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Environmental management for concrete and concrete structures —

Part 6:
Use of concrete structures

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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 of 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 www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 71, *Concrete, reinforced concrete and pre-stressed concrete*, Subcommittee SC 8, *Environmental management for concrete and concrete structures*.

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.

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

Introduction

With their extremely long period of use and large size compared with other industrial products, concrete structures undergo damage and deterioration during this period due to a variety of mechanical and environmental actions. Maintenance/remedial activities are therefore carried out during this period of use to maintain their functions and performances. Remedial activities can also be carried out to enhance their functions and performances to adapt to changes in the social circumstances. These activities cause environmental impacts, such as input of resources including repair materials and fuels, greenhouse gas emissions including CO_2, and waste disposal including construction wastewater and concrete rubble. Therefore, environmental management related to maintenance/remedial activities during the period of use of concrete structures is necessary.

For a concrete building, the energy consumed during the period of its use is known to be greater than the energy consumed for activities such as the production of raw materials, production/transportation of concrete, and construction/demolition of the building. Energy consumption for air conditioning, lighting, etc., and the concomitant emission of greenhouse gas are particularly enormous. Though the ISO 13315 series does not directly cover energy efficiency of air conditioning and lighting equipment, it covers the case where reduction in the environmental impacts, such as reduction of energy consumption, is achieved by utilizing the properties of concrete. This include, for instance, mitigation of room temperature changes by the thermal mass property of concrete. It also includes the use of pervious concrete to suppress the heat island phenomenon, which reduces the energy consumption for air conditioning, with the concomitant reduction in the emission of greenhouse gas. On the other hand, hazardous substances can leach or radiate from concrete during the period of use of concrete structures. Therefore, appropriate management of such various environmental influences generated during the period of use of concrete structures is also necessary.

Environmental management for concrete and concrete structures —

Part 6: Use of concrete structures

1 Scope

This document provides the principles and procedures of environmental management for maintenance/remedial activities of concrete structures, and environmental management during the operation of concrete structures.

When the environmental design of a concrete structure is to be carried out based on ISO 13315-4, this document provides detailed information on the design for its use stage.

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

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

ISO 13315-4, *Environmental management for concrete and concrete structures — Part 4: Environmental design of concrete structures*

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

ISO 14050, *Environmental management — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 13315-1, ISO 13315-2, ISO 13315-4, ISO 14040 and ISO 14050 and the following 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
maintenance
light work carried out to maintain the functions and performances of concrete and concrete structures

Note 1 to entry: Maintenance includes visual inspection on foot or by car and investigations for diagnosis.

3.2
remedial activity
construction work carried out to maintain or enhance the functions and performances of concrete and concrete structures

Note 1 to entry: Remedial activities include repair, rehabilitation, refurbishment, renewal, renovation, retrofitting, strengthening, and protection against corrosive agents.

3.3
target remedial activity
remedial activity (3.2) for which environmental consideration is given

3.4
reference remedial activity
conventional standard *remedial activity* (3.2) having the same purpose as the *target remedial activity* (3.3) to be used for comparison in environmental management related to remedial activity

3.5
target concrete structure
target structure
concrete structure for which environmental consideration is given

3.6
reference concrete structure
reference structure
standard (concrete) structure having the same structural and durability aspects as a *target concrete structure* (3.5) or an existing (concrete) structure prior to environmental improvement, to be used for comparison in environmental management related to operation of concrete structures

4 Symbols

Symbols used in this document are as follows:

$P_{trem}(i)$	expected or attained environmental performance of the target remedial activity expressed as a function of indicator *i*;
$P^{e}_{trem}(i)$	expected environmental performance of the target remedial activity expressed as a function of indicator *i*;
$P^{a}_{trem}(i)$	attained environmental performance of the target remedial activity expressed as a function of indicator *i*;
$P_{rrem}(i)$	environmental performance of the reference remedial activity expressed as a function of indicator *i*;
$S_{rem}(i)$	environmental performance requirement of the remedial activity expressed as a function of indicator *i*;
$R^{a}_{trem}(i)$	reduction amount of environmental impact of the target remedial activity in comparison with the reference remedial activity;
$R^{r}_{trem}(i)$	reduction rate of environmental impact of the target remedial activity in comparison with the reference remedial activity;
$P_{tco}(i)$	expected or attained environmental performance of the target (concrete) structure during operation expressed as a function of indicator *i*;
$P^{e}_{tco}(i)$	expected environmental performance of the target (concrete) structure during operation expressed as a function of indicator *i*;

$P^{a}_{tco}(i)$	attained environmental performance of the target (concrete) structure during operation expressed as a function of indicator *i*;
$P_{rco}(i)$	environmental performance of the reference (concrete) structure expressed as a function of indicator *i*;
$S_{co}(i)$	environmental performance requirement of the (concrete) structure during operation expressed as a function of indicator *i*;
$R^{a}_{tco}(i)$	reduction amount of environmental impact of the target (concrete) structure during operation in comparison with the reference (concrete) structure;
$R^{r}_{tco}(i)$	reduction rate of environmental impact of the target (concrete) structure during operation in comparison with the reference (concrete) structure;
$R^{r}_{trem\_tco}(i)$	reduction rate of environmental impact in consideration of both remedial activity and operation of the structure.

5 Principles and procedures for environmental management related to maintenance/remedial activities of concrete structures

5.1 General

This clause provides the principles and procedures to appropriately carry out environmental management for maintenance works and various construction works related to remedial activities.

NOTE See ISO 16311-1 regarding general principles of maintenance and remedial activities.

5.2 Maintenance of concrete structures

Since environmental impacts due to maintenance works are generally small, environmental management can be simplified by either of the following methods:

a) for maintenance works that are repeated on a routine basis, carry out environmental management by taking up a typical set of works and in consideration of the number of times and frequency;

b) for maintenance works that scarcely generate environmental impacts, exclude these works from the subject of environmental management with clear documentation.

NOTE 1 Works that are repeated on a routine basis include, for instance, regular visual inspection by car.

NOTE 2 Works that scarcely generate environmental impacts include, for instance, routine looking-around on foot.

5.3 Remedial activities for concrete structures

5.3.1 General

Environmental management of remedial activities shall be conducted appropriately in accordance with the following procedure:

a) client briefing (see 5.3.2);

b) setting of environmental performance requirements (see 5.3.3);

c) design (see 5.3.4);

d) estimation (see 5.3.5);

e) verification (see 5.3.6);

f) execution and related works (see 5.3.7);

g) inspection (see 5.3.8);

h) documentation (see 5.3.9).

Figure 1 shows the flow chart of the procedure.

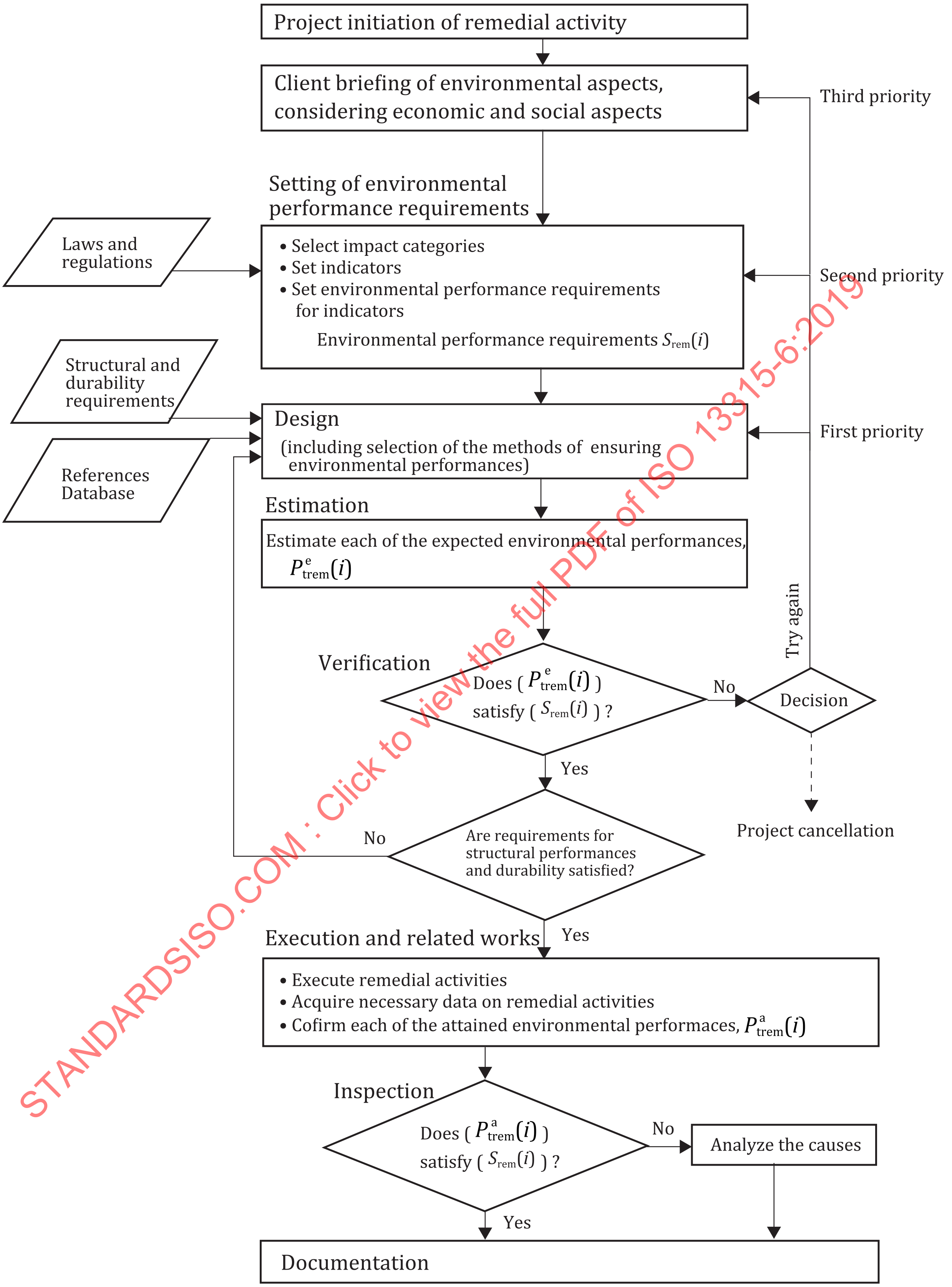

Figure 1 — Procedure for environmental management of remedial activities

5.3.2 Client briefing

A client brief shall be formulated regarding the environmental aspect required for the target remedial activities in consideration of the social and economic aspects.

NOTE See ISO 16311-2 regarding assessment of concrete structure.

5.3.3 Setting of environmental performance requirements

5.3.3.1 Selection of impact categories

Based on the client brief, the impact categories to be considered shall be selected from among the following items:

— global climate change;

— natural resources use;

— stratospheric ozone level;

— land use/habitat alteration;

— eutrophication;

— acidification;

— air pollution;

— water pollution;

— soil contamination;

— pollution due to radioactive substances;

— impacts due to waste generation;

— noise/vibration;

— environmental impact improvement.

NOTE ISO 14040 and ISO 14044 serve as references for selecting impact categories.

5.3.3.2 Setting of indicators

Appropriate indicators shall be set for each category selected.

The reduction amount of environmental impact or the reduction rate of environmental impact of the target remedial activity in comparison with the reference remedial activity may be used as an indicator. The environmental performance of the reference remedial activity shall be appropriately estimated.

NOTE ISO 21929-1, ISO/TS 21929-2, ISO 21931-1 and Annex A serve as references for setting indicators.

5.3.3.3 Setting of environmental performance requirements for indicators

An environmental performance requirement shall be set for each indicator.

The environmental performance requirements shall be quantitatively set in the form of upper limits, lower limits, or ranges, when the indicators are expressible in numerals.

NOTE The reduction amount of environmental impact of the target remedial activity, $R_{\text{trem}}^{\text{a}}(i)$, refers to the difference between the environmental performance of the reference remedial activity and the expected or attained environmental performance of the target remedial activity. It is defined as Formula (1).

$$R_{\text{trem}}^{\text{a}}(i) = P_{\text{rrem}}(i) - P_{\text{trem}}(i) \quad (1)$$

The reduction rate of environmental impact of the target remedial activity, $R_{\text{trem}}^{\text{r}}(i)$, refers to the ratio of the reduction of the environmental impact, $R_{\text{trem}}^{\text{a}}(i)$, to the environmental performance of the reference remedial activity. It is defined as Formula (2).

$$R_{\text{trem}}^{\text{r}}(i) = \frac{P_{\text{rrem}}(i) - P_{\text{trem}}(i)}{P_{\text{rrem}}(i)} \quad (2)$$

5.3.4 Design

Remedial activities shall be designed to meet the environmental performance requirements set in 5.3.3. Methods to ensure the required environmental performance include, for instance, the following:

a) selection of products, resources, and formwork/false work with low environmental impact (for example, adopt alternative products/methods, optimize the transportation routes, etc.);

b) selection of energy sources with low environmental impact (for example, adopt renewable energy sources);

c) selection of machinery/equipment with low environmental impact (for example, adopt hybrid heavy machinery);

d) appropriate control/disposal of substances discharged on the site;

e) application of appropriate soundproof/vibration-proof measures (for example, install soundproof walls).

NOTE See ISO 16311-3 regarding design of remedial activities.

5.3.5 Estimation

Each of the expected environmental performances of the remedial activity designed in 5.3.4 shall be estimated.

5.3.6 Verification

Verification shall be made as to whether or not each of the expected environmental performances, estimated in 5.3.5, meets the performance requirements set in 5.3.3. If any of the expected environmental performances fails to meet the performance requirements, then re-design shall be conducted by returning to 5.3.4. If the re-design fails to meet the requirements, the environmental performance requirements shall be reviewed by returning to 5.3.3. If the re-design fails to meet the reviewed environmental performance requirements, client briefing shall be carried out again by returning to 5.3.2.

When it is impossible to formulate and execute environmental design that meets the environmental performance requirements, the project can be cancelled.

5.3.7 Execution and related works

Construction works shall be carried out based on the design of the remedial activity, and necessary data shall be acquired. Based on the acquired data, each of the attained environmental performances of the remedial activity shall be confirmed.

NOTE See ISO 16311-4 regarding execution of remedial activities.

5.3.8 Inspection

Inspection shall be conducted as to whether or not the attained environmental performances meet the environmental performance requirements. If the performances fail to meet the requirements, the causes shall be analysed to contribute to the improvement of remedial activities in the future.

5.3.9 Documentation

All information related to the environmental management of remedial activities shall be recorded regardless of the results of verification and inspection, and the record shall be stored by the designer of remedial activities and the owner of the concrete structure for the required period.

Information related to the environmental management of remedial activities should preferably be used to help the planning of similar projects.

6 Principles and procedures for environmental management during operation of concrete structures

6.1 General

This clause provides the principles and procedures to appropriately carry out the environmental management during the operation of concrete structures.

Environmental management during the operation of concrete structures shall appropriately be conducted in accordance with the following procedure:

a) client briefing (see 6.2);

b) setting of environmental performance requirements (see 6.3);

c) design (see 6.4);

d) estimation (see 6.5);

e) verification (see 6.6);

f) execution and related works (see 6.7);

g) inspection (see 6.8);

h) documentation (see 6.9).

Figure 2 shows the flow chart of the procedure.

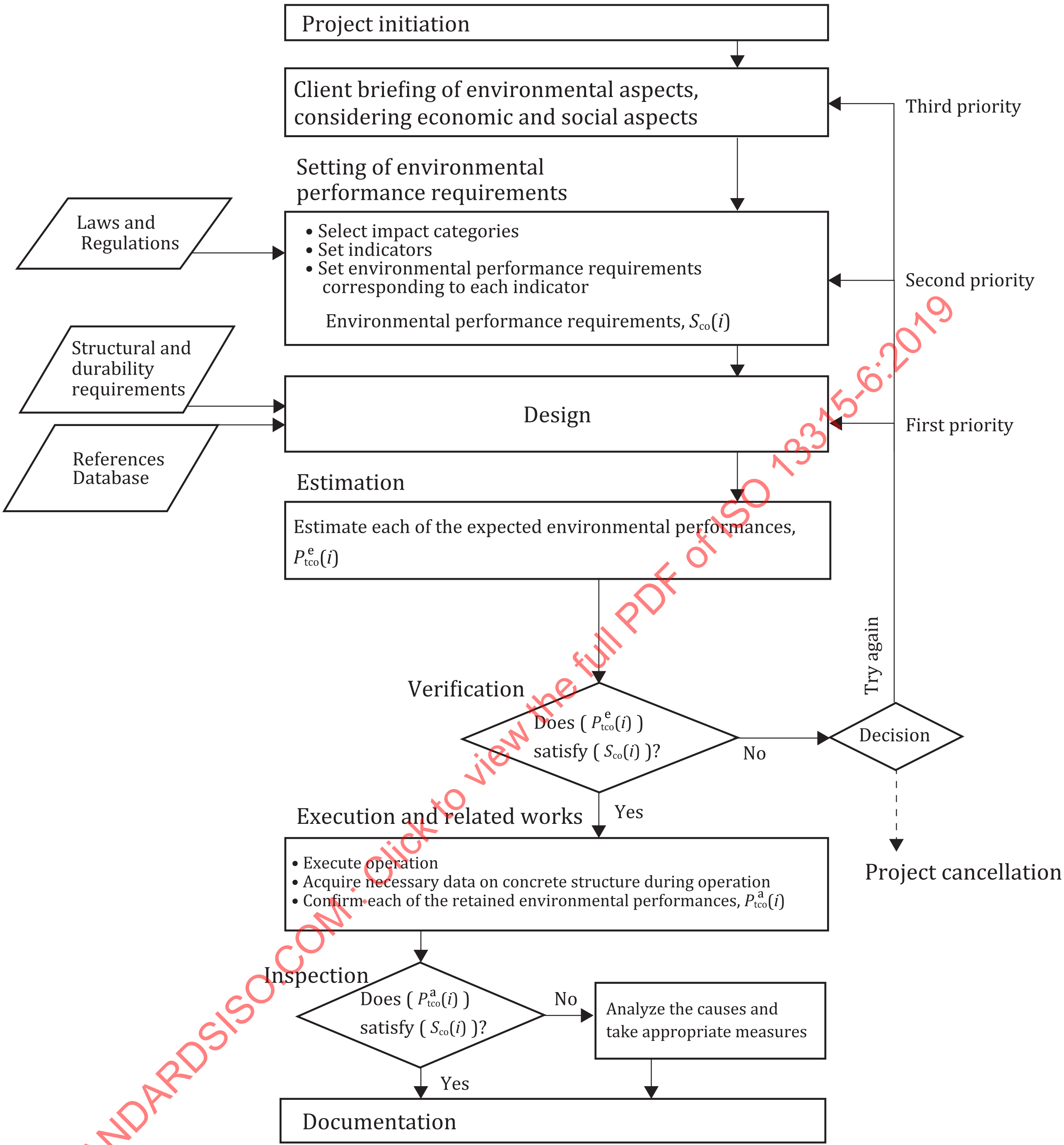

Figure 2 — Procedure for environmental management during operation of concrete structures

6.2 Client briefing

A client brief shall be formulated regarding the environmental aspect related to the intended functions of concrete and concrete structures during their operation, in consideration of the social and economic aspects.

NOTE 1 The use of concrete and concrete structure has negative and beneficial environmental impacts during their operation.

— Negative impacts include, for instance, emission of ammonia, radiation of radioactive radon contained in aggregate, and leaching of heavy metals from underground concrete structures in an environment with a constant stream of groundwater.

— Beneficial impacts include, for instance, reductions in the consumption of fuels for air conditioning and emission of greenhouse gas by utilizing the thermal mass effect of concrete, water purification and suppression of the heat island phenomenon by utilizing pervious concrete, and reduction in CO_2 in the atmosphere due to concrete carbonation.

NOTE 2 Annex B serves as a reference for methods of environmental consideration for concrete and concrete structures in operation.

6.3 Setting of environmental performance requirements

6.3.1 Selection of impact categories

Based on the client brief, the impact categories to be considered shall be selected from among the following items:

— global climate change;

— natural resources use;

— stratospheric ozone level;

— land use/habitat alteration;

— eutrophication;

— acidification;

— air pollution;

— water pollution;

— soil contamination;

— pollution due to radioactive substances;

— impacts due to waste generation;

— noise/vibration;

— environmental impact improvement.

NOTE ISO 14040 and ISO 14044 serve as references for selecting impact categories.

6.3.2 Setting of indicators

Appropriate indicators shall be set for each category selected.

The reduction amount of environmental impact or the reduction rate of environmental impact of the target (concrete) structure in comparison with the reference (concrete) structure may be used as an indicator.

NOTE ISO 21929-1, ISO/TS 21929-2, ISO 21931-1 and Annex A serve as references for setting indicators.

6.3.3 Setting of environmental performance requirements for indicators

An environmental performance requirement shall be set for each indicator.

The environmental performance requirements shall be quantitatively set in the form of upper limits, lower limits, or ranges, when the indicators are expressible in numerals.

NOTE The reduction amount of environmental impact of the target (concrete) structure during its operation, $R_{\text{tco}}^{\text{a}}(i)$, refers to the difference between the environmental performance of the reference (concrete) structure in operation and the expected or retained environmental performance of the target (concrete) structure in operation. It is defined as Formula (3).

$$R_{\text{tco}}^{\text{a}}(i) = P_{\text{rco}}(i) - P_{\text{tco}}(i) \quad (3)$$

The reduction rate of environmental impact of the target structure in operation, $R_{\text{tco}}^{\text{r}}(i)$, refers to the ratio of the reduction of the environmental impact, $R_{\text{tco}}^{\text{a}}(i)$, to the environmental performance of the reference (concrete) structure in operation. It is defined as Formula (4).

$$R_{\text{tco}}^{\text{r}}(i) = \frac{P_{\text{rco}}(i) - P_{\text{tco}}(i)}{P_{\text{rco}}(i)} \quad (4)$$

6.4 Design

6.4.1 New concrete structures

Environmental design of a new concrete structure during its operation shall be carried out in accordance with ISO 13315-4 to meet the performance requirements set in 6.3.

When the requirements are set by comparison with a reference (concrete) structure, the design of the reference (concrete) structure shall be carried out in accordance with ISO 13315-4 so that the comparison would be appropriate.

6.4.2 Existing concrete structures

When environmental performance improvement in the operation of an existing concrete structure is necessary, design shall be carried out so as to meet the environmental performance requirements set in 6.3.

6.5 Estimation

6.5.1 New concrete structures

Each of the expected environmental performances of a new concrete structure in operation as designed under 6.4.1 shall be estimated.

When the requirements are set by comparison with the reference (concrete) structure in 6.3, each of the expected environmental performances of the reference (concrete) structure designed under 6.4.1 shall also be estimated.

6.5.2 Existing concrete structures

Each of the expected environmental performances of an existing concrete structure in operation as designed under 6.4.2 shall be estimated.

When the requirements are set by comparison with the reference (concrete) structure in 6.3, each of the environmental performances of the reference (concrete) structure shall be confirmed by acquiring data on the current state of the operation in the existing concrete structure.

6.6 Verification

Verification shall be made as to whether or not each of the expected environmental performances, estimated in 6.5, meets the performance requirements set in 6.3. If any of the expected environmental performances fails to meet the performance requirements, re-design shall be conducted by returning to 6.4. If the re-design fails to meet the requirements, the environmental performance requirements shall be reviewed. If the re-design fails to meet the reviewed environmental performance requirements, client briefing shall be carried out again.

When it is impossible to formulate and execute environmental design that meets the environmental performance requirements, the project can be cancelled. In the existing concrete structure, it can be necessary to consider demolition or abandonment by comprehensively taking account of its economic efficiency and social value.

6.7 Execution and related works

The concrete structure shall be put into operation based on the environmental design, and necessary data shall be acquired. Based on the data, each of the actual retained environmental performances shall be confirmed.

6.8 Inspection

Inspection shall be conducted as to whether or not the retained environmental performances meet the environmental performance requirements. If the performances fail to meet the requirements, the causes shall be analysed and appropriate measures shall be taken.

6.9 Documentation

All information related to the environmental management in operation shall be recorded regardless of the results of verification and inspection, and the record shall be stored by the designer who conducted the environmental design of operation of concrete structures and the owner of the concrete structure for the required period.

Annex A
(informative)

Example of indicators for the environmental management

Tables A.1 to A.12 show examples of indicators for respective impact categories.

Table A.1 — Example of indicators on global climate change

Indicator	Greenhouse gas emission can be set as an indicator. Greenhouse gas includes, for example: — carbon dioxide (CO_2); — methane (CH_4); — dinitrogen monoxide (N_2O); — hydrofluorocarbons (HFCs); — perfluorocarbons (PFCs); — sulphur hexafluoride (SF_6).

NOTE Global climate change can be characterized as CO_2 equivalent[1].

Table A.2 — Example of indicators on natural resource use

Indicator	The amount of mined abiotic resources can be set as an indicator. Abiotic resources include, for example: — rock for producing aggregate; — limestone and silica stone used for producing cement and additions; — natural resources (for example, iron ore) used for producing section steel and coal and limestone as materials for coke; — natural resources (for example, Tungsten ore) used for producing rare metals (for example, tungsten) contained in the attachments of heavy machinery. The amount of water used can be set as an indicator. Water includes, for example, tap water, industrial water, and groundwater. The amount of each type of fossil fuel used can be set as an indicator. Fossil fuel includes, for example, heavy oil, heating oil, light oil, and natural gas. The amount of materials made of biotic resources can be set as an indicator. Biotic resources include, for example, raw wood used for producing plywood for formwork.

NOTE Abiotic resources can be characterized as antimony equivalent[2].

Table A.3 — Example of indicators on stratospheric ozone level

Indicator	Discharge amount of ozone-depleting substances can be set as an indicator. Ozone-depleting substances include, for example: — CFCs (including, for example, CFC-11 and CFC-113); — halons (including, for example, halon 1301); — carbon tetrachloride; — methyl-chloroform; — HCFCs (including, for example, HCFC-225); — HBFC (including, for example, $CHFBr_2$); — bromo-chloromethane; — methyl bromide.

NOTE Stratospheric ozone level can be characterized as CFC-11 equivalent[1].

Table A.4 — Example of indicators on land use/habitat alternation

Indicator	Amount of land to be altered can be set as indicators. The amount of land include, for example: — land area; — soil volume; — soil weight.

Table A.5 — Example of indicators on eutrophication

Indicator	For discharged water, concentration of eutrophication contributors and the amount of discharged water can be set as indicators. Eutrophication contributors include, for example: — chemical oxygen demand (COD); — total nitrogen; — total phosphorus; — total organic carbon (TOC). For exhaust gas, concentration of eutrophication contributors and the amount of exhaust gas can be set as indicators. Eutrophication contributors include, for example: — NOx; — ammonia.

NOTE Eutrophication can be characterized as phosphate equivalent[3].

Table A.6 — Example of indicators on acidification

Indicator	Amount of acidification contributors can be set as an indicator. Acidification contributors include, for example: — nitrogen oxides (NOx); — sulphur oxides (SOx); — ammonia (NH3); — hydrochloric acid (HCl).

NOTE Acidification can be characterized as SO_2 equivalent[4] .

Table A.7 — Example of indicators on air pollution

Indicator	Amount of air pollutant emission can be set as an indicator. Air pollutants in urban environment include, for example: — nitrogen oxides (NOx); — sulphur oxides (SOx); — particulate matter (PM). Air pollutants in smog include, for example, non-methane volatile organic compounds (NMVOC). Air pollutants in indoor environment include, for example, volatile organic compounds.

Table A.8 — Example of indicators on water pollution

Indicator	Amount of water pollution contributors released into nature can be set as an indicator. Water pollution contributors include, for example: — heavy metals; — alkaline substances; — acidic substances; — toxic chemicals.

Table A.9 — Example of indicators on soil contamination

Indicator	Amount of soil contamination contributors discharged into soil can be set as an indicator. Soil contamination contributors include, for example: — heavy metals; — alkaline substances; — acidic substances; — toxic chemicals.

Table A.10 — Example of indicators on pollution due to radioactive substances

Indicator	Radioactivity can be set as an indicator.

Table A.11 — Example of indicators on impacts due to waste generation

Indicator	Waste generation can be set as an indicator. Waste includes, for example: — rubble (for example, concrete rubble, crushed brick, and pottery waste); — waste plastic; — rubber; — sludge; — wood chips; — fibres waste; — paper waste; — waste oil; — incineration residue; — asbestos; — waste acid/waste alkali.

NOTE Waste generation can be characterized as final disposal volume[5].

Table A.12 — Example of indicators on sound and vibration

Indicator	Sound/vibration level can be set as an indicator. Sound/vibration levels include, for example: — sound level (dB); — vibration level (dB).

Annex B
(informative)

Examples of environmental consideration during operation

See Tables B.1 and B.2.

Table B.1 — Methods of environmental improvement during operation

Purpose	Methods	Commentary
Mitigation of global climate change	Utilization of heat-storage effect of concrete	Air-conditioning energy consumption can be reduced by utilizing heat storage effect of concrete to control emission of global warming substances (See Annexes C and D).
	Water spray on the roof made of water retention concrete	Air-conditioning energy consumption can be reduced by utilizing latent heat of water evaporation from concrete to control emission of global warming substances.
	Absorption of CO_2 by carbonation of concrete	CO_2 can be stored by carbonation of concrete.
Removal of hazardous substances	Filtration of hazardous substances by pervious concrete	Water pollution can be reduced by filtering polluted water through pervious concrete.

Table B.2 — Methods of reducing environmental impacts during operation

Purpose	Typical methods	Commentary
Suppression of emission, leaching and radiation of hazardous substances	Selection of aggregate with no radon	Residents' exposure to radiation can be reduced by selecting aggregate containing no radioactive substances.
	Concrete mix-design with low water-to-cement-ratio (W/C)	Leaching of heavy metals from concrete in contact with groundwater can be reduced by using low W/C concrete.

Annex C
(informative)

Example of environmental design of concrete structures during operation (Use of void slabs)

C.1 Assumption

This example assumes the following:

- the target concrete structure is a new structure.
- the reference concrete structure is a reinforced concrete structure having the same structural and durability aspects without void slabs.
- the gross floor area is 5 000 m^2 in which void slabs total 4 000 m^2.
- energy consumption of the building during its operation is limited to cooling.
- the energy source for the cooling loads totally depends on external electric supply.
- the daily cooling time is 8 hours. The annual cooling period is 100 days.
- the specific CO_2 emission per electric power consumption is 0,6 kg-CO_2/kWh.
- only CO_2 is considered as a greenhouse gas.
- the structural and durability performances of both cases with and without void slabs satisfies the performance requirements. Time-related performance changes are not taken into consideration.
- the annual electric power consumption of the reference concrete structure amounts to 2 600 000 kWh.

NOTE The energy consumption of concrete buildings can be estimated using energy consumption calculation software.

C.2 Client briefing

Client briefing is carried out.

C.3 Setting of environmental performance requirements

C.3.1 Selection of impact categories

Global climate change is selected as the impact category based on the briefing.

C.3.2 Setting of indicators

The reduction of CO_2 emissions due to the energy consumption of the target concrete structure during operation in comparison to that of the reference concrete structure is set as the indicator.

C.3.3 Setting of requirements for indicators

The CO_2 emissions due to energy consumption of the target concrete structure during operation are required to be reduced by 50 tons per year of use in comparison with that of the reference concrete structure.

In other words, Formula (C.1) or equivalent Formula (C.2) is required:

$$P_{rco}(E_{CO_2}) - P_{tco}(E_{CO_2}) > 50 \quad \text{(C.1)}$$

$$R_{tco}^{a}(E_{CO_2}) > 50 \quad \text{(C.2)}$$

where

E_{CO_2}	refers to CO_2 emission;
$P_{rco}(E_{CO_2})$	is the environmental performance of the reference (concrete) structure during operation and expressed as the CO_2 emission due to energy consumption of the reference (concrete) structure during operation. (ton-CO_2/year);
$P_{tco}(E_{CO_2})$	is the environmental performance of the target (concrete) structure during operation and expressed as the CO_2 emission due to energy consumption of the target (concrete) structure during operation. (ton-CO_2/year).

C.4 Design

Environmental design of the target concrete structure during operation is carried out so as to satisfy the requirements of C.3 based on ISO 13315-4. “Void slab” is adopted as a method of environmental improvement.

C.5 Estimation

According to The Concrete Centre[6], a reduction in the power consumption of 40 W per m^2 of the floor is expected by the adoption of void slabs. As this building is cooled for 8 hours per day and 100 days per year as given in the assumptions (see C.1), the reduction in the CO_2 emissions due to the adoption of void slabs is calculated with Formula (C.3):

$$R_{tco}^{a}(E_{CO_2}) = 4\,000 \times 40 \times 8 \times 100 \times 0{,}6 = 76{,}8 \quad \text{(C.3)}$$

C.6 Verification

The reduction of CO_2 emissions due to the use of void slabs, $R_{tco}^{a}(E_{CO_2})$, of 76,8 tons of CO_2 per year satisfies the requirement set in C.3, of $R_{tco}^{a}(E_{CO_2})$ greater than 50 tons of CO_2 per year.

C.7 Execution and related works

The building is operated based on the environmental design. By summing up the data offered from the electric power company, the electric power consumption of the building over a year from the beginning of operation is found to total 2 510 000 kWh/year.

The CO_2 emissions of the target concrete structure due to the cooling load is calculated with Formula (C.4):

$$2\,510\,000 \times 0,6 = 1\,506 \quad (C.4)$$

From the assumptions of C.1, the CO_2 emissions of the reference concrete structure due to the cooling load is calculated with Formula (C.5):

$$2\,600\,000 \times 0,6 = 1\,560 \quad (C.5)$$

Therefore, $R_{\text{tco}}^{\text{a}}(\text{E}_{\text{CO}_2}) = 1\,560 - 1\,506 = 54$.

C.8 Inspection

The results in C.7 satisfies the requirement set in C.3, of $R_{\text{tco}}^{\text{a}}(\text{E}_{\text{CO}_2})$ greater than 50 tons of CO_2 per year.

C.9 Documentation

The entire procedure mentioned above is documented and recorded.

Annex D
(informative)

Example of environmental retrofitting using concrete masonry unit

D.1 Assumption

This example presents a case where Clauses 5 and 6 are simultaneously applied.

This example involves retrofitting for external heat insulation of a house and its operation after retrofitting. The following conditions are assumed:

- the existing house is regarded as the reference structure;
- concrete masonry units with exterior insulation (CMU) is adopted as a method of retrofitting;
- the house after the retrofitting is regarded as the target structure;
- the house is located in ASHRAE Zone 3C[7];
- the gross floor area of the house is 200 m^2, and the external wall area is 260 m^2;
- the existing house is made of wood-framed walls;
- the existing house annually consumes an electric energy of 5 000 kWh;
- energy consumption of the house during its operation is limited to cooling loads. the energy source for cooling loads totally depends on external electric supply. the cooling equipment is not renewed;
- the structural and durability performances satisfy the performance requirements and remain unchanged after retrofitting. Time-related performance changes are not taken into consideration. The service life of the building is not extended by the retrofitting;
- the period to be considered is 20 years;
- only CO_2 is considered as a greenhouse gas;
- the specific CO_2 emission per electric consumption is 0,6 kg-CO_2/kWh;
- the specific CO_2 emission due to retrofitting work per external wall area is 31 kg-CO_2/m^2;
- the waste generated due to retrofitting work is limited to gypsum and wood;
- the specific gypsum waste generation due to retrofitting work per external wall area is 0,01 m^3/m^2;
- the specific wood waste generation due to retrofitting work per external wall area is 0,02 m^3/m^2;
- wood waste can be combusted for waste reduction. Volume is reduced into 10 % after the combustion. CO_2 emission due to the combustion is ignored;
- waste due to operation of the house is ignored.

NOTE The specific CO_2 emission due to retrofitting work is set in reference to the inventory data of reinforced concrete building construction works in Japan. Wood volume reduction is set from wood biomass inventory data.

D.2 Client briefing

Client briefing is carried out.