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Bases for design of structures — General requirements

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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 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 98, *Bases for design of structures*, Subcommittee SC 2, *Reliability of structures*.

This second edition cancels and replaces the first edition (ISO 22111:2007), which has been technically revised. The main change compared to the previous edition is as follows:

— the document has been made consistent with the latest edition of ISO 2394 (ISO 2394:2015).

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document incorporates the general principles of structural design as set out in ISO 2394. The general requirements relevant to the design of structures given here are expressed according to the semi-probabilistic approach as presented in ISO 2394. The general requirements are based on the premise that sufficient information is available on all aspects that are needed to set target levels of reliability and for uncertainty representation to be categorized and standardized, to ensure realization of such reliability through a semi-probabilistic approach. Procedures for deriving semi-probabilistic requirements and design methods from risk and reliability approaches are provided in ISO 2394.

The general requirements for actions on structures and the material independent resistance of the structures provided in this document are expressed on the basis of related standards for all actions and structural materials relevant to the scope of application.

The main duties for standards organisations in adopting this document are:

— to set target levels of reliability;

— to provide a suitable format and a set of quantitative design parameters;

— to establish the relevant standards from which input values for actions and resistance are to be obtained.

International Standards on actions are referenced here in lieu of standards within the jurisdiction of the adopting group.

As this document is an International Standard, its scope represents general consensus for standardized procedures for the semi-probabilistic design verification requirements of structural reliability. Thus, this document is intended to promote harmonization of structural design practice. Additional requirements and procedures need to be added to provide for specific types of structures, conditions or design practice.

This document has the following aims:

— to facilitate international practice in structural design by expressing the general requirements for the basis for the design of structures;

— to obtain international standardization of the process for setting up rules for structural design, while allowing each economy to specify its own levels of structural performance, in accordance with its own needs;

— to provide a means of promoting commonality, interchangeability, consistency and comparability of structural standards developed by different economies, such that regulators, standards writers, designers and academics could then adopt such standards with confidence in their international acceptance;

— to encourage regulatory authorities in each country to describe their mandatory requirements in an internationally agreed format;

— to facilitate future coordination between the various specialist subcommittees and working groups for ISO structural standards;

— to create transparency in the process of comparison of national standards for structural design.

Annex A to Annex D provide additional guidance on the adoption of this document and its adaptation to suit the conditions and requirements of the relevant standardization organisation.

Bases for design of structures — General requirements

1 Scope

This document provides the requirements for structural design and procedures following a semi-probabilistic approach that conform to the general principles for structural reliability as stipulated by ISO 2394. The scope of requirements and procedures are accordingly limited to the design of structures for which sufficient knowledge and experience are commonly available on design and construction practice to ensure that target levels of reliability account for the nature and consequences of structural failure. Situations outside these limitations are covered by ISO 2394.

The methods that are included in this document are the semi-probabilistic limit states approaches that are proven to achieve sufficient and consistent levels of structural reliability.

This document relies on standardized procedures for the characterization of the load bearing performance of the structures within its scope. Sufficient information is needed on uncertainties of design variables and models to be able to derive semi-probabilistic design measures for verification of structural reliability within the scope of this and the related design standards.

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 13823, *General principles on the design of structures for durability*

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 General terms

3.1.1
structure
organized combination of connected parts including geotechnical structures designed to provide *resistance* (3.3.14) and rigidity against various *actions* (3.3.1)

[SOURCE: ISO 2394:2015, 2.1.1]

3.1.2
structural performance
qualitative or quantitative representation of the behaviour of a *structure* (3.1.1) (e.g. load bearing capacity, stiffness, etc.) related to its safety and *serviceability* (3.1.6), durability and *robustness* (3.1.7)

3.1.3
reliability
ability of a *structure* (3.1.1) or structural member to fulfil the specified requirements, during the service life, for which it has been designed

Note 1 to entry: Reliability is often expressed in terms of probability.

Note 2 to entry: Reliability covers safety, serviceability, and durability of a structure.

[SOURCE: ISO 2394:2015, 2.1.8]

3.1.4
reliability index
β
substitute for the *failure* (3.2.7) probability p_f by $\beta = -\Phi^{-1}(p_f)$ where Φ^{-1} is the inverse standardized normal distribution

[SOURCE: ISO 2394:2015, 2.2.22]

3.1.5
structural safety
ability (of a *structure* (3.1.1) or structural member) to avoid exceedance of *ultimate limit states* (3.2.14), including the effects of specified accidental phenomena, with a specified level of *reliability* (3.1.3), during a specified period of time

[SOURCE: ISO 2394:2015, 2.1.9]

3.1.6
serviceability
ability of a *structure* (3.1.1) or structural member to perform adequately for normal use under all expected *actions* (3.3.1)

[SOURCE: ISO 2394:2015, 2.1.32]

3.1.7
robustness
damage insensitivity or ability of a *structure* (3.1.1) to withstand adverse and unforeseen events (like fire, explosion, impact) or consequences of human errors without being damaged to an extent disproportionate to the original cause

[SOURCE: ISO 2394:2015, 2.1.46, modified — "ability of a structure…" is modified to "damage insensitivity or ability of a structure …".]

3.2 Terms related to design and assessment

3.2.1
design situations
sets of physical conditions representing a certain time interval for which it shall be demonstrated that relevant *limit states* (3.2.12) are not exceeded

[SOURCE: ISO 2394:2015, 2.2.1]

3.2.2
persistent design situation
normal condition of use for the *structure* (3.1.1)

[SOURCE: ISO 2394:2015, 2.2.2]

3.2.3
transient design situation
provisional condition of use or exposure for the *structure* (3.1.1), for example, during its construction or repair, representing a time period much shorter than the *design service life* (3.2.10)

[SOURCE: ISO 2394:2015, 2.2.3, modified — "… design working life…" is modified to "… design service life …".]

3.2.4
accidental design situation
design situation (3.2.1) involving possible exceptional conditions for the *structure* (3.1.1) in use or exposure, including flooding, fire, explosion, impact, mal-operation of systems, or local *failure* (3.2.7)

[SOURCE: ISO 2394:2015, 2.2.4]

3.2.5
seismic design situation
design situation (3.2.1) involving the exceptional conditions when the *structure* (3.1.1) is subject to seismic event

[SOURCE: ISO 2394:2015, 2.2.5]

3.2.6
basic variable
variable representing physical quantities which characterize *actions* (3.3.1) and environmental influences, material and soil properties, and geometrical quantities

[SOURCE: ISO 2394:2015, 2.2.15]

3.2.7
failure
loss of load-bearing capacity or inadequate *serviceability* (3.1.6) of a *structure* (3.1.1) or structural member, or rupture or excessive deformation of the ground, in which the strengths of soil or rock are significant in providing *resistance* (3.3.14)

[SOURCE: ISO 2394:2015, 2.2.6, modified — "insufficient load-bearing capacity…" is modified to "loss of load-bearing capacity…".]

3.2.8
consequence class
categorization of the consequences of structural *failure* (3.2.7) used to distinguish between *structures* (3.1.1), components, and *limit states* (3.2.12)

[SOURCE: ISO 2394:2015, 2.1.34, modified — the phrase "used to distinguish between structures, components, and limit states" is newly added.]

3.2.9
reliability class
specific *target reliability* (3.2.16) against *failure* (3.2.7), based upon *consequence classes* (3.2.8) for *structures* (3.1.1), structural members and *limit states* (3.2.12)

3.2.10
design service life
assumed period for which a *structure* (3.1.1) or a structural member is to be used for its intended purpose with anticipated maintenance, but without substantial repair being necessary

[SOURCE: ISO 2394:2015, 2.2.16]

3.2.11
reference period
period of time used as a basis for assessing the design value of variable and/or *accidental actions* (3.3.5)

[SOURCE: ISO 2394:2015, 2.2.31]

3.2.12
limit state
state beyond which a *structure* (3.1.1) no longer satisfies the design criteria

[SOURCE: ISO 2394:2015, 2.2.7]

3.2.13
serviceability limit state
limit state (3.2.12) concerning the criteria governing the functionalities related to normal use

[SOURCE: ISO 2394:2015, 2.2.10]

3.2.14
ultimate limit state
limit state (3.2.12) concerning the maximum load-bearing capacity

[SOURCE: ISO 2394:2015, 2.2.8]

3.2.15
irreversible limit states
limit states (3.2.12) which will remain permanently exceeded when the *actions* (3.3.1) which caused the exceedance are no longer present

Note 1 to entry: Conversely, reversible limit states are defined as limit states which will not be exceeded when the actions which caused the exceedance are no longer present.

[SOURCE: ISO 2394:2015, 2.2.11, modified — a note to entry has been added.]

3.2.16
target reliability
target reliability index
reliability (3.1.3) (index) corresponding to acceptable safety or *serviceability* (3.1.6) for a given *reference period* (3.2.11), which can coincide with the *design service life* (3.2.10)

[SOURCE: ISO 2394:2015, 2.2.23, modified — "for a given reference period, which can coincide with the design service life" is newly added.]

3.2.17
semi-probabilistic method
verification method in which allowances made for the uncertainties and variability are assigned to the *basic variables* (3.2.6) by means of representative values, partial factors and, if relevant, additive quantities

Note 1 to entry: Factors may be related to individual random variables or global variables and may be stated as unitary or partial factors; representative values may be related to service life, the nature of the limit state or action, or to the target reliability.

3.3 Terms related to actions and resistances

3.3.1
action
assembly of concentrated or distributed forces acting on a *structure* (3.1.1) (direct actions), displacements or thermal effects imposed to the structure, or constrained in it; or environmental influences that can cause changes with time in the material properties or in the dimensions of a structure

[SOURCE: ISO 2394:2015, 2.3.1, modified — "... that may cause change ..." is modified to "... that can cause change ...".]

3.3.2
effect of action
action effect
result of *actions* (3.3.1) on a structural member (e.g. internal force, moment, stress, strain) or on the whole *structure* (3.1.1) (e.g. deflection, rotation)

[SOURCE: ISO 2394:2015, 2.3.12]

3.3.3
permanent action
action (3.3.1) which is likely to act continuously throughout the *design service life* (3.2.10) and for which variations in magnitude with time are small compared with the mean value

[SOURCE: ISO 2394:2015, 2.3.3, modified — "... design working life..." is modified to "... design service life ...".]

3.3.4
variable action
action (3.3.1) which is likely to act during a given *design service life* (3.2.10) and for which the variation in magnitude with time is neither negligible nor monotonic

[SOURCE: ISO 2394:2015, 2.3.4, modified — "... design working life..." is modified to "... design service life ...".]

3.3.5
accidental action
action (3.3.1) which is unlikely to occur with a significant value during the *design service life* (3.2.10) of the *structure* (3.1.1)

[SOURCE: ISO 2394:2015, 2.3.5, modified — "... design working life..." is modified to "... design service life ...".]

3.3.6
individual action
single action
action (3.3.1) which can be assumed to be independent in time and space of any other actions on the *structure* (3.1.1)

[SOURCE: ISO 2394:2015, 2.3.2]

3.3.7
frequent value
value of *action* (3.3.1) determined in such a way that either the total time, within a chosen period, during which it is exceeded is only a given small part of the chosen period of time or the frequency of its exceedance is limited to a given value

Note 1 to entry: This "frequent value" may be expressed as the characteristic value reduced by a factor Ψ_1.

[SOURCE: ISO 2394:2015, 2.3.23, modified — "value determined in such a way…" is modified to "value of action determined in such a way …".]

3.3.8
load case
compatible load arrangement, set of deformations, and imperfections considered for a particular verification of the specific *limit state* (3.2.12)

[SOURCE: ISO 2394:2015, 2.3.25]

3.3.9
characteristic value
value of a *basic variable* (3.2.6) specified preferably on statistical bases, so it can be considered to have a prescribed probability of not being exceeded

Note 1 to entry: For variable actions, the characteristic value corresponds to either of the following:

— an upper value with an intended probability of not being exceeded or a lower value with an intended probability of being achieved, during some specific reference period;

— a nominal value, which may be specified in cases where a statistical distribution is not known.

[SOURCE: ISO 2394:2015, 2.2.30]

3.3.10
representative value
characteristic value (3.3.9), nominal value, *combination value* (3.3.13), *frequent value* (3.3.7), or *quasi-permanent value* (3.3.11) of an *action* (3.3.1)

[SOURCE: ISO 2394:2015, 2.3.20, modified — the definition has been reworded so that it can replace the term in context.]

3.3.11
quasi-permanent value
value of *action* (3.3.1) determined in such a way that the total time, within a chosen period, during which it is exceeded is of the magnitude half the period

Note 1 to entry: This "quasi-permanent value" may be expressed as the characteristic value reduced by a factor Ψ_2.

[SOURCE: ISO 2394:2015, 2.3.24, modified — "value determined in such a way…" is modified to "value of action determined in such a way …".]

3.3.12
load combination
design value of the different *actions* (3.3.1) considered simultaneously in the verification of the *reliability* (3.1.3) of a *structure* (3.1.1) for a specific *limit state* (3.2.12)

[SOURCE: ISO 2394:2015, 2.3.26]

3.3.13
combination value
value of *action* (3.3.1) determined in such a way that the probability of action effect caused by several combination values being exceeded is approximately the same as the probability of the design value being exceeded by a *single action* (3.3.6)

Note 1 to entry: The "combination value" may be expressed as the characteristic value reduced by a factor Ψ_0.

[SOURCE: ISO 2394:2015, 2.3.21, modified — "value determined in such a way…" is modified to "value of action determined in such a way …".]

3.3.14
resistance
ability of *structure* (3.1.1) (or a part of it) to withstand *actions* (3.3.1) without *failure* (3.2.7)

[SOURCE: ISO 2394:2015, 2.1.27]

3.3.15
characteristic value of a material property
priori specified fractile of the statistical distribution of the material property in the relevant supply

4 Symbols and abbreviated terms

4.1 General

The following symbols are used in this document. All symbols are based on ISO 2394, whilst ISO 3898 defines standard notations for structural design.

4.2 Latin characters

A	accidental action
a	geometrical quantity
$\mathbf{a}_d$	vector containing the design values of the geometry
C_d	design value of the permissible serviceability constraint
E	function determining the effect of actions
E_d	design value of the effect of actions
$E_{d,dst}$	design value of destabilizing actions
$E_{d,stb}$	design value of stabilizing actions
f_k	characteristic value of material property
G	permanent action
$G_{k,i}$	characteristic value of the i-th permanent action G_i,
$G_{d,i}$	design value of i-th permanent action as factored characteristic value
$G_{r,i}$	design value of the i-th permanent action corresponding to annual probability of exceedance of 1/r
Q	variable action
$Q_{k,j}$	characteristic values of leading variable action Q_j
$Q_{k,i}$ $(i \neq j)$	characteristic values of the i-th accompanying variable action, Q_i $(i \neq j)$
$Q_{d,j}$	design value of variable actions as factored characteristic values
$Q_{r,i}$	i-th variable action with r_i-year return period value, which corresponds to the value with $1/r_i$ annual probability of exceedance
R	resistance

R_d design value of the resistance

R_k characteristic value of the resistance

R_n specified resistance

X_k basic variable at characteristic value (action, material property, geometric dimension)

V coefficient of variability of basic variable

4.3 Greek characters

α_i standardized sensitivity factor for actions (E) or resistance (R)

β reliability index

β_n reliability index for reference period of n year

γ partial factor

γ_{ci} load factors for accompanying variable load

$\gamma_{G,i}$ partial (or load) factor for permanent action G_i,

γ_j load factors for leading variable load

$\gamma_{Q,j}$ partial factor for variable action Q_j; the value for $\gamma_{Q,j}$ is dependent on whether the variable action is leading or accompanying

γ_m partial factors for material properties [used in the partial factor (γ_m) method (for example, EN 1990)]

γ_M generalized partial factors for resistance properties taking account of material, model, and geometric uncertainties

γ_S partial factor for model uncertainties of action effects

γ_R partial factor for model uncertainties of resistance (partial factor for resistance)

μ mean value (of basic variable)

σ standard deviation (of basic variable)

σ_E, σ_R standard deviation of action effects and resistance, respectively

$\Phi(.)$ cumulative normal distribution function

ϕ resistance (capacity) factor (used for example, in the LRFD format)

Ψ_0 factor for determining combination values of actions

Ψ_1 factor for determining frequent values of actions

Ψ_2 factor for determining quasi-permanent values of actions

4.4 Subscripts

d design value

E action effect

i number denoting basic variable (accompanying action)

j number denoting basic variable (leading action)

k characteristic value

n reference period (y) for specifying target reliability

R resistance

5 Fundamental requirements for structural performance

5.1 General

A structure shall, with appropriate degree of risk and reliability, fulfil the following performance requirements:

— function adequately under all expected actions throughout its service life, providing service and functionality;

— provide reliable safety against extreme and/or frequently repeated and permanent actions, as well as environmental exposures occurring during its construction, anticipated use, and decommissioning;

— provide assurance that degradation of resistance over the service life does not reduce the reliability for safety or functionality below the acceptable targets;

— provide reliability with respect to damage and its consequences;

— provide sufficient robustness so as not to suffer severe damage or cascading failure by extraordinary and possibly unforeseen events like natural hazards, accidents, or human errors.

Target performance levels shall be based on the risk-based approach. The appropriate degree of reliability shall be judged with due regard to the possible consequences of failure, the associated expense, and the level of efforts and procedures necessary to reduce the risk of failure and damage. When the consequences of failure and damage are well understood and within normal ranges, reliability-based assessment can be applied to derive target reliabilities.

Design shall account for performance throughout the life cycle of the structure. The assessment of other phases in the life of the structure shall be based on directly related information, such as considering construction, operation, inspection, maintenance, decommissioning, life cycle management and the assessment of existing structures (see ISO 13822).

For the semi-probabilistic approach, uncertainties shall be categorized and standardized, to be represented through design values and characteristic values together with specified design equations, load cases, and action combination factors. The characteristic values shall, when relevant, account for available information relating, for example, to loads and material properties.

The validity of all assumptions underlying decisions concerning structures, e.g. the relevance of and the uncertainty associated with available knowledge and information, the intended use, the service life, as well as the environmental and operational loads, should be controlled, ensured and documented. Alternatively, it should be ensured that the performance of the structures is still adequate despite possible violations of or deviations from assumptions. Quality management plays a central role for the performance of structures and shall be completely integrated in the decision-making processes related to design and assessment of structures.