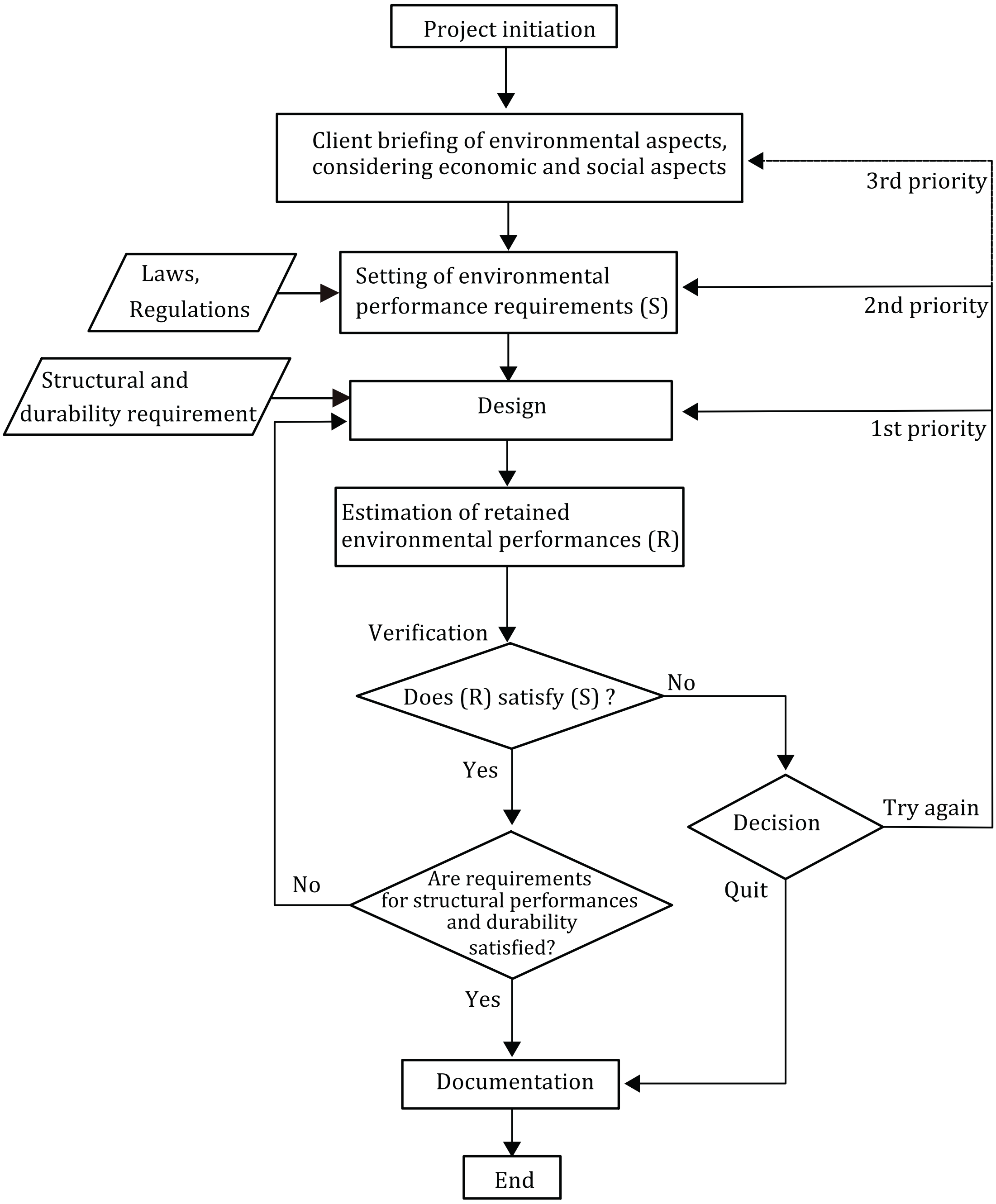

Figure 1 — Environmental design of concrete structures

5 Client briefing and environmental performance requirements

A client's brief on the environmental aspects of a project shall be prepared with consideration of economic and social aspects related to the purpose of executing the project, such as LCC and historical context.

For a client's brief, LCC and environmental aspects to be considered shall be specified. Various levels may be specified, including an impact category indicator (inventory), impact category, category endpoints and objects of protection.

NOTE An example of a brief with an impact category indicator (inventory), impact category, category endpoints and objects of protection is shown in Figure A.1 (see Annex A).

Appropriate impact category indicators for performance verification shall be selected for the environmental aspects specified in the client's brief.

When impact categories, category endpoints and objects of protection are specified as the levels of environmental aspects in the client's brief, impact category indicators that can estimate these levels shall be selected.

Impact category indicators may include the following:

— carbon dioxide (CO_2) equivalents;

— trichlorofluoromethane (CFC) equivalents;

— nitrogen oxide (NO_x);

— sulfur oxide (SO_x);

— total nitrogen;

— total phosphorus;

— heavy metals (lead, copper, chromium, cadmium, zinc, etc.);

— non-methane volatile organic compounds (NMVOC);

— fossil fuels (coal, oil, natural gas);

— abiotic resources;

— particulate matter (PM);

— wastes;

— water;

— amount of resource recycling.

When seeking harmony with the landscape and surrounding environment, impact category indicators may be selected for these factors as required.

The environmental performance requirements shall be quantitatively set to satisfy the relevant laws and regulations, and the client's brief.

6 Design

In design, specific measures shall be taken regarding constituents, mix proportions and structural details (such as member dimensions and steel content) to incorporate the environmental aspects set as the environmental performance requirements.

NOTE 1 The effects of thermal mass, water retention, water permeation, and planting can also be taken into account.

NOTE 2 Annex B lists examples of specific measures necessary for satisfying the requirements for some impact category indicators considered as environmental aspects.

7 Estimation

The retained environmental performance of a concrete structure or a concrete structure complex shall be appropriately estimated according to the established impact category indicators.

The LCA method in this document shall be in accordance with the ISO 14040 series, and the system boundary and inventory data shall be determined according to ISO 13315-2. The retained environmental performance shall be estimated by inventory analysis.

When the selected impact category indicators are noise, vibration, dust, electromagnetic waves and changes in water table levels, the value measured or analysed in the past (or in a similar environment) shall be used for estimation.

If the established impact category indicator is an environmental aspect for which no quantitative estimation method has been established, or an environmental aspect not suitable for quantitative estimation, then the estimation shall be carried out by an appropriate method.

NOTE Relevant environmental aspects include landscape disturbance and landform change, for which estimation can be qualitatively carried out from social-scientific points of view.

8 Verification

Verification shall be carried out to determine whether or not the retained environmental performance of a designed concrete structure satisfies the environmental performance requirements.

NOTE Annex C shows an example of inventory analysis based on LCA and verification.

When verification reveals that the retained environmental performance of the designed concrete structure satisfies all performance requirements, verification ends.

When verification reveals that the retained environmental performance of the designed concrete structure does not satisfy the performance requirements, the process flow shall return to the “Design” step to change constituents, mix proportions and structural details (such as member dimensions and steel content) or, if this is not possible, to the “Client briefing” step to reconsider the performance requirements through discussions. If the project is not judged to be feasible, the client or owner may decide to discontinue the project.

9 Documentation

All information related to the environmental design of the project shall be recorded and stored regardless of the results of verification.

When the project is executed as a result of verification, the record shall be retained by the owner and designer for the whole service life of the concrete structure.

It is desirable that information related to the environmental design in the project be utilized for the planning of similar projects.

Annex A
(informative)

Example structure of inventory, impact category, category endpoints and objects of protection

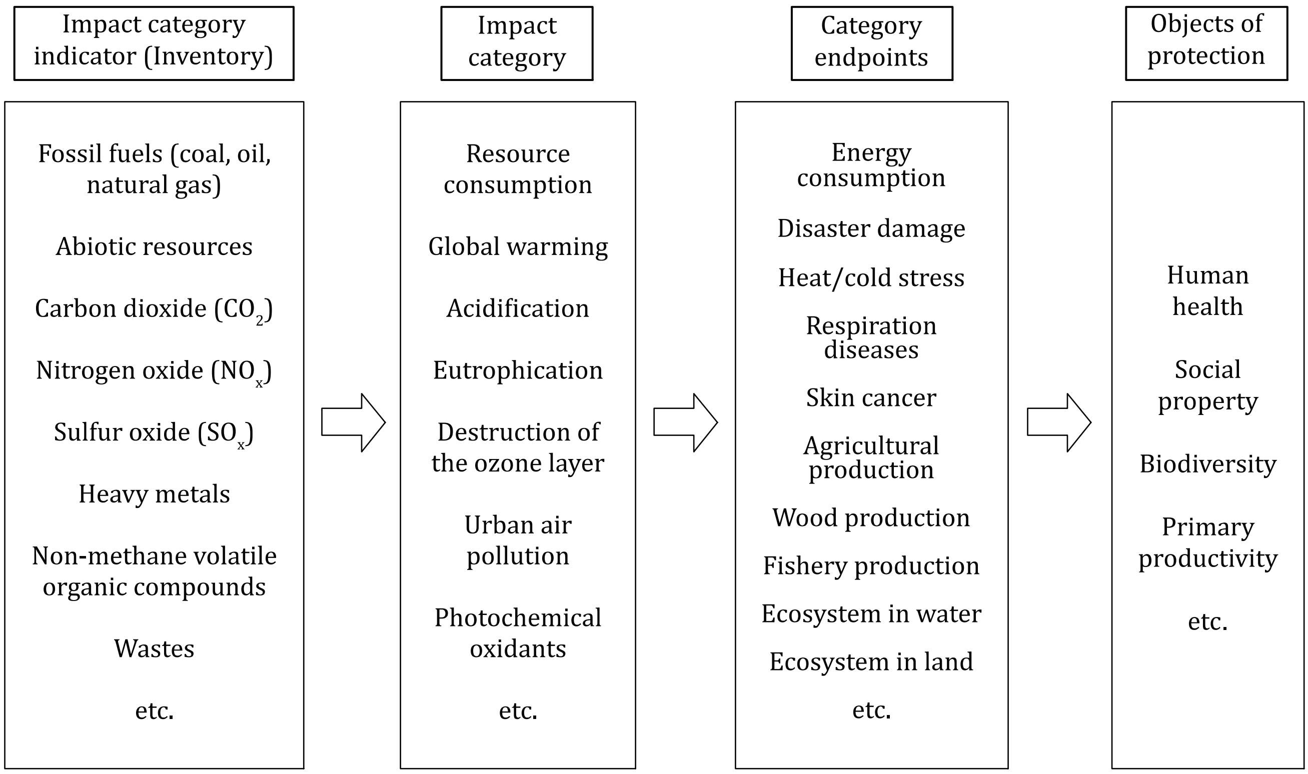

Figure A.1 — Example structure of inventory, impact category, category endpoints and objects of protection

Annex B
(informative)

Examples of measures to satisfy requirements for impact category indicators in the “Design” stage

The following are examples of specific measures that may become necessary to satisfy the requirements for each impact category indicator. These are to be considered as environmental aspects in the “Design” stage, in the case where carbon dioxide (CO_2), nitrogen oxide (NO_x), sulfur oxide (SO_x), particulate matter (PM) or the recycling amount of resources are considered as an impact category indicator.

When the impact category indicator is carbon dioxide (CO_2), nitrogen oxide (NO_x), sulfur oxide (SO_x), or particulate matter (PM), the possible options are as follows:

— to optimize strength requirement and structural requirement satisfying the design service life;

— to reduce the Portland cement content by using blended cement;

— to reduce the fossil fuel consumption by substituting biomass fuel sources for fossil fuel sources in plants;

— to reduce the amounts of materials by improving the structure types and execution methods;

— to reduce the fossil fuel consumption by using fuel-efficient construction machinery and equipment;

— to reduce the fossil fuel consumption by strictly adhering to the idling stop practice;

— to reduce the fossil fuel consumption by substituting biomass fuel sources for fossil fuel;

— to choose appropriate methodology related to all activities in construction;

— to utilize high water permeability and high water retention ability of pervious concrete for the reduction of heat island phenomena;

— to extend the design service life of the structure and members by using high strength and high performance concrete;

— to extend the design service life of the structure and members by enhancing adaptability to various changes in the future;

— to utilize a thermal storage effect of concrete (buildings).

When the impact category indicator is the recycling amount of resources, the possible options are as follows:

— to use supplementary cementitious materials;

— to use recycled aggregate and various slag aggregates;

— to use recovered aggregate.

Annex C
(informative)

Example of inventory analysis based on the LCA method and verification (mix proportion of concrete)

C.1 Requirement and assumptions

In this example, 30 % reduction of CO_2 emission is required in a concrete structure. This reduction will be attained from concrete used in the structure.

It is assumed that concrete with a water cement ratio of 0,50 is needed from the structural and durability performances of the concrete structure.

If it is assumed that 75 % of the CO_2 emission of the structure comes from the concrete, the concrete has to meet the requirement of 40 % reduction of concrete-originated CO_2 emission.

Ordinary Portland cement, tap water, crushed sand and crushed stone are used as cement, mixing water, fine aggregate and coarse aggregate, respectively. To simplify the conditions of the example here, it is assumed that the transportation method and distance between a supplier and purchaser for cement, fine aggregate and coarse aggregate are not changed regardless of the types of cement, fine aggregate and coarse aggregate. Also, the same environmental impacts for producing concrete are assumed for any type of cement, fine aggregate and coarse aggregate.

C.2 Inventory analysis

The system boundaries of each constituent and concrete are determined in accordance with ISO 13315-2.

A conventional mix proportion of concrete to satisfy the structural and durability performance requirements is shown in Table C.1.

Table C.1 — Conventional mix proportion of concrete

M.S.[a]	**Slump**	**Air**	**W/C**[b]	**s/a**[c]	**Unit content** (kg/m^3)				
(mm)	(cm)	(%)		(%)	**W**	**C**	**S**	**G**	**WR/AE**[d]
20	12	5,0	0,50	44	173	346	787	1 002	2,64

a Maximum aggregate size.

b Water/cement ratio.

c Ratio of fine aggregate to total aggregate in volume.

d Water-reducing/air-entraining admixture.

To satisfy 40 % reduction of concrete-originated CO_2 emission, the mix proportion of concrete containing ground granulated blast furnace slag in Table C.2 is chosen. Then to assure the same structural and durability performances of the concrete structure due to the change of the binder, the water binder ratio of concrete is reduced from 0,50 to 0,45 and the chemical admixture is changed from water-reducing/air-entraining admixture to slump and air retention/high range water reducing/air entraining admixture.

Table C.2 — Mix proportion of concrete containing ground granulated blast furnace slag

M.S. (mm)	Slump (cm)	Air (%)	W/B[a]	s/a (%)	Unit content (kg/m^3)					
					W	C	GGBFS[b]	S	G	HRWR/AE[c]
20	12	5,0	0,45	43	150	133	200	780	1 033	1,95

[a] Water/binder ratio.

[b] Ground granulated blast furnace slag.

[c] Slump and air retention/high range water reducing/air entraining admixture.

To calculate CO_2 emission in each mix proportion, the following inventory data, which are collected based on ISO 13315-2, are used for each constituent material.

Water: 0,003 5 kg CO_2/m^3

Cement: 780 kg CO_2/t

GGBFS: 27 kg CO_2/t

Sand: 3,7 kg CO_2/t

Gravel: 2,9 kg CO_2/t

WR/AE: 150 kg CO_2/t

HRWR/AE: 150 kg CO_2/t

The CO_2 emissions for 1 m^3 of each concrete mix are as follows:

Conventional mix: 0,003 5 × 0,173 + 780 × 0,346 + 3,7 × 0,787 + 2,9 × 1,002 + 150 × 0,002 64 = 276,1 ≈ 276 kg CO_2/m^3

The mix with GGBFS: 0,003 5 × 0,150 + 780 × 0,133 + 27 × 0,200 + 3,7 × 0,780 + 2,9 × 1,033 + 150 × 0,001 95 = 115,3 ≈ 115 kg CO_2/m^3

C.3 Verification

The reduction of CO_2 emission by adopting the alternative mix proportion is approximately 58 % which can satisfy the requirement for concrete. Accordingly, the requirement as the structure is satisfied.

Bibliography

[1] ISO 13315-1, *Environmental management for concrete and concrete structures — Part 1: General principles*

[2] ISO 14050, *Environmental management — Vocabulary*

ICS 13.020.10; 91.080.40; 91.100.30

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