INTERNATIONAL STANDARD

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Bases for design of structures — General requirements

Bases du calcul des constructions — Exigences générales

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 22111 was prepared by Technical Committee ISO/TC 98, *Bases for design of structures*, Subcommittee SC 2, *Reliability of structures*.

Introduction

This International Standard incorporates the general principles of structural design set out in ISO 2394. It covers the partial factors method, and ISO 2394 should be consulted for other methods.

This International Standard is relevant to the design of any structure, and as with all standards, a degree of judgement should be used in the normal course of engineering.

It has been drafted with wording and format suitable for direct use by practising engineers when the appropriate levels of safety have been chosen, and the relevant national loading and materials standards referenced by National Authorities. It is a template intended to facilitate the widespread use of International Standards.

The annexes give guidance on adoption of this International Standard but need not be included in the National Standard.

This International Standard has the following aims.

a) To facilitate international practice in structural design.

b) 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.

c) To provide a means of promoting commonality, interchangeability, consistency and comparability of structural standards developed by different economies. Regulators, standards writers, designers and academics could then adopt such standards with confidence in their international acceptance.

d) To encourage regulatory authorities in each country to describe their mandatory requirements in an internationally agreed format.

e) To facilitate future coordination between the various specialist subcommittees and working groups for ISO structural Standards.

f) To create transparency in the process of comparison of National Standards.

Bases for design of structures — General requirements

1 Scope

This International Standard specifies the general requirements for the structural design of buildings and industrial and civil engineering structures using reliability-based concepts.

This International Standard is applicable to the design of complete structures, the structural elements making up the structure and the foundation. Information on the assessment of existing structures is given in ISO 13822.

To allow for the differences in design practice between different countries, certain parameters are left to be quantified by national building codes or standards.

2 Normative references

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

ISO 2394:1998, *General principles on reliability for structures*

ISO 3898:1997, *Bases for design of structures — Notations — General symbols*

ISO 8930:1987, *General principles on reliability for structures — List of equivalent terms*

ISO 13822:2001, *Bases for design of structures — Assessment of existing structures*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 8930 and the following apply.

3.1
accidental action
action that is unlikely to occur with a significant value on a given structure over a given reference period

NOTE Adapted from ISO 8930:1987.

3.2
accompanying action
for a particular combination of actions, an action taken as being at a reduced value with respect to its maximum extreme design value

3.3
characteristic value of an action
principal representative value of an action

NOTE 1 Adapted from ISO 8930:1987.

NOTE 2 It is chosen

a) either, when a statistical basis is available, so that it can be considered to have a prescribed probability of not being exceeded (towards unfavourable values) during a reference period, or

b) on acquired experience, or

c) on physical constraints.

3.4
combination value of a variable action
value chosen, insofar as it can be determined on a statistical basis, so that the probability that the effects caused by the combination will be exceeded is approximately the same as by the characteristic value of an individual action

NOTE 1 It may be expressed as a certain part of the characteristic value by using a factor $\psi_0 \leqslant 1{,}0$.

NOTE 2 Adapted from ISO 8930:1987.

3.5
deformability
deformability is the capacity to resist displacement-based actions

NOTE Examples of displacement-based actions are indirect actions such as seismic ground motions, differential settlement and volume changes in structural materials.

3.6
design situation
set of conditions under which the design is required to demonstrate that relevant limit states are not exceeded during a specific time interval

NOTE Adapted from ISO 2394:1998.

3.7
design working life
duration of the period during which a structure or a structural element, when designed, is assumed to perform for its intended purpose with expected maintenance but without major repair being necessary

NOTE Adapted from ISO 2394:1998.

3.8
direct action
set of concentrated or distributed forces acting on the structure

[ISO 8930:1987]

3.9
durability
ability of a structure or a structural element to maintain adequate performance for a given time under expected actions and environmental influences

3.10
dynamic action
action which causes significant accelerations of the structure or structural members

[ISO 8930:1987]

3.11
fixed action
action which has a fixed distribution on a structure, such as its magnitude and direction, determined unambiguously for the whole structure when determined at one point on the structure

NOTE Adapted from ISO 8930:1987.

3.12
free action
action which may have any distribution in space over the structure, within certain limits

[ISO 8930:1987]

3.13
frequent value of a variable action
value determined, insofar as it can be determined on a statistical basis, so that either the total time, within the reference period, during which it is exceeded is only a small part of the reference period, or the frequency of it being exceeded is limited to a given value

NOTE 1 It may be expressed as a determined part of the characteristic value by using a factor $\psi_1 \leqslant 1{,}0$.

NOTE 2 Adapted from ISO 8930:1987.

3.14
indirect action
set of deformations or accelerations imposed on a structure or constrained within it

NOTE Adapted from ISO 8930:1987.

3.15
leading action
for a particular combination of actions, the action that is taken to be at its maximum extreme design value

3.16
limit states
states beyond which a structure no longer satisfies the design requirements

[ISO 8930:1987]

NOTE These boundaries between desired and undesired performance of the structure are often represented mathematically by “limit-state functions”.

3.17
maintenance
total set of activities performed during the design working life of a structure to enable it to fulfil the requirements for reliability

[ISO 2394:1998]

3.18
occupancy action
variable action imposed on the structure due to the intended use or occupancy of the structure

3.19
partial factors format
calculation format in which allowance is made for the uncertainties and variabilities assigned to the basic variables by means of representative values, partial factors and, if relevant, additive quantities

[ISO 2394:1998]

NOTE The load and resistance factor format is a version of the partial factor format.

3.20
permanent action
action which is likely to act throughout a given reference period of time, and for which the variation in magnitude with time around its mean value is negligible, or for which the variation is monotonic (i.e. always in the same direction) until the action attains a certain limiting value

NOTE Adapted from ISO 8930:1987.

3.21
quasi-permanent value of a variable action
value determined so that the total period of time for which it is exceeded is a large fraction of the reference period

NOTE 1 It may be expressed as a determined part of the characteristic value by using a factor $\psi_2 \leqslant 1{,}0$.

NOTE 2 Adapted from ISO 8930:1987.

3.22
reference period
chosen period of time that is used as a basis for assessing the design value of variable or accidental actions or both

NOTE Adapted from ISO 8930:1987.

3.23
reliability
ability of a structure or structural element to fulfil the specified requirements, including the design working life, for which it has been designed

[ISO 2394:1998]

3.24
representative value of an action
value assigned to the action for a specific purpose

NOTE 1 Adapted from ISO 8930:1987.

NOTE 2 It can be used, for instance, for the verification of a limit state.

3.25
robustness
ability of a structure (or part of it) to withstand events (like fire, explosion, impact) or consequences of human errors, without being damaged to an extent disproportionate to the original cause

NOTE 1 Adapted from ISO 2394:1998.

NOTE 2 Robustness is sometimes referred to as structural integrity.

3.26
strength
ability of a cross-section or an element of a structure to withstand actions without mechanical failure

EXAMPLES Bending strength, buckling strength, tension strength.

3.27
serviceability limit states
states corresponding to conditions beyond which specified serviceability requirements for a structure or structural element are no longer met

NOTE 1 Adapted from ISO 2394:1998.

NOTE 2 They are related to the user's comfort, function of the structure or element, risk of deterioration, or intended maintenance.

3.28
static action
action that does not cause significant acceleration of a structure or a structural element

NOTE Adapted from ISO 8930:1987.

3.29
structural model
idealization of the structural system used for the purposes of analysis, design and verification

[EN 1990:2002]

3.30
ultimate limit states
states associated with collapse, or with other similar forms of structural failure

NOTE They generally correspond to the maximum load-carrying resistance of a structure or structural element but in some cases to the maximum applicable strain or deformation.

[ISO 2394:1998]

3.31
variable action
action for which the variation in magnitude with time is neither negligible in relation to the mean value nor monotonic

NOTE Adapted from ISO 8930:1987.

4 Symbols

The symbols used in this International Standard follow the guidelines given in ISO 3898 and ISO 2394.

A: accidental action

A_{d}: design value of a leading accidental action (see Annex B)

C_{d}: serviceability limit; see Equation (5)

E_{d}: design-action effect

$E_{\mathrm{d,destab}}$: design effect of destabilising actions

$E_{\mathrm{d,stab}}$: design effect of stabilising actions

F: action in general

F_i, F_j: various actions

G: permanent action

G_i: permanent action for a particular combination

$G_{ki,\mathrm{stab}}$: the component of the permanent action that is relied upon to stabilise the structure (see 9.2.2)

G_k: characteristic value of permanent action (see Annex B)

$G_{k,i}$: characteristic permanent action for a particular combination (see 9.2.1)

$G_{kj,\mathrm{inf}}$: lower characteristic value of permanent action (see Annex B)

$G_{kj,\mathrm{sup}}$: higher characteristic value of permanent action (see Annex B)

Q:	variable action
Q_k:	characteristic value of a variable action in a combination
$Q_{k,1}$:	characteristic value of a leading variable action (see 9.2.1)
$Q_{k,i}$:	characteristic value of an accompanying variable action (see 9.2.1)
R_d:	design resistance
R_s:	design resistance of the restraining elements (if any)
β:	reliability index (beta)
β_I, β_II, β_III, β_IV:	values of reliability index appropriate to various consequence levels
γ :	partial factor (gamma)
$\gamma_{\text{a},i}$:	factor applied to the characteristic action to determine the accompanying action (see B.2)
γ_i:	partial factor of the accompanying variable action
γ_j:	partial factor for leading variable or accidental action
γ_m:	partial material factor
$\gamma_{Gi,\text{stab}}$:	the load factor for the permanent action that is relied upon to stabilise the structure
$\gamma_{Gj,\text{inf}}$:	factor for the lower combination value of a permanent action (see Annex B)
$\gamma_{Gj,\text{sup}}$:	factor for the higher combination value of a permanent action (see Annex B)
γ_G, γ_{Gi}:	partial factors for various permanent actions
γ_{Qi}:	factor for combination value of an accompanying variable action (see Annex B)
$\gamma_{Q,1}$:	factor for combination value of a leading variable action (see Annex B)
ψ_i:	factor for combination value of a particular action (psi)
ψ_0:	factor for combination of a variable action
ψ_1:	factor for frequent value of a variable action (see Annex B)
ψ_2:	factor for quasi-permanent value of a variable action (see Annex B)
$\psi_{2,1}$:	factor for quasi-permanent value of a leading variable action (see Annex B)
$\psi_{2,i}$:	factor for quasi-permanent value of an accompanying variable action (see Annex B)
ϕ:	resistance factor
ξ :	reduction factor for unfavourable permanent actions (see B.1)

5 Application

When this International Standard is used to develop a National Standard, appropriate values for those factors not specified shall be determined in accordance with ISO 2394 using the appropriate International and National Standards, which shall be mutually consistent.

NOTE Guidance on the application of this International Standard is given in Annexes A to D.

6 Basic requirements for structural performance

A design working life shall be selected for the structure. The structure shall be designed, constructed and maintained in such a way that during construction and for its design working life it will, with appropriate degrees of reliability, sustain all actions and influences likely to occur. It shall be designed with the following:

a) *ultimate limit-state requirements*: to withstand extreme or frequently repeated actions, or both, occurring during its construction and anticipated use;

b) *robustness requirements*: so that it will not be damaged to an extent disproportionate to the original cause, by events like fire, explosion or impact or as a consequence of human error;

c) *serviceability requirements*: to perform adequately under all expected actions;

d) *durability requirements*: to satisfy all of the above for its design working life, given appropriate maintenance.

Compliance with these requirements shall be demonstrated by verifying that the structure and its elements satisfy a specified set of limit-state conditions in accordance with the principles of Clause 11.

7 Classification of structures and elements of structures

Structures and elements of structures shall be classified according to Table 1.

For the purposes of demonstrating compliance under 11.2, structures shall be classified in terms of consequences of failure in accordance with Table 1.

Table 1 — Classification of structures and elements of structures

Consequence class [a]	Consequences of failure [b]	Comments
I	Low	**Low** consequence for loss of human life, *or* **small or moderate** economic, social or environmental consequences
II	Ordinary	**Medium** consequence for loss of human life, *or* **considerable** economic, social or environmental consequences
III	High	**High** consequence for loss of human life, *or* **very great** economic, social or environmental consequences
IV	Exceptional	Circumstances where reliability must be set on a case-by-case basis

[a] Examples of structures that fit into these classes are to be given in the annex of the adopting group or stated elsewhere (see Annex C).

[b] To life or to society.

8 Actions

8.1 General

All physical conditions likely to affect the performance of the structure shall be considered.

8.2 Evaluation of values of actions

Actions shall be evaluated in accordance with the following:

a) the nature of the action (including whether fixed or free, static or dynamic and frequency of occurrence);

b) the consequence class;

c) the design working life of the structure.

8.3 Permanent actions

Permanent actions (G) include, but are not limited to, the following:

a) self-weight of the structure (except possibly certain parts during certain phases of construction);

b) weight of superstructures, including any permanent formwork or fixtures;

c) forces applied by static earth pressure, resulting from the mass of the soil;

d) deformations imposed by the construction sequence of the structure;

e) action resulting from shrinkage of concrete and from welding;

f) action due to fluids, where permanent;

g) action due to subsidence (support settlements and mining);

h) pre-stressing action.

NOTE Information on permanent actions is given in the relevant International Standards, e.g. ISO 9194.

8.4 Variable actions

Variable actions (Q) include, but are not limited to, the following:

a) action imposed due to use and occupancy action;

b) wind action;

c) snow action;

d) seismic action;

NOTE 1 Seismic action can be categorised as accidental action if so designated in the national building code or standard.

e) action due to ponding of water;

f) action due to fluids, where variable;

g) action due to forces and effects arising from contraction or expansion resulting from temperature changes, moisture changes, creep, and from movement due to differential settlement;

h) ice action;

i) action due to currents;

j) action due to waves;

k) action due to moving loads and their effects;

l) action applicable to a specific situation.

NOTE 2 Information on variable actions is given in the relevant International Standards, e.g. ISO 2103, ISO 2633, ISO 3010, ISO 4354, ISO 4355, ISO 12494.

8.5 Accidental actions

Accidental actions (A) include, but are not limited to, the following:

a) action due to fire;

b) action due to explosion;

c) action due to collision;

d) seismic action;

NOTE 1 Seismic action can be categorised as variable action if so designated in the national building code or standard.

e) action due to vegetation;

f) action due to erosion;

g) action applicable to a specific accidental situation.

NOTE 2 Accidental actions are not normally assessed unless specifically applicable.

NOTE 3 For fire action, the structural performance is defined in terms of the structural resistance for a required period of time, while the structure is under the effects of fire and other actions.

9 Combinations of actions

9.1 General

Actions shall be considered to act in the following combinations, whichever produces the most unfavourable effect in the structure, foundation or structural element being considered. Effects of one or more variable actions not acting shall be considered, if they produce more unfavourable effects.

9.2 Ultimate limit states

9.2.1 Strength

The design-action effects (E_d), for examining strength (and deformation, where applicable) shall be determined by combining the values of uncorrelated actions, both unfavourable and favourable, that are considered to occur simultaneously. Sufficient combinations shall be made to evaluate all realistic limit-state conditions. Each combination of actions shall include the following:

a) all permanent actions $\Sigma\ (\gamma_{Gi}\ G_{k,i})$;

b) the design value of one leading variable or accidental action $(\gamma_{k,1}\ Q_{k,1})$;

c) the design combination values of accompanying variable actions $\Sigma\ (\gamma_i\ \psi_i\ Q_{k,i})$.

E_{d} may be expressed as a combination as follows:

$$\left\{\sum\left(\gamma_{Gi}\ G_{k,i}\right);\left(\gamma_j\ Q_{k,1}\right);\sum\left(\gamma_i\ \psi_i\ Q_{k,i}\right)\right\} \tag{1}$$

NOTE 1 For correlated actions (e.g. storm surge and wind), there can be more than one leading action.

NOTE 2 When the combination includes an accidental action, the design combination values for permanent and accompanying variable actions can be adjusted.

9.2.2 Static equilibrium

The design-action effects for examining sliding, overturning and uplift shall be separated into two components; the stabilising action effects $E_{\text{d,stab}}$ and the destabilising action effects $E_{\text{d,destab}}$ as follows:

a) The stabilising action effects ($E_{\text{d,stab}}$) shall be determined by combining those design values of permanent actions that can be relied on to stabilize the structure at all times, i.e.

$$E_{\text{d,stab}} = \sum\left(\gamma_{Gi,\text{stab}}\ G_{ki,\text{stab}}\right)\quad\left(\gamma_{Gi,\text{stab}} < 1{,}0\right) \tag{2}$$

where

$G_{ki,\text{stab}}$ is the component of the permanent action that is relied upon to stabilise the structure;

$\gamma_{Gi,\text{stab}}$ is the corresponding load factor.

a) The destabilising action effects ($E_{\text{d,destab}}$) shall be determined by combining those values of actions that destabilise the structure occurring in the combinations given in 9.2.1.

9.3 Serviceability limit states

Distinction shall be made of the effects of characteristic values, frequent values and quasi-permanent values of the actions both individually and in combination.

9.4 Formats for presentation of design values for leading and accompanying actions

The design value for a leading or accompanying action can be described using a characteristic value for the action and the factors ψ and ξ, as appropriate.

For some actions from natural phenomena, the characteristic value for adoption in an ultimate limit state may be determined for an event having a factor of 1,0 (see Annex B).

Each permanent action shall have a number of values, including a favourable value and an unfavourable value. These can be expressed by using a characteristic value in association with partial factors ($\gamma > 1{,}0$ for an unfavourable value, $\gamma < 1{,}0$ for a favourable value).

Each variable action may have a number of values, including a leading value and accompanying values. For variable actions that can be statistically assessed (such as environmental actions), the values can be expressed in terms of annual probabilities of exceedance (i.e. the inverse of the average return period).

NOTE Guidance on formats for presentation of design values for use in combinations is given in Annex B.

10 Analysis and testing

10.1 Analysis

Analysis shall be based on a calculation model of a structure that can predict the structural behaviour, with an acceptable level of accuracy appropriate to the requirements under consideration.

For static analysis, structural models shall be based on an adequate choice of the force-deformation relationship of the elements and their connections, and between the elements and the ground. Effects of deformations and displacements shall be taken into account, if they result in a significant increase of the effect of the action or reduction in capacity.

When dynamic actions are specified as equivalent static actions, the dynamic aspects of actions shall be considered either by including them in the static values or by applying equivalent dynamic amplification factors to the static actions.

For dynamic analysis, structural models shall be based on relevant properties, such as masses, stiffnesses and damping characteristics of structural and relevant non-structural components. The structural response may be determined using modal analysis, time histories or any other appropriate method.

The geometrical quantities used in the computation generally refer to nominal values (i.e. the values given in the drawings, etc.). Where the structural behaviour is sensitive to imperfections (e.g. deviations from intended geometry such as geometrical tolerances), the allowable deviations for the execution of works shall be considered.

10.2 Testing

The design may be based on a combination of tests and calculations.

Testing may be used in the following circumstances:

a) if adequate calculation models are not available;

b) for prototype testing (if a large number of similar components are to be used);

c) to confirm assumptions made in the design.

Design assisted by testing shall achieve the same level of reliability required for the relevant design condition. Statistical uncertainty due to a limited number of tests must be taken into account.

11 Demonstrating compliance with requirements

11.1 General

All relevant limit states and all combinations of actions shall be considered in the design. Compliance with the basic requirements of this International Standard shall be demonstrated.

11.2 Ultimate limit state

11.2.1 Strength

When considering collapse, rupture or excessive deformation of a structure, element or connection, it shall be demonstrated that, during construction and throughout the design working life of the structure, the following expression is satisfied:

$$R_d \geqslant E_d \quad (3)$$

where

R_d is the design strength;

E_d is the design-action effect.

The design strength shall be determined with appropriate allowance for the following:

a) the uncertainties resulting from construction activities;

b) variation in material properties;

c) the characteristics of the site;

d) the degree of accuracy inherent in the methods used to assess structural behaviour.

11.2.2 Static equilibrium

When considering instability due to overturning, uplift and sliding, it shall be demonstrated that, during construction and throughout the design working life of the structure, the following expression is satisfied:

$$E_{d,stab} + R_s \geqslant E_{d,destab} \quad (4)$$

where

$E_{d,stab}$ is the the design effect of stabilising actions which can be relied upon;

R_s is the design strength of the restraining elements (if any);

$E_{d,destab}$ is the design effect of destabilising actions.

11.3 Robustness

Compliance with the robustness requirement shall be demonstrated by an appropriate choice of one or more of the following:

a) avoiding, eliminating or reducing the hazards to which the structure can be subjected;

b) selecting a structural form which has low sensitivity to the hazards considered;

c) selecting a structural form and design that can survive adequately the accidental removal of an individual element or a limited part of the structure, or the occurrence of acceptable localised damage;

d) avoiding, as far as possible, structural systems that can collapse without warning;

e) tying the structural elements together;

f) providing additional strength.

11.4 Serviceability

Appropriate serviceability criteria representing structural responses shall be chosen for demonstrating compliance with serviceability requirements. The serviceability criterion shall take into account whether the serviceability limit state is reversible or irreversible.

When considering serviceability limit states, it shall be verified that:

$$E_\mathrm{d} \leqslant C_\mathrm{d} \tag{5}$$

where

C_d is the serviceability limit;

E_d is the design-action effect.

11.5 Durability

The durability of the structure and structural elements in their environment shall be such that they remain fit for use during their design working lives, given appropriate maintenance.

The design working life of an element shall be selected depending on a number of factors, including environmental conditions, consequences of failure, accessibility, life-cycle cost, and the design working life of the structure.

Durability shall be secured by either a maintenance programme or, in those cases when the structure is not expected to be subjected to maintenance by design, such that deterioration will not lead to the failure of the structure in those cases when the structure is not expected to be subjected to maintenance.

The actual service life of an element due to material deterioration may be estimated on the basis of theoretical or experimental investigation and experience.

NOTE For more specific methods for assessing and achieving durability, see ISO 15686 and ISO 13823, which is currently being prepared, might also be relevant.

Annex A
(informative)

Guidance for adopting groups

A.1 General

This Annex gives further information on issues to be considered by a national group during adoption of this International Standard. A number of clauses have been left open so that authorities in control of construction can set values and requirements appropriate to their particular condition. It is expected that the standard will be adopted by the addition of a national annex or annexes setting out the additional information necessary for use.

A.2 Process for adoption

A.2.1 General

The adopting group will use this International Standard as a template. The intention is that this International Standard may be directly used for design and, therefore, the adopted standard must contain all necessary values to enable the design of structures to be carried out. This Annex is provided as guidance to the adopting group and may be removed along with the other informative Annexes, as users do not need them.

It is intended that the standard be adopted with the addition of an annex (provided by the adopting group) that gives the necessary values for use in design.

The adoption should take into account the national conditions and the loading and design documents to be used with it. These national documents will be referred to in the adopted standard.

Where wind actions are expressed in terms of velocity then this International Standard allows for environmental actions (e.g. strong winds) to be expressed by the adopting authorities in some regions, as an ultimate limit-state design event (with a partial factor = 1,0), so as to account for the differing non-linearity of the action for different structural responses. (Response loads may increase with respect to wind speed, to the power 2 or 3, depending on the structure.)

The adopted standard should provide for alternative paths to compliance through the use of basic principles, research or testing to prove reliability (see ISO 2394). Such alternatives would need to be supported by documentation to the satisfaction of the authority approving the structure.

A.2.2 Classification of structures and elements

The adopting group should elaborate further on the kinds of structure applicable to each class. Annex C gives guidance on calibration for different consequence classes.

A.2.3 Applicable actions

The types and means of specifying of actions need to be stated, in order for the user to be clear about what actions must be considered in the design. While most adopting groups will be able to reference national documents for most major actions, there may be little or no information that can be specifically stated for some actions. Therefore, the list of actions and the referenced documents may be modified as needed by the adopting group.

It is important that the variables used as the means of specifying each action should be the same as that given in the corresponding International Standard, if available (see the Bibliography for a list of relevant International Standards).

In the context of this International Standard, accidental actions can be considered as rare events. In some environments, particular actions may be considered to be accidental rather than variable.

In some situations, wind actions may include the effect of wind-borne debris on building envelopes and thus on internal pressure.

A.2.4 Combinations of actions

It is expected that the adopting group will insert a set of combinations that are appropriate, given the construction conditions and the other design information to be used (e.g. load data and materials design methods).

If format A is used for presenting load combinations (see B.1), further guidance can be found in EN 1990.

If format B is used for presenting load combinations (see B.2), load specifications from the USA, Australia/New Zealand, Canada, etc. may be used as examples.

A.2.5 Analysis and testing

It may be necessary to specify accepted methods for analysis, particularly for dynamic actions such as earthquakes and wind.

It may also be necessary to specify the conditions for the acceptance of testing as a supplement to calculations. Various methods are available for treating the uncertainty due to a limited number of tests and to ensure the reliability level of design using test data, e.g. ISO 2394. These may also need to be specified by the adopting group.

A.2.6 Demonstrating compliance with requirements

A.2.6.1 Strength

There are alternative methods for specifying the strength of a structure. The two most common methods are

a) the partial factor (γ_m) method (for example, EN 1990), and

b) the resistance (capacity) factor (ϕ) method (for example, the US LRFD format; Load and Resistance factor format).

Structural strength is normally defined in terms of the maximum load-carrying capacity of a structure or structural element. For slender structures with a large deformation capacity, the strength may be defined by the load-carrying capacity that corresponds to the maximum acceptable strain or deformation.

A.2.6.2 Static equilibrium

When considering sliding, overturning and uplift, the following applies.

a) Permanent actions contributing to stabilising effects should be limited to permanent actions that cannot be removed from the structure and they should have load factors less than 1,0, while all permanent actions contributing to destabilising effects should be included and they should have load factors greater than 1,0.

b) Variable actions contributing to stabilising effects should be excluded, while all variable actions contributing to destabilising effects should be included in combinations, as given in 9.2.1.

A.2.6.3 Robustness

Additional measures for robustness may be introduced by the adopting group, such as minimum lateral strength for elements and connections, minimum sizes or other quantifiable measures such as limiting the area of damage, etc. Tying the structure together could include consideration of the transmission of forces in both the horizontal and vertical directions.

A.2.6.4 Serviceability

The adopting group needs to be clear on its specification of serviceability criteria (actions and associated response limits) and may or may not determine this criterion to be normative. Lists of acceptable serviceability criteria that are material-independent should be established in the national standard as either normative or informative guidance. Serviceability criteria that are material-dependent should be provided in the appropriate design document for the specific material.

A.2.6.5 Durability

The performance of the structure should ensure reliability throughout its design working life. Durability criteria may or may not be considered as normative and the adopting group needs to be clear on this in its specification. Since the method of design for durability is normally material-dependent, details for compliance should be established in the appropriate design document for the specific material.

Annex B
(informative)

Formats for presentation of design values for use in combinations of actions

B.1 Format A

Design situations are classified as normal and accidental. Combinations of actions can be expressed in table form, see Tables B.1 and B.2. In Table B.1, Method 1 or Method 2 (applying both Expressions A and B) can be used.

NOTE An example of this format can be found in EN 1990.

Table B.1 — Action combinations for ultimate limit states

Design situation			Permanent Σ		Leading variable action	Accompanying variable action	
			Unfavourable	**Favourable**		**Main**	**Other, Σ**
Strength							
Normal (persistent and transient)	Method 1		$\gamma_{Gj,\text{sup}} G_{kj,\text{sup}}$ [1,35]	$\gamma_{Gj,\text{inf}} G_{kj,\text{inf}}$ [1,0]	$\gamma_{Q,1} Q_{k,1}$ [1,5]		$\gamma_{Qi} \psi_0 Q_{k,i}$ [1,5 × 0,7]
	Method 2	Expression A	$\gamma_{Gj,\text{sup}} G_{kj,\text{sup}}$ [1,35]	$\gamma_{Gj,\text{inf}} G_{kj,\text{inf}}$ [1,0]		$\gamma_{Q,1} \psi_0 Q_{k,1}$ [1,5 × 0,7]	$\gamma_{Qi} \psi_0 Q_{k,i}$ [1,5 × 0,7]
		Expression B	$\xi \gamma_{Gj,\text{sup}} G_{kj,\text{sup}}$ [0,85 × 1,35]	$\gamma_{Gj,\text{inf}} G_{kj,\text{inf}}$ [1,0]	$\gamma_{Q,1} Q_{k,1}$ [1,5]		$\gamma_{Qi} \psi_0 Q_{k,1}$ [1,5 × 0,7]
Accidental			$G_{kj,\text{sup}}$	$G_{kj,\text{inf}}$	A_d	$\psi_{1,1} Q_{k,1}$ or $\psi_{2,1} Q_{k,1}$ [1,5]	$\psi_{2,i} Q_{k,1}$ [0,3]
Static equilibrium			$\gamma_{Gj,\text{sup}} G_{kj,\text{sup}}$ [1,1]	$\gamma_{Gj,\text{inf}} G_{kj,\text{inf}}$ [0,9]	$\gamma_{Q,1} Q_{k,1}$ [1,5]		$\gamma_{Qi} \psi_0 Q_{k,1}$ [1,5 × 0,7]

When Method 2 is used, both Expressions A and B should be used.

NOTE The values in brackets are typical values for illustrative purposes only of load action factors (γ and $\xi\gamma$). The combination values ψ_0, ψ_1, and ψ_2 vary, dependant on the type of structures and the type of loading.

Table B.2 — Action combinations for serviceability limit states

Design situation	Permanent Σ	Leading variable action	Accompanying variable action
Characteristic	$\Sigma\ G_i$	Q_k	$\Sigma\ \psi_{0,i}Q_k$ [0,7]
Frequent	$\Sigma\ G_i$	$\psi_{1,1}\ Q_k$ [0,5]	$\Sigma\ \psi_{2,i}Q_k$ [0,3]
Quasi-permanent	$\Sigma\ G_i$	$\psi_{2,1}\ Q_k$ [0,5]	$\Sigma\ \psi_{2,i}Q_k$ [0,3]

NOTE 1 Characteristic values are usually applied in the case of irreversible cases. Frequent values are usually applied in the case of reversible cases.

NOTE 2 The γ and ψ values in brackets are for illustrative purposes only.

B.2 Format B

Design situations are classified as normal and accidental. The combinations can be expressed as given in Tables B.3 and B.4.

NOTE This format is consistent with that used in load and resistance factor formats.

Table B.3 — Action combinations for ultimate limit states

Design situation	Permanent actions		Leading variable or accidental action	Accompanying variable actions
	Unfavourable	Favourable		
Strength [see Equation (3)]:				
— normal	$\Sigma\ \gamma_{Gi,\mathrm{sup}}\ G_{k,i}$ [1,2]	$\Sigma\ \gamma_{i,\mathrm{inf}}\ G_{k,l}$ [0,9]	$\gamma_{Q,1}\ Q_{k,1}$ [1,4 – 1,6]	$\Sigma\ \gamma_{\mathrm{a},i}\ Q_{k,i}$ [0,5]
— accidental	$\Sigma\ \gamma_{Gi,\mathrm{sup}}\ G_{k,i}$ [1,0]	$\Sigma\ \gamma_{i,\mathrm{inf}}\ G_{k,l}$ [1,0]	A_{d}	$\Sigma\ \gamma_{\mathrm{a},i}\ Q_{k,i}$ [0,5]
Static equilibrium [see Equation (4)]:				
— normal	$\Sigma\ \gamma_{Gi,\mathrm{sup}}\ G_{k,i}$ [1,2]	$\Sigma\ \gamma_{Gi,\mathrm{inf}}\ G_{k,l}$ [0,9]	$\gamma_{Q,1}\ Q_{k,1}$ [1,4 – 1,6]	$\Sigma\ \gamma_{\mathrm{a},i}\ Q_{k,i}$ [0,5]
— accidental	$\Sigma\ \gamma_{Gi,\mathrm{sup}}\ G_{k,i}$ [1,0]	$\Sigma\ G_{k,l}$ [1,0]	A_{d}	$\Sigma\ \gamma_{\mathrm{a},i}\ Q_{k,i}$ [0,5]

The determination of a simplified expression for "$\Sigma\gamma_{\mathrm{a},i}Q_{k,i}$" should be based on reliability analysis. ISO 2394 includes an informative annex on how this can be carried out.

Variable actions which are strongly correlated, such as wind action and icing of cables, should consider two alternatives, the un-iced cable subjected to the design wind action and the iced structure subjected to a frequent wind action, the latter based on a reliability analysis in accordance with ISO 2394.

The γ and ψ values in brackets are for illustrative purposes only. These values vary with types of actions, types of combinations and the target reliability level. For example, γ = 1,2 should be increased for components subjected primarily to permanent actions.

For favourable permanent actions, consideration should be given to omitting components of permanent actions that can be removed from the structure.

NOTE This table can be simplified when applied to specific facilities, such as building structures, bridges, towers, underground tunnels and pipes.

Table B.4 — Action combinations for serviceability limit states

Design situation	Permanent actions	Leading variable or accidental action	Accompanying variable actions
Characteristic	$\Sigma\ G_{k,l}$	$Q_{k,1}$	$\Sigma\ \psi_{1,i}Q_{k,i}$ [0,7]
Frequent	$\Sigma\ G_{k,l}$	$\psi_{1,1}\ Q_{k,1}$ [0,5]	$\Sigma\ \psi_{2,i}Q_{k,i}$ [0,3]
Quasi-permanent	$\Sigma\ G_{k,l}$	$\psi_{2,1}\ Q_{k,1}$ [0,5]	$\Sigma\ \psi_{2,i}Q_{k,l}$ [0,3]

NOTE 1 Combinations of actions for serviceability depend very much on the serviceability limit state (e.g. deflection causing damage to non-structural components, vibration affecting people or equipment or causing fatigue, loss of appearance) and the mechanisms leading to failure (e.g. elastic response, creep, shrinkage, fatigue crack growth, material deterioration) which are material dependant. Simplified serviceability criteria are contained in codes for buildings and structures and in material design standards.

NOTE 2 The γ and ψ values in brackets are for illustrative purposes only. These values vary with types of actions, types of combinations and the target reliability level.

B.3 Format C

For actions that can be statistically assessed, such as environmental actions, e.g. wind, snow, seismic activity, etc., the design values can be expressed in terms of the annual probabilities of exceedance (i.e. the inverse of the average return intervals) with a load factor of 1,0. The combinations may then be described in either Format A or B with appropriate combination and resistance factors assigned (calibrated in the usual manner).

The design events are also classified into two groups: leading events (with very low probabilities of exceedance) and accompanying events (with relatively larger probabilities of exceedance).

The design values can then be specified as a function of the consequence class.

If Format C is used, a national body shall specify the actions at the annual probability of exceedance or the method by which these actions can be computed. The computation of reliability shall be calculated on a consistent basis.

NOTE An example of this format can be found in Table B.5.

Table B.5 — Annual probabilities of exceedance

Consequence class	Annual probability of exceedance			
	Wind		Earthquake	Snow
	Cyclonic	Non-cyclonic		
I	1:500	1:250	1:500	1:250
II	1:1000	1:1000	1:1000	1:500
III	1:2500	1:2500	1:1500	1:750
IV	Determine for actual case	Determine for actual case	Determine for actual case	Determine for actual case

NOTE 1 The figures are given for illustrative purposes only. The figures vary with geographic conditions and target reliability.

NOTE 2 The actual figures are to be determined by the appropriate national authority.

NOTE 3 Format C can lead to better reliability consistency for systems with highly variable geographic conditions or with non-linear characteristics.

Annex C
(informative)

Calibration of design values

This Annex gives further information on the calibration of design values for the adoption of this International Standard by national bodies. The calibration is intended to ensure that consistent reliability of structures in each class is achieved and provides transparency in comparison between National Standards resulting from different adopting groups.

Calibration should be carried out using reliability theory and the principles laid out in ISO 2394.

Target reliability indices (β) for various design situations for specified reference periods should be selected by the adopting group as illustrated in Table C.1. Table C.1 shows how the indices relate to selected consequence classes. It also gives an example of the possible subdivision of classes together with typical example structures depending on the needs of the adopting group. Which structures are placed in each class is a matter of policy for the society adopting the standard and therefore should be stated in a regulatory context. This table provides for differentiation of reliability to provide for more important and less important structures. The specified reference periods are usually 1 year for serviceability and 50 years for ultimate limit states.

Table C.1 — Examples of target reliability indices

Consequence class	Examples of typical policy direction; to be decided by the adopting group			
	Example subdivisions	**Example descriptors**	**Example structures based on the purpose and function of the structure**	**Target reliability indices** [a]
I	I	Low	Farm structures	β_I
II	II	Ordinary	All structures not in other classes, housing, small commercial buildings	β_{II}
III	IIIa	Crowds	Theatres, schools	β_{IIIa}
	IIIb	Post-disaster	Major hospitals	β_{IIIb}
IV	IV	Exceptional	Major dam	β_{IV} (to be selected on a case-by-case basis)

[a] These values should not be included in the adopted standard as they are to be set by the national building code or standard.

The target reliability indices to be used for a particular adoption are usually selected by reliability analysis of the existing or historical methods of design and construction. These values may be adjusted if found inconsistent or inadequate before being set as targets. Alternatively, the target indices (and hence the design probability values to be published) may be established by economic optimisation, i.e. the balance between consequences of failure and the cost of increased performance.

Various methods of reliability analysis as outlined in ISO 2394 may be used. The selected method and the probabilistic models for actions and resistance should be stated as well as the target safety indices. Such information supports the standard but should be published separately as it may mislead or confuse the user. Values of a variable action may be provided by probabilistic or deterministic methods or a combination of both, depending on the data available.

Annex D
(informative)

Design procedure

The following procedures set out the method for design.

D.1 Strength and static equilibrium

Ultimate-limit-states design should be carried out by the following procedure.

a) Determine the consequence class of the structure.

b) Determine the types of actions that will have to be considered.

c) Evaluate the loads appropriate to the actions.

d) Determine the appropriate load combinations for the ultimate limit states.

e) Analyse the structure and its parts for the relevant load combinations to obtain the ultimate action effects.

f) Design and detail the structure for structural robustness and durability.

g) Determine the strength of the structure (and restraining elements).

h) Verify that there is no loss of static equilibrium of the structure or part of the structure.

i) Verify that the ultimate design resistance exceeds the appropriate ultimate action effects.

D.2 Serviceability

Serviceability-limit-states design should be carried out by the following procedure.

a) Determine, for the whole structure and for individual elements, the required design serviceability actions and associated constraints to be considered.

b) Determine the appropriate serviceability loads.

c) Determine the appropriate limiting values of serviceability constraints.

d) Determine the appropriate serviceability load combinations.

e) Determine the serviceability response of the structure (or part of the structure) for each constraint using appropriate methods of analysis.

f) Verify that the modelled serviceability response does not exceed the appropriate limiting values for each of the serviceability constraints identified.

Bibliography

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[2] ISO 2633, *Determination of imposed floor loads in production buildings and warehouses*

[3] ISO 3010, *Basis for design of structures — Seismic actions on structures*

[4] ISO 4354, *Wind actions on structures*

[5] ISO 4355, *Bases for design of structures — Determination of snow loads on roofs*

[6] ISO 9194, *Bases for design of structures — Actions due to the self-weight of structures, non-structural elements and stored materials — Density*

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[8] ISO 13823, *General principles on the design of structures for durability*

[9] ISO 15686 (all parts), *Buildings and constructed assets — Service life planning*

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