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Performance and assessment requirements for design standards on structural concrete

Exigences de performance et d'évaluation pour la conception des normes relatives au béton structurel

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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

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Foreword

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

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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

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

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

The committee responsible for this document is ISO/TC 71, *Concrete, reinforced concrete and pre-stressed concrete*, Subcommittee SC 4, *Performance requirements for structural concrete*.

This third edition cancels and replaces the second edition (ISO 19338:2007), of which it constitutes a minor revision. It also incorporates the Technical Corrigenda ISO 19338:2007/Cor, 1:2008 and ISO 19338:2007/Cor, 2:2009.

Introduction

Concrete is the most popular material used in the construction market. Presently, about one-third of a ton of concrete is produced each year for every human being in the world (some 2 billion tons per year).

International Standards on concrete technology can play a significant role for improving the global trade climate. International Standards in the field of concrete and its use in civil infrastructure are ever more needed as the economic development of the world continues.

ISO/TC 71/SC 4 was established to develop standards for performance requirements of structural concrete. This International Standard gives the performance and assessment requirements for design standards on concrete structures. It is an umbrella-type document with general provisions and guidelines intended to provide wide latitude of choice in terms of general requirements for performance and assessment of concrete structures. It should be used, therefore, in conjunction with sound engineering judgment.

National and regional standards are generally more prescriptive in nature than International Standards and vary somewhat from region to region.

In a document accessible at http://isotc.iso.org/livelink/livelink/Open/ISO_19338, ISO/TC 71/SC 4 has defined a procedure to assess whether a national or regional standard can be deemed to satisfy this International Standard. This separate document also gives the list of national and regional standards that so far have gone through the procedure and are deemed to satisfy this International Standard.

Performance and assessment requirements for design standards on structural concrete

1 Scope

This International Standard provides performance and assessment requirements for design standards of structural concrete. It can be used for international harmonization of design and construction requirements.

This International Standard includes

a) requirements, which define the required structural concrete performance,

b) criteria, which give means for expressing the requirements, and

c) assessment clauses, which give acceptable methods of verifying the specific criteria.

2 Normative references

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

ISO 2394, *General principles on reliability for structures*

ISO 6241, *Performance standards in building — Principles for their preparation and factors to be considered*

ISO 7162, *Performance standards in building — Contents and format of standards for evaluation of performance*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
accidental load
actions whose chance of occurrence is very small but intensity is very large compared with variable actions

3.2
action
assembly of concentrated or distributed mechanical forces acting on/in a structure (direct actions), deformations imposed on the structure or contained within it (indirect actions), or *environmental actions* (3.7)

3.3
analysis
acceptable methods of evaluating the performance index or verifying the compliance of specific criteria

Note 1 to entry: Analysis may also be called assessment.

3.4
criteria
means of expressing the performance requirements for structural concrete by specific technical values and appropriate limits

3.5
design service life
period for which the structure or structural element is to be used for its intended purpose with anticipated maintenance but without substantial repair being necessary

3.6
durability
ability of a structure or structural element to assure no deterioration that is harmful to required performance in the relevant environment

3.7
environmental actions
assembly of physical, chemical, or biological influences which may cause restraint effects or deterioration to the materials making up the structure, which in turn may adversely affect its serviceability, restorability, and safety

3.8
experimental analysis
use of physical models to determine load-carrying capacity and serviceability of prototype design

3.9
limit state
critical state specified using a performance index, beyond which the structure no longer satisfies the design performance requirement

3.10
limit states design
design procedure where actions under factored loads are used to determine structural response and where resistance at limit state conditions is made equal to or greater than the response

3.11
load factors
multiplier(s) applied to load

3.12
maintenance
total set of activities performed during the design service life of the structure to enable it to fulfil the performance requirements

3.13
models
simplified mathematical descriptions of actions simulating experimental setup, material properties, the behaviour of a structure, etc.

3.14
partial safety factors for materials
devisors applied to the material characteristic strength in general conformance with reliability-based design requirements

Note 1 to entry: See also *resistance factor* (3.21).

3.15
performance evaluation
procedure where actions at service load are used to determine structural response and limits are placed on response at service loads

3.16
performance requirement
definition of the required structural performance in designed concrete structures

3.17
permanent load
self-weights of structures including permanent attachments

3.18
reliability
ability of a structure or structural element to fulfil the specified requirements during design service life of the structure

3.19
representative value of action
value of action used for the verification of criteria

3.20
resistance
ability of a member to bear loads or section forces

Note 1 to entry: The resistance is also used to control response values, such as permissible crack width and deflection.

3.21
resistance factor
multiplier applied to resistance in general conformance with reliability-based design requirements

Note 1 to entry: When applied to materials, these multipliers may also be called **material factors**. See *partial safety factors for materials* (3.14).

3.22
robustness
ability of a structure not to be damaged by events like fire, explosions, impact, or consequences of human errors, to an extent disproportionate to the original cause

3.23
restorability
ability of a structure or structural element to be repaired physically and economically when damaged under the effects of considered actions

3.24
safety
ability of a structure or structural element to assure no casualty to users of, and people around, the structure, within the limits of acceptable probability

3.25
serviceability
ability of a structure or structural elements to provide appropriate behaviour or functionality in use under the effects of considered actions at serviceability limit state

3.26
structural integrity
ability of a structure to avoid widespread collapse when localized damage occurs

3.27
variable load
weights of moving objects on structures, as well as any other loads whose intensity is variable, including traffic loads, wave loads, wind loads, water pressures, earth pressures, and loads induced by temperature

4 General requirements

4.1 Overall structural concept

The overall quality of a structure shall be implemented through strict quality control and care by a knowledgeable qualified design professional complying with ISO 2394, ISO 6241, and ISO 7162. In conceiving a structural system, load-carrying behaviour under maximum and frequent loads, materials and their combinations, constructibility, costs, and environmental aspects and aesthetics shall be considered.

4.2 Structural integrity

Design of concrete structures shall provide general structural integrity, directly or implicitly. Localized damage or deterioration in a structure shall not impair general structural integrity.

4.3 Design approach

A design standard for structural concrete shall be based on quantitative performance evaluation at the limit states. Design shall consider safety, serviceability, restorability, structural integrity, robustness, environmental adequacy, and durability. Where applicable, limit states caused by fatigue, fire, explosion, impact, and rare accidental actions or other extreme loadings or actions shall be considered.

4.4 Design service life

Design service life shall be defined in consideration of the structural role, the social importance of the structures concerned, and the economically justified service life. Structural requirements shall be satisfied throughout the defined design life.

4.5 Workmanship, materials and quality assurance

In order for the properties of the completed structure to be consistent with the requirements and the assumptions made during the planning and design, quality assurance and execution expectations for construction shall be considered and adequate quality control measures shall be taken.

5 Performance requirements

5.1 General

For limit states, the design standard shall specify sets of action combinations and a reliability-based design concept that can be analytically demonstrated to give an adequate performance level during the design life of the structure.

5.2 Structural safety and ultimate limit states

The safety level shall be selected considering the consequences of failure, the inability of the facility to fulfill its function, the relative importance of the expected modes of failure, the redundancy of the structure, and the ability to inspect and maintain the finished structure during service. Compressive stresses in concrete under any loads, including sustained loads, shall not cause crushing of the concrete.

5.3 Serviceability limit states

5.3.1 General

Service load deflections, vibrations, and cracking shall be limited so that they do not impair the use of the structure. Serviceability limit states shall be considered using factored loads and load combinations

in which the load factors correspond to an acceptable probability of occurrence of the serviceability limit state being checked.

5.3.2 Vibration limit state

Dynamic response and/or periods of vibration of a structure shall be considered and limited to avoid discomfort to occupants, impairing use of the structure, and/or avoid the risk of resonance. Dynamic analyses shall be used where required.

5.4 Restorability limit states

Damages in structures caused by loadings and actions, such as earthquake forces and environmental actions, shall be limited so that the maintenance and repair works could be conducted by an economically and technically feasible way. Restorability shall be considered using factored loads and action combinations in which the load factors correspond to an acceptable probability of occurrence of the restorability limit state being checked.

5.5 Durability limit state

The structure shall be designed such that deterioration does not cause it to reach an ultimate limit state, a serviceability limit state, a restorability limit state, or a fatigue limit state during its design life. Regular maintenance shall be prescribed (in the standard or through reference to an international, national, or regional standard) and considered in determining the design service life of a structure.

5.6 Fire resistance limit state

When exposure to fire during the life of a structure is possible, the structural concrete can provide adequate fire resistance with regard to life safety and residual structural capacity during and after a fire.

5.7 Fatigue limit state

For structures or parts of structures where fatigue may be a limiting design consideration, the fatigue limit state shall be considered. Where fatigue is considered, performance requirements under fatigue loading shall be specified.

6 Loadings and actions

6.1 General

Loads due to use and occupancy and environmental actions shall be defined considering excess probability or recurrence interval based on statistically surveyed data.

6.2 Load factors

Load factors in general conformance with reliability-based design concept shall differentiate between the different variabilities of permanent loads, frequent variable loads due to use and occupancy, frequent environmental actions, and rare loads. Load factors shall also differentiate between stabilizing and unstabilizing loads.

6.3 Action combinations

Action combinations used shall recognize the reduced probability of the simultaneous occurrence of variable loads.

6.4 Permanent loads

Permanent loads, including self-weight and the weight of permanently attached items, shall be included.

6.5 Variable loads

Variable loads that result from use of the structure shall be included.

6.6 Accidental loads

Where accidental loads due to collision, explosion, or other unusual actions are possible, such actions shall be considered.

6.7 Construction loads

Loads during any stage of construction that may lead to the ultimate limit state shall be considered.

6.8 Impact load

The impact load shall include dynamic effects of actions on the structure.

6.9 Earthquake forces

Earthquake forces shall include dynamic amplification. Where earthquakes are anticipated, actions shall be specified by national regulations or shall be determined for site-specific conditions.

6.10 Wind forces

Pressure due to wind effects shall be considered.

6.11 Environmental actions

Environmental actions shall be considered when physical, chemical, or biological influences can adversely affect serviceability, durability, restorability, and safety.

7 Assessment

7.1 Materials

Materials used in structural concrete shall satisfy codes of practice for water, aggregates, admixtures, cementitious materials, concrete, and reinforcement.

7.2 Analysis of concrete structures

7.2.1 Analysis for ultimate limit states

An acceptable standard for the design of structures shall allow the use of the following types of analysis for the ultimate limit states:

a) linear analysis;

b) nonlinear analysis;

c) linear analysis with redistribution;

d) plastic analysis (with specified minimum levels of ductility).

For the analysis, the structural elements are classified as one-dimensional, two-dimensional, or three-dimensional models. Reliability of analytical methods allowed in the standard shall be verified against experimental observation.

7.2.2 Analysis for serviceability limit states

For serviceability limit states, linear analysis or nonlinear analysis shall be allowed.

7.2.3 Analytical results

Analytical results shall be verified using established equilibrium checks.

7.2.4 Experimental analysis

Experimental analyses may be used provided they are carried out by personnel experienced in experimental analysis and providing that the variabilities of the material strengths and the resistances of the actual structure are taken into account.

7.3 Strength calculations

7.3.1 General

Strength calculations shall be based on ultimate limit state conditions. The calculation procedures shall be based on engineering principles and shall show agreement with a wide range of relevant test results.

7.3.2 Flexure and combined flexure and axial load

Flexural strength calculations shall account for:

a) nonlinear concrete stress distribution at failure,

b) nonlinear stress-strain curves for steel,

c) strain compatibility, and

d) sustained load effect.

7.3.3 Shear and torsion

Strength calculations for shear and torsion shall be based on engineering principles and shall be shown to agree with experimental results.

7.3.4 Bond, anchorage and splices

Forces in reinforcement shall be designed to develop on each side of every critical section by one or more of the following mechanisms:

— bond and anchorage of reinforcement;

— hooks, mechanical anchorages;

— lap splices.

7.3.5 Bearing

Bearing stresses and forces on concrete shall be such as to prevent failure. Confinement may be used to enhance the bearing strength.

7.4 Partial safety factors for materials

These safety factors

a) are assumed to take into account the differences between the strength of test specimens of the structural materials and their *in situ* strength and

b) are also intended to cover possible weaknesses of the structure arising from any cause other than the reduction mentioned in item a).

7.5 Resistance factors

Resistance factors used shall recognize, directly or indirectly, the different variabilities of concrete and steel, the different calculation models, and the different levels of ductility in the probable failure mode.

7.6 Resistance criteria

Criteria shall be established so that resistance exceeds actions by a specified margin. The resistance shall be established to agree with established principles or shall be based on tests.

7.7 Stability

7.7.1 General

Design requirements shall consider the stability of members and structures. Design requirements for columns shall distinguish between braced frames and frames which are free to sway.

7.7.2 Design for stability

Design for stability shall allow for the effects of cracking and creep where these are significant. Design for stability should also account for progressive development (increasing the number) of plastic hinges in the structural system.

7.8 Precast concrete and composite action

When precast concrete structures are being considered, the design standard shall provide for the overall structural integrity. It shall also give requirements for composite action between previously cast and newly cast elements of structural members.

7.9 Prestressed concrete

7.9.1 Design of prestressed concrete structures

The design standard for structural concrete structures shall include design requirements for prestressed concrete, if this is to be included in the structure.

7.9.2 Prestress losses

Design of structural concrete containing prestressing steel shall account for prestress losses.

7.9.3 Grouting of tendons

Bonded tendons shall be grouted. Corrosion protection shall be provided for all corrosion-prone tendons.