

# INTERNATIONAL STANDARD

# ISO 2394

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## General principles on reliability for structures

*Principes généraux de la fiabilité des constructions*



Reference number  
ISO 2394:2015(E)

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## ISO 2394:2015(E)



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## ISO 2394:2015(E)

### 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](http://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](http://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 98, *Bases for design of structures*, SC 2, *Reliability of structures*.

This fourth edition cancels and replaces the third edition (ISO 2394:1998), which has been technically revised.

## Introduction

The present fourth edition of this International Standard is intended to reflect advances in the common basis for decision making related to load-bearing structures relevant to the construction industry. Advances range from the development of systematic and rational treatment of risk to implementation of reliability-based design through codes and standards.

Compliance with this International Standard should therefore promote harmonization of design practice internationally and unification between the respective codes and standards such as for actions and resistances for the respective structural materials.

The principles and appropriate instruments to ensure adequate levels of reliability provide for special classes of structures or projects where the common experience base need to be extended in a rational manner.

In particular, a risk framework has been introduced which is scenario based, facilitates unified modelling approaches over different applications, accounts for consequences of both a direct and indirect nature, and has emphasis on robustness.

Whereas requirements to safety and reliability in the previous edition of this International Standard took their basis in efficiency requirements of a heuristic character, these are now based on risk considerations and socio-economics. This, in turn, facilitates a more relevant use of the International Standard in the context of sustainable societal developments and adaptation for application of the International Standard in different nation states in accordance with economic capacity and preferences.

The present International Standard, thus, enables the possibility to regulate, verify, and document the adequate safe performance of structures and also to consider them in a broader sense as part of societal systems. The International Standard provides for approaches at three levels, namely the following:

- risk informed;
- reliability based;
- semi-probabilistic.

The methodical basis for this edition of ISO 2394 is described in the Probabilistic Model Code<sup>[8]</sup> and Risk Assessment in Engineering — Principles, System Representation and Risk Criteria<sup>[9]</sup> by the Joint Committee on Structural Safety (JCSS), and EN 1990 (2007), where the reader will find additional information of relevance for its use.

Informative Annexes are included to this International Standard as a support to its users in the interpretations and use of the principles contained in its clauses.





# General principles on reliability for structures

## 1 Scope

This International Standard constitutes a risk- and reliability-informed foundation for decision making concerning design and assessment of structures both for the purpose of code making and in the context of specific projects.

The principles presented in this International Standard cover the majority of buildings, infrastructure, and civil engineering works, whatever the nature of their application and use or combination of the materials used<sup>1)</sup>. The application of this International Standard will require specific adaptation and detailing in special cases where there are potentially extreme consequences of failure<sup>2)</sup>.

This International Standard is intended to serve as a basis for those committees responsible for the task of preparing international standards, national standards, or codes of practice in accordance with given objectives and context in a particular country.

The present International Standard describes how the principles of risk and reliability can be utilized to support decisions related to the design and assessment of structures and systems involving structures over their service life. Three different but related levels of approach are facilitated, namely, a risk-informed, a reliability-based, and a semi-probabilistic approach.

The general principles are applicable to the design of complete structures (buildings, bridges, industrial structures, etc.), the structural elements and joints making up the structures and the foundations. The principles of this International Standard are also applicable to the successive stages in construction, the handling of structural elements, their erection, and all work on-site, as well as the use of structures during their design working life, including maintenance and rehabilitation, and decommissioning.

Risk and reliability are concepts accounting for and describing actions, structural response, durability, life-cycle performance, consequences, design rules, workmanship, quality control procedures, and national requirements, all of which are mutually dependent.

The application of this International Standard necessitates knowledge beyond what is contained in the Clauses and the Annexes. It is the responsibility of the user to ensure that this knowledge is available and applied.

## 2 Terms and definitions

### 2.1 General terms

#### 2.1.1

##### **structure**

organized combination of connected parts including geotechnical structures designed to provide resistance and rigidity against various actions

#### 2.1.2

##### **structural member**

physically distinguishable part of a structure, e.g. column, beam, plate, foundation

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1) The present International Standard is completely general from the perspective of basic principles and can be applied for any structure below, on, and over the surface of the Earth.

2) This concerns, for example, structures of nuclear power plants and offshore oil and gas facilities in highly sensitive environments.

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### 2.1.3

#### **system**

bounded group of interrelated, interdependent, or interacting members forming an entity that achieves a defined objective in its environment through interaction of its parts and interactions of its parts with the environment

### 2.1.4

#### **structural system**

load-bearing members of a building or civil engineering structure and the way in which these members function together and interact with the environment

### 2.1.5

#### **requirement**

demand with respect to structural aspects like safety for people and environment, functionality, usage, and commitment of resources and cost efficiency

### 2.1.6

#### **compliance**

fulfilment of specified requirements

### 2.1.7

#### **life cycle**

life cycle incorporates initiation, project definition, design, construction, commissioning, operation, maintenance, refurbishment, replacement, deconstruction, and ultimate disposal, recycling, or re-use of the structure (or parts thereof), including its components, systems, and building services

### 2.1.8

#### **reliability**

ability of a structure or structural member to fulfil the specified requirements, during the working 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.

### 2.1.9

#### **structural safety**

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

### 2.1.10

#### **durability**

capability of a structure or any structural member to satisfy with planned maintenance the design performance requirements over a specified period of time under the influence of the environmental actions

### 2.1.11

#### **exposure events**

events which may cause damage or otherwise affect the performance indicators for the structure

### 2.1.12

#### **assessment**

total set of activities performed in order to verify the reliability of an existing structure

### 2.1.13

#### **upgrading**

modifications of an existing structure, construction works, and procedures to improve its structural performance or facilitate its use for new purposes

### 2.1.14

#### **repair (of a structure)**

restoring the condition of a structure that has been damaged or deteriorated

**2.1.15**

**rehabilitation**

repairing or upgrading of an existing structure

**2.1.16**

**monitoring**

frequent or continuous, normally long-term, observation or measurement of structural conditions or actions or structural response

**2.1.17**

**inspection**

on-site examination within the scope of quality control and condition assessment aiming to assess the present condition of a structure

**2.1.18**

**constituent events**

events associated with damage or failure of structural members or parts of these, such as individual cross sections and joints

**2.1.19**

**reliability-based design**

design procedure that is subjected to prescribed reliability level of the structure

**2.1.20**

**member reliability**

reliability of a single structural member which has one single dominating failure mode

**2.1.21**

**system reliability**

reliability of a system of more than one relevant structural member or a structural member which has more than one relevant failure mode

**2.1.22**

**population**

set of entities for which the same probabilistic descriptions (mean values, etc.) are valid

**2.1.23**

**outcome space**

set of all possible outcomes of a random phenomenon

**2.1.24**

**constituent**

component or ingredient contributing to a certain performance

**2.1.25**

**performance indicator**

parameter describing a certain property of the structure or a certain characteristic of the structural behaviour

**2.1.26**

**structural performance**

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

**2.1.27**

**resistance**

ability of a structure (or a part of it) to withstand actions without failure

**2.1.28**

**quality control**

activities to control quality of design, execution, use, and decommissioning of a structure

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### 2.1.29

#### **damage**

unfavourable change in the condition of a structure that can affect the structural performance unfavourably

### 2.1.30

#### **collapse**

development of failure mechanisms in a structure to a degree involving disintegration and falling (parts of) structural members

### 2.1.31

#### **deterioration**

process that adversely affects the structural performance including reliability over time

Note 1 to entry: Deterioration may be caused by naturally occurring chemical, physical, or biological actions, normal or severe environmental actions, repeated actions such as those causing fatigue, wear due to use, and improper operation and maintenance of the structure.

### 2.1.32

#### **serviceability**

ability of a structure or structural member to perform adequately for a normal use under all expected actions

### 2.1.33

#### **scenario description**

determination of different sequences of events which affect the performance indicators, taking into account the likelihood of occurrence

### 2.1.34

#### **consequence class**

categorization of the consequences of structural failure

### 2.1.35

#### **reliability class**

class of structures or structural members for which a particular specified degree of reliability is required

### 2.1.36

#### **reliability differentiation**

socio-economic optimization of the resources to be used to build construction works, taking into account all the expected consequences of failures and the cost of the construction

### 2.1.37

#### **hazard scenario**

set of situations, transient in time, that a system might happen to undergo and which may endanger the system itself, the people, and the environment

### 2.1.38

#### **risk-informed design**

design optimized with due consideration of the total risks, including loss of lives and injuries, damages to the qualities of the environment, and monetary losses

Note 1 to entry: Risk-based design is presently not generally accepted by all national standards and codes.

### 2.1.39

#### **safety plan**

plan specifying the performance objectives, the hazard scenarios to be considered for the structure, and all present and future measures (design, construction, or operation, e.g. monitoring) to ensure the safety of the structure

#### **2.1.40**

##### **risk**

effect of uncertainty on the objectives

Note 1 to entry: From the view point of the decision theory, risk is the expected value of all undesirable consequences, i.e. the sum of all the products of the possible consequences of an event and the corresponding probabilities.

#### **2.1.41**

##### **marginal lifesaving cost**

increment of cost associated with saving one additional life through additional safety measures

#### **2.1.42**

##### **risk screening**

investigation into and classification of risks identified for all the hazard situations

#### **2.1.43**

##### **Life Quality Index**

##### **LQI**

indicator of the societal preference and capacity for investments into life safety expressed as a function of GDP, life expectancy at birth, and ratio between leisure to working time

#### **2.1.44**

##### **utilisation plan**

plan containing the intended use (or uses) of the structure and listing the operational conditions of the structure including maintenance requirements and the corresponding performance requirements

#### **2.1.45**

##### **reliability target**

specified average acceptable failure probability that is to be reached as close as possible

Note 1 to entry: Reliability targets are generally model dependent and need to be set for each case considered based on the models used.

#### **2.1.46**

##### **robustness**

##### **damage insensitivity**

ability of a structure 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

#### **2.1.47**

##### **hazard**

unusual and severe threat, e.g. a possible abnormal action or environmental influence, insufficient strength or stiffness, or excessive detrimental deviation from intended dimensions

## **2.2 Terms related to design and assessment**

### **2.2.1**

#### **design/assessment situations**

set of physical conditions representing a certain time interval for which it shall be demonstrated that relevant limit states are not exceeded

### **2.2.2**

#### **persistent design situation**

normal condition of use for the structure

### **2.2.3**

#### **transient design situations**

provisional condition of use or exposure for the structure, for example, during its construction or repair, representing a time period much shorter than the design working life

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### 2.2.4

#### **accidental design situations**

design situation involving possible exceptional conditions for the structure in use or exposure, including flooding, fire, explosion, impact, mal-operation of systems, or local failure

### 2.2.5

#### **seismic design situation**

design situation involving the exceptional conditions when the structure is subjected to a seismic event

### 2.2.6

#### **failure**

insufficient load-bearing capacity or inadequate serviceability of a structure or structural member, or rupture or excessive deformation of the ground, in which the strengths of soil or rock are significant in providing resistance

### 2.2.7

#### **limit states**

state beyond which a structure no longer satisfies the design criteria

### 2.2.8

#### **ultimate limit states**

limit states concerning the maximum load-bearing capacity

### 2.2.9

#### **design criteria**

quantitative formulations describing the conditions to be fulfilled for each limit state

### 2.2.10

#### **serviceability limit states**

limit state concerning the criteria governing the functionalities related to normal use

### 2.2.11

#### **irreversible limit states**

limit states which will remain permanently exceeded when the actions which caused the exceedance are no longer present

### 2.2.12

#### **reversible limit states**

limit states which will not be exceeded when the actions which caused the exceedance are no longer present

### 2.2.13

#### **condition limit state**

well-defined and controllable limit state without direct negative consequences, which is often an approximation to a real limit state that cannot be well defined or is difficult to calculate

Note 1 to entry: In applications relating to durability aspects, the condition limit state is often referred to as the durability limit state.

### 2.2.14

#### **limit state function**

function  $g(X_1, X_2, \dots, X_n)$  of the basic variables, which characterizes a limit state when  $g(X_1, X_2, \dots, X_n) = 0$

### 2.2.15

#### **basic variables**

variables representing physical quantities which characterize actions and environmental influences, material and soil properties, and geometrical quantities

### 2.2.16

#### **design service life**

assumed period for which a structure or a structural member is to be used for its intended purpose with anticipated maintenance, but without substantial repair being necessary

**2.2.17**

**model uncertainty**

basic variable related to the accuracy of physical or statistical models

**2.2.18**

**aleatory uncertainty**

inherent variability typically associated with the loading environment, the geometry of the structure, and the material properties

**2.2.19**

**epistemic uncertainty**

lack of knowledge that, in principle, can be reduced by measurements or improved theories

Note 1 to entry: The exact borderline between aleatory and epistemic is not always unambiguous.

**2.2.20**

**hierarchical modelling of uncertainty**

random variable is a function of other random variables

**2.2.21**

**probabilistic methods**

verification methods in which the relevant basic variables are treated as random variables, random processes, and random fields, discrete or continuous

**2.2.22**

**reliability index**

$\beta$

substitute for the failure probability  $\beta = -\Phi^{-1}(p_f)$  where  $\Phi^{-1}$  is the inverse standardized normal distribution

**2.2.23**

**target reliability (index)**

reliability (index) corresponding to acceptable safety or serviceability

**2.2.24**

**semi-probabilistic or partial factors methods**

verification method in which allowance is made for the uncertainties and variability assigned to the basic variables by means of representative values, partial factors and, if relevant, additive quantities

Note 1 to entry: Partial factors may be related to individual random variables or global variables.

**2.2.25**

**structural model**

idealisation of the structure, physical, mathematical, or numerical, used for the purposes of analysis, design, and verification

**2.2.26**

**static system**

idealisation of the structure, used for the purposes of static analysis, design, and verification

**2.2.27**

**levels of verification**

levels of the verification used to assess the compliance with the objectives for all design/assessment situations

Note 1 to entry: The following levels are commonly recognised: the risk level, the probabilistic reliability level, and the semi-probabilistic level.

**2.2.28**

**First/Second Order Reliability Methods**

**FORM/SORM**

numerical methods used for determination of the reliability index  $\beta$

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### 2.2.29

#### **reliability elements**

numerical quantities used in the partial factors format, by which the specified target reliability is assumed to be reached

Note 1 to entry: The reliability elements include partial factors and load combination factors.

### 2.2.30

#### **characteristic value**

value 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.

### 2.2.31

#### **reference period**

period of time used as a basis for assessing the design value of variable and/or accidental actions

### 2.2.32

#### **nominal value**

value fixed on a non-statistical basis, for instance, on acquired experience or on physical constraints

### 2.2.33

#### **alternative load path**

##### **ALP**

alternative for a load to be transferred from a point of application to a point of resistance

### 2.2.34

#### **consequence reducing measures**

measure aiming at reducing the direct and indirect consequences of failure and thus the total risk

### 2.2.35

#### **key element**

structural member upon which the ultimate limit state performance of the structure depends

### 2.2.36

#### **code calibration**

determination of the reliability elements in a given code format in order to reach the reliability target

### 2.2.37

#### **load testing**

test of the structure (or part of it) by loading to evaluate its behaviour or properties or to predict its load bearing capacity

## 2.3 Terms related to actions, action effects, and environmental influences

### 2.3.1

#### **action**

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

### 2.3.2

#### **individual action**

##### **single action**

action which can be assumed to be independent in time and space of any other action acting on the structure



### 2.3.3

#### **permanent action**

action which is likely to act continuously throughout the design working life and for which variations in magnitude with time are small compared with the mean value

### 2.3.4

#### **variable action**

action which is likely to act during a given design working life and for which the variation in magnitude with time is neither negligible nor monotonic

### 2.3.5

#### **accidental action**

action which is unlikely to occur with a significant value during the design working life of the structure

### 2.3.6

#### **fixed action**

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

### 2.3.7

#### **free action**

action that may have an arbitrary spatial distribution over the structure within certain limits

### 2.3.8

#### **dynamic action**

action that may cause significant acceleration of the structure or structural members

### 2.3.9

#### **static action**

action that will not cause significant acceleration of the structure or structural members

### 2.3.10

#### **bounded action**

action that has a limiting value which cannot be exceeded and which is exactly or approximately known

### 2.3.11

#### **design value of an action**

$F_d$

value of an action used in semi-probabilistic verification calibrated to the reliability target

Note 1 to entry: In the partial factor method, the value is obtained by multiplying the representative value by the partial factor  $\gamma_F$ .

### 2.3.12

#### **effect of actions**

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

### 2.3.13

#### **prestress**

force applied intentionally to a structure by imposing deformations

### 2.3.14

#### **geotechnical action**

action transmitted to the structure by the ground, fill, or groundwater

### 2.3.15

#### **seismic action**

action caused by earthquake ground motions

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### 2.3.16

#### **imposed load**

load resulting from occupancy in buildings

### 2.3.17

#### **construction load**

load specifically related to execution activities

### 2.3.18

#### **environmental influences**

physical, chemical, or biological influences which may deteriorate the materials constituting a structure, which in turn may affect its serviceability and safety in an unfavourable way

### 2.3.19

#### **load arrangement**

identification of the position, magnitude, and direction of a free action

### 2.3.20

#### **representative value of an action**

one of the following quantities of an action: the characteristic value, nominal value, combination value, frequent value, and quasi-permanent value

### 2.3.21

#### **combination value**

values 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

Note 1 to entry: The 'combination value' may be expressed as the characteristic value reduced by a factor  $\Psi_0$ .

### 2.3.22

#### **action model**

model describing the magnitude, position, direction, duration, etc. of the action

Note 1 to entry: Sometimes, there is an interaction between the components. There may, in certain cases, also be an interaction between the action and the response of the structure.

### 2.3.23

#### **frequent value**

value 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  $\Psi_1$ .

### 2.3.24

#### **quasi-permanent value**

value 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  $\Psi_2$ .

### 2.3.25

#### **load case**

compatible load arrangement, set of deformations, and imperfections considered for a particular verification of a specific limit state

### 2.3.26

#### **load combination**

design values of the different actions considered simultaneously in the verification of the reliability of a structure for a specific limit state

### 2.3.27

#### **fundamental combination of actions**

combination of permanent actions and variable actions (the leading action plus the accompanying actions) in persistent and transient design situations used for verification of ultimate limit states in general

### 2.3.28

#### **accidental combination of actions**

combination for accidental design situations, involving either an explicit accidental action (e.g. fire or impact) or the situation following an accidental event

### 2.3.29

#### **characteristic combination of actions**

combination of permanent and variable actions used for verification of irreversible serviceability limit states

### 2.3.30

#### **frequent combination of actions**

combination of permanent and variable actions used for verification of reversible serviceability limit states

### 2.3.31

#### **quasi-permanent combination of actions**

combination of permanent and variable actions used for verification of long-term effects of serviceability limit states

## **2.4 Terms related to structural response, resistance, material properties, and geometrical quantities**

### 2.4.1

#### **material model**

model describing relations between internal forces or stresses and deformations including strain rates

Note 1 to entry: The parameters of such relations are modulus of elasticity, yield limit, ultimate strength, etc. which generally are considered as random variables. In some cases, they are time or space dependent. Often, there is a correlation between the parameters.

### 2.4.2

#### **stiffness**

property relating deformation to the action causing it

### 2.4.3

#### **characteristic value of a material property**

priori specified fractile of the statistical distribution of the material property in the relevant supply

### 2.4.4

#### **design value of a material property**

value of material property used in semi-probabilistic methods obtained by dividing the characteristic value by a partial factor  $\gamma_M$  or, in special circumstances, by direct assessment

### 2.4.5

#### **conversion factor or function**

factors or functions which convert properties obtained from test specimens to those in calculation models

### 2.4.6

#### **characteristic value of a geometrical quantity**

quantity usually corresponding to dimensions (nominal values) specified by the designer