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Bases for design of structures — General principles on risk assessment of systems involving structures

Bases du calcul des constructions — Principes généraux sur l'évaluation du risque pour les systèmes comprenant des structures

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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 13824 was prepared by Technical Committee ISO/TC 98, *Bases for design of structures*, Subcommittee SC 2, *Reliability of structures*.

Introduction

Recently, special attention has been has been focused on risk. Although risk assessment of structures is done with a common basis, it has been implemented under various contexts in diversified ways. Therefore, this International Standard provides a common basis for assessing risk relevant to design, assessment, maintenance and decommissioning of structures. This International Standard accords with the umbrella International Standard of risk management being prepared as ISO 31000 by ISO/TMB.

In a risk assessment, hazard identification and the estimation of consequence are primary major procedures. For these, it is necessary to assess the risk of systems involving structures rather than just the structures, since structural failure has significant consequence for systems, and a failure of systems such as fire protection systems can cause serious consequences. However, actions for risk treatment are taken within the scope of structural design. Such considerations are reflected in the title of this International Standard.

This International Standard is intented to serve as a basic document, along with other relevant standards on risk management, for those assessing risk for systems involving structures.

Annexes A to H of this International Standard are for information only.

Bases for design of structures — General principles on risk assessment of systems involving structures

1 Scope

This International Standard specifies general principles of risk assessment for systems involving structures. The focus is on strategic and operational decision-making related to design, assessment, maintenance and decommissioning of structures. This also includes formulation and calibration of related codes and standards. Systems involving structures can expose stakeholders at various levels in society to significant risks. The aim of this International Standard is to facilitate and enhance decision-making with regard to monitoring, reducing and managing risks in an efficient, cost-effective and transparent manner. Within the broader context of risk management, risk assessment provides decision-makers with procedures to determine whether or not and in what manner it is appropriate to treat risks.

This International Standard provides a general framework as well as a procedure for identifying hazards and estimating, evaluating and treating risks of structures and systems involving structures. This International Standard also provides a basis for code writers as well as designers to set reasonable target-reliability levels, such as stated in ISO 2394, based on the result of risk considerations. For existing structures, assessment of the risks associated with the events that were not considered in the original design or with changes in use shall be implemented according to the principles stated in this International Standard. This International Standard can also be used for risk assessment of exceptional structures, the design of which is usually beyond the scope of existing codes.

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, *General principles on reliability for structures*

ISO/TS 16732, *Fire safety engineering — Guidance on fire risk assessment*

ISO/IEC Guide 51:1999, *Safety aspects — Guidelines for their inclusion in standards*

ISO Guide 73, *Risk management — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2394, ISO/TS 16732, ISO/IEC Guide 51 and ISO/IEC Guide 73, together with the following, apply.

3.1
acceptable risk
level of risk that an individual or society accepts to secure certain benefits

3.2
cost/benefit analysis
analysis contributing to decision-making on whether to adopt a project or a plan by quantifying and comparing its costs and benefits

3.3
extraordinary event
event that cannot be anticipated or expected technologically by experts, or an event whose occurrence probability is estimated as extremely low

3.4
hazard
potential source of undesirable consequences

3.4.1
hazard identification
process to find, list and characterize hazards

3.4.2
hazard curve
exceedence probability of a specified hazard magnitude for a specified period of time

3.4.3
hazard screening
process of identifying significant hazards that shall be considered during risk assessment of systems involving the structures

3.5
option
possible measures for managing the risk

NOTE Doing nothing can be a feasible option when other options cannot mitigate the risk against their invested costs.

3.6
reliability
ability of a structure or structural element to fulfil the specified requirements, including working life for which it has been designed

3.7
residual risk
risk remaining after risk treatment

3.8
risk
combination of the probability or frequency of occurrence of an event and the magnitude of its consequence

NOTE From the view point of a strict decision theory, it is the expected value of all undesirable consequences, i.e. the sum of all the products of the consequences of an event and their probabilities.

3.9
risk acceptance
decision to accept a risk

3.10
risk assessment
overall process of establishment of structural engineering context, definition of system, identification of hazards and consequences, risk estimation, risk evaluation and evaluation of treatment options

3.11
risk calculation
act of representing a combination of probabilities and consequences of occurrence of risks as a scalar, in order to compare with risk options

NOTE See 8.6.

3.12
risk communication
exchange or sharing of information about risk among the decision-makers, other stakeholders and engineers

NOTE 1 The information can relate to the existence, nature, form, probability, severity, acceptability, treatment or other aspects of risk.

NOTE 2 Engineers are the main source for risk information and encourage stakeholders to communicate with each other.

3.13
risk control
actions implementing risk-management decisions

NOTE Risk control can involve monitoring, re-evaluation and compliance with decisions.

3.14
risk criteria
criteria against which the results of the risk analysis are assessed

NOTE 1 The criteria are generally based on regulations, standards, experience, and/or theoretical knowledge used as a basis of the decision on acceptable risk.

NOTE 2 Risk criteria can depend on associated costs and benefits, legal and statutory requirements, socio-economic and environmental aspects, the concerns of stakeholders, priorities and other inputs to the assessment.

3.15
risk estimation
process of assigning values to the probability of occurrence of events and their consequences

NOTE Risk estimation can consider cost, benefits, the concerns of stakeholders and other variables, as appropriate for risk evaluation.

3.16
risk evaluation
process of comparing the estimated risk with given risk criteria to determine the significance of the risk

NOTE Risk evaluation can be used to assist in the decision to accept or to treat a risk.

3.17
risk treatment
process of selection and implementation of measures to optimise risk

3.18
scenario
qualitative description of a series of events in time and space and their inter-relationship given the occurrence of a hazard

3.19
structural engineering context
background or reasons why the risk assessment shall be implemented from structural perspectives

3.20
stakeholder
any individual, group, organization or authority that can affect, be affected by, or perceive itself to be affected by, a risk

NOTE The decision-maker is a stakeholder.

3.21
structure
arrangement of materials that is expected to withstand certain actions and to perform some intended function

3.22
system
delimited group of interrelated, interdependent or interacting objects that is assessed for a potential risk

NOTE 1 This definition implies that the system is identifiable and is made up of interacting elements or subsystems, that all elements are identifiable, and that the boundary of the system can be identified.

NOTE 2 A system involving structures includes the structural system defined in ISO 2394 as a subsystem.

NOTE 3 In terms of technological hazards, a system is normally formed from a physical subsystem, a human subsystem, their management and environment.

3.23
undesirable consequence
direct and indirect harm, stated in terms of personal injury, death, environmental damage, and monetary loss

NOTE 1 There can be more than one negative consequence from an event.

NOTE 2 Consequences can be expressed qualitatively or quantitatively.

NOTE 3 Both immediate and long-term consequences should be included.

NOTE 4 “Environmental damage” is based on a versatile point of view and sometimes various kinds of damage can be included, such as social and political damage.

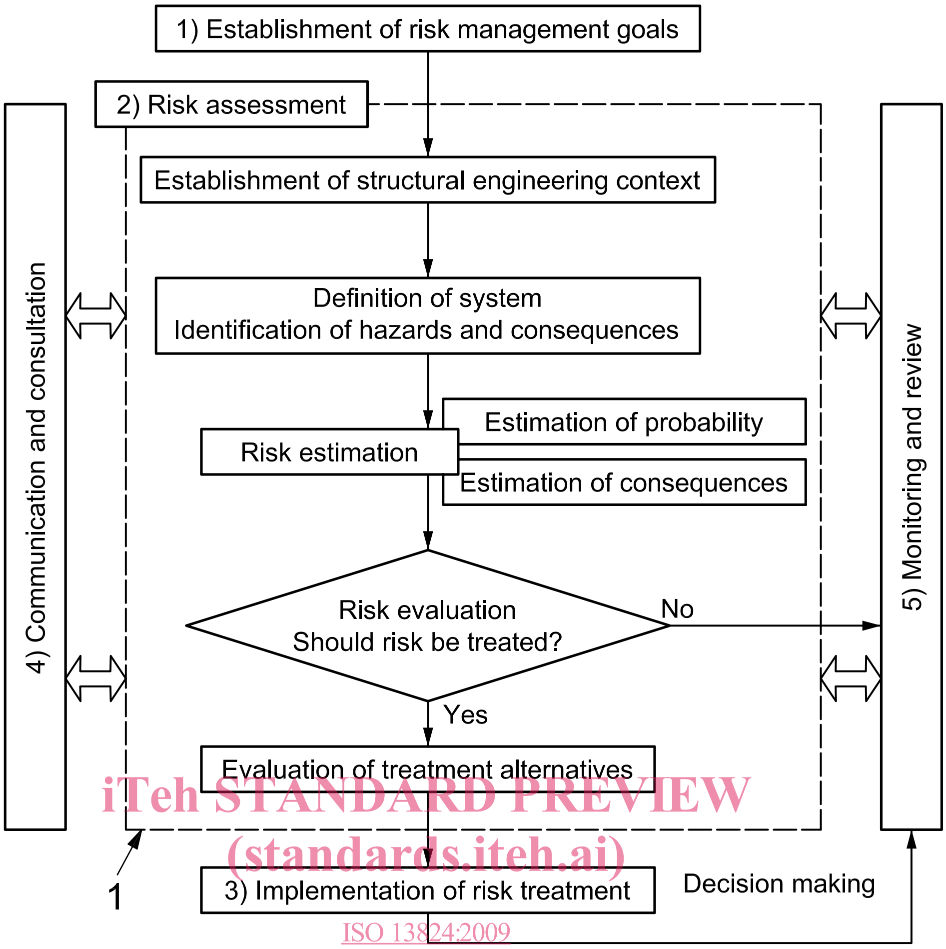
3.24
undesirable event
event that can have undesirable consequences

4 General framework of risk assessment of systems involving structures

4.1 Overview of risk management of systems involving structures

4.1.1 General

The objective of risk management is generally to allocate limited resources “optimally” for the stakeholders such as society, local community, individuals, and various organizations. Risk management typically consists of the establishment of risk-management goals, risk assessment, risk treatment, communication and consultation, and monitoring and review, as illustrated in Figure 1 and described in 4.1.2. Risk management is not a one-way process but shall be an iterative process.



Key

1 scope of risk assessment

Figure 1 — Risk-management process and the scope of risk assessment of systems involving structures

4.1.2 Steps in the risk-management process

4.1.2.1 Establishment of risk-management goals

Procedures for establishing risk-management goals are outside the scope of this document. For the risk management of either a new structure or an existing structure, the risk associated with the proposed design specification(s) or current condition(s) is estimated objectively by an engineering approach within the process of risk assessment. It is expected that risk-management goals related to a risk assessment be expressed in terms of the protection of assets, maintaining health and safety level, environmental protection, regulatory requirements, functional changes/requirements, etc. These goals are typically determined by comparison of 1) cost/benefit of optional solutions or 2) various risks, for example, those known as acceptable to society.

4.1.2.2 Risk assessment

Risk assessment consists of the establishment of the structural engineering context, the definition of structural system, identification of hazards and consequences, risk estimation, risk evaluation and evaluation of options for risk treatment where it is decided that the risk shall be treated. Although the establishment of a structural-engineering context and the evaluation of options for risk treatment are generally considered as outside the scope of risk assessment, they are included within the scope of this International Standard in order to make the outcome of the risk assessment meaningful.

4.1.2.3 Implementation of risk treatment

In the process of risk treatment, decisions are made about the implementation of risk-reducing measures based on cost-effectiveness considerations or other social value judgements. Based on their sense of values, their social and cultural perspective, etc., the stakeholders can decide to accept a risk that the evaluation has found to be too high.

4.1.2.4 Communication and consultation

There shall be thorough communication and appropriate consultation with the stakeholders for each element of the risk-management process and for the process as a whole. After the risk assessment is complete, its results shall be conveyed in a suitable manner so that the stakeholders can understand them and make appropriate decisions.

4.1.2.5 Monitoring and review

The level of risk shall be monitored in order to keep it under a target level, regardless of whether or not the risk is treated. Also, the effectiveness of all elements of the risk-management process shall be reviewed in order to ensure continuous improvement of the process. For each element of the risk-management process, records shall be kept for future reference to guarantee that decisions are understood and to assist in the continuous improvement of the process.

4.2 Applicability of risk assessment

Risk assessment is useful in circumstances when an event is very rare yet its consequences are very severe, or where frequent events result in medium to large consequences. A huge earthquake occurring in an urban area is a typical example of the former circumstance, whereas a road accident is an example of the latter.

Risk assessment is also useful in circumstances where the size of a structure is very large or the number of people or amount of goods inside a structure is very large. High-rise buildings are a typical example of this circumstance.

Risk assessment is essential when the uncertainty of input parameters has a significant impact on the structural behaviour and the consequences resulting from such behaviour.

Risk assessment is also essential when damage and total loss of the function of a structure has significant influence on a community. Hospitals, fire rescue and police stations, power-generating and distribution networks and structures containing highly toxic materials are typical examples of such structures.

5 Establishment of structural engineering context

5.1 Structural-engineering context

The structural-engineering context defines the role of risk assessment in the framework of risk management for structures. The typical structural engineering contexts are the following:

a) establishment of design basis;

b) assessment of existing structures;

c) assessment of exceptional structures and/or extraordinary events; see Annex B;

d) preparation of risk information for decision.

Stakeholders shall be identified based on the established structural-engineering context.

5.2 Establishment of design basis

5.2.1 A design code prescribes a series of criteria for the design of structural members. The criteria are often based on target reliability levels that can be predetermined based on risks associated with exceedance of relevant limit states. Results of risk assessment can provide a rational basis for determining the target reliability levels.

5.2.2 Risk assessment can be carried out to check the target reliability level of existing structural design codes.

5.3 Assessment of existing structures

5.3.1 The risk associated with existing structures, including heritage structures, should be assessed when the structure is damaged, its use is changed or it is in other relevant situations. If the risk is too large, results from the risk assessment shall be reported to the stakeholders.

NOTE ISO 13822 can be used for risk estimation.

5.3.2 It is necessary to assess the risk due to extraordinary events beyond the design-based events and to verify that the results should be within the acceptable level. It is recommended, where practicable, that the acceptable level should be equivalent to that for newly designed structures; however, the level for existing structures can be determined with cost/benefit consideration.

In many cases for old buildings, it is challenging or practically impossible to assess the reliability and compare it to that of a new-built structure because it is not possible to apply modern design rules to old buildings and structures. Materials and construction techniques are used for which design rules no longer exist. Also, detailing can be in conflict with present detailing rules without representing necessarily an increased and unacceptable risk. In situations where an existing structure is difficult to assess accurately, emphasis should be put on the option of mitigating the risk.

5.4 Assessment of exceptional structures or extraordinary events

Exceptional structures are those whose design is beyond the scope of existing codes. Risk assessment of such structures shall be carried out if their failures can have serious consequences. Risk assessment shall also be implemented for some extraordinary events (see Annex B), such as fires and some critical event scenarios.

5.5 Preparation of risk information for decision

When several optional strategies or concepts are available, the optimum strategy shall be determined based on the result of risk assessment. Risk-based optimization can have two principal objectives:

a) to minimize risk given limited economic resources;

b) to determine the optimal level of investment in risk reduction.

In both situations, the optional use of economic resources should be considered to examine whether they contribute to optimal risk reduction.

Options should be compared according to net utility, cost/benefit or cost-effectiveness; see Annex H. If the aim of decision-making is to minimize risk within economic restraints, any of these criteria may be used provided that all technical solutions are consistent with best practice.

6 Definition of system

6.1 Representation of the system

Fundamentally, the system representation shall facilitate decision-making and, thus, shall be adapted to the structural engineering context described in Clause 5. The definition of the system involving structures shall include a clear identification of the functions provided by the structures and how these functions are supported by the structural components. The extent of the system that is considered in risk assessment shall be clearly identified based on the structural engineering context.

6.2 Identification of the subsystems

The characteristics of each subsystem, such as type of structure(s), codes and standards used in the design of the structure(s), use, importance, location and working life, shall be identified. The limit states of the system shall also be specified.

7 Identification of hazards and consequences

7.1 Identification of possible hazards

During their service lives, structures can be exposed to various natural hazards and man-made hazards. The hazards that can cause undesirable events shall be identified. For hazards that can cause a series of events in time and space (e.g., fire), scenario analysis shall be performed. For the detailed procedure on scenario analysis for fire, see ISO/TS 16732 and ISO/TS 16733.

7.2 Identification of extent of scenarios

Having identified a possible hazard, scenarios shall be identified as the sequences or combinations of events or processes necessary for system failure and resulting undesirable consequences for the system involving structures. The essential techniques used for schematic representation of scenarios are fault trees and event trees. A scenario should include collapse or damage of the structure(s), loss of functionality, human death or injury and other economic and/or social losses caused by or to the stakeholders.

7.3 Identification of consequences

Consequences resulting from the hazards and following events shall be identified. They should be described in terms of several measures, e.g., monetary loss, human fatalities and environmental damage. Some consequences can be identified by scenario analyses considering the extent of influences due to failure of the structural systems in time and space.

7.4 Hazard screening

7.4.1 General

Although all possible hazards should be taken into consideration, hazards important to a system shall be selected on the basis of their significance and incorporated in the risk assessment. As each hazard has its inherent characteristics and possible consequences, it is recommended to categorize hazards by the original cause, the degree of quantification, and the significance of consequences. The screening of hazards in accordance with their importance for risk assessment can then be performed based on experience and expertise of the engineer. The results of the hazard screening shall be documented.

7.4.2 Hazard screening criteria

Preliminary risk estimation (see 8.1) shall be carried out to identify the significant risks. The criteria for the hazard screening are, in principle, based on the magnitude of the risk from the preliminary risk estimation. Frequency of the hazard and/or significance of the relevant consequences can also be useful criteria. Hazards with obviously negligible risk compared with the acceptable risk level may be screened out.

The hazard screening criteria shall be clearly described in terms of frequency of the event and magnitude of its consequence. They may be based on the past experience, human perception and relevant values specified elsewhere.

8 Risk estimation

8.1 Types of risk estimation

8.1.1 General

Risk estimation shall be undertaken according to the purpose of the estimation, required degrees of details, information, data and resources available. The types of estimation fall into three broad categories, i.e., qualitative, semi-quantitative and quantitative, depending on the circumstances. In practice, qualitative estimation is often used, as a preliminary risk estimation, to obtain a general indication of the level of risk and to reveal the risks that shall be considered. Later, it can be necessary to undertake more specific or quantitative estimation on the revealed risk.

8.1.2 Qualitative estimation

In qualitative estimation, risk is subjectively estimated and ranked in a descriptive manner. Qualitative estimation should be used

a) as an initial screening activity to identify risks that require more detailed estimation;

b) where the qualitative estimation provides sufficient information for decision-making;

c) where the numerical data or resources are insufficient for a quantitative estimation.

8.1.3 Semi-quantitative estimation

In semi-quantitative estimation, a ranking scale more expanded than the one usually achieved in qualitative estimation shall be adopted. It should be noted that the numbers chosen cannot properly reflect relativities and this can lead to inconsistent, anomalous or inappropriate outcomes.

8.1.4 Quantitative estimation

In quantitative estimation, numerical values rather than descriptive scales shall be used in qualitative and semi-quantitative estimation for both consequences and probability using data from a variety of sources. The quality of the estimation depends on the accuracy and completeness of the numerical values and the validity of the models used.