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General principles on reliability for structures

Principes généraux de la fiabilité des constructions

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Foreword

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

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For an explanation 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[8] and Risk Assessment in Engineering — Principles, System Representation and Risk Criteria[9] 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[1]. The application of this International Standard will require specific adaptation and detailing in special cases where there are potentially extreme consequences of failure[2].

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.

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

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

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

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
β
substitute for the failure probability $\beta = -\Phi^{-1}(p_f)$ where Φ^{-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 β