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Bases for design of structures — Assessment of existing structures

Bases du calcul des constructions — Évaluation des constructions existantes

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Foreword

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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 13822 was prepared by Technical Committee ISO/TC 98, *Bases for design of structures*, Subcommittee SC 2, *Reliability of structures*.

This second edition cancels and replaces the first edition (ISO 13822:2001), which has been technically revised, including the addition of a new Annex I, the associated change to the Foreword and with some minor editorial changes.

Introduction

The continued use of existing structures is of great importance because the built environment is a huge economic and political asset, growing larger every year. The assessment of existing structures is now a major engineering task. The structural engineer is increasingly called upon to devise ways for extending the life of structures whilst observing tight cost constraints. The establishment of principles for the assessment of existing structures is required because it is based on an approach that is substantially different from design of new structures and requires knowledge beyond the scope of design codes. This document is intended not only as a statement of principals and procedures for the assessment of existing structures but also as a guide for use by structural engineers and clients. Engineers can apply specific methods for assessment in order to save structures and to reduce a client's expenditure. The ultimate goal is to limit construction intervention to a strict minimum, a goal that is clearly in agreement with the principles of sustainable development.

The basis for the reliability assessment is contained in the performance requirements for safety and serviceability of ISO 2394. Economic, social and sustainability considerations, however, result in a greater differentiation in structural reliability for the assessment of existing structures than for the design of new structures.

Bases for design of structures — Assessment of existing structures

1 Scope

This International Standard provides general requirements and procedures for the assessment of existing structures (buildings, bridges, industrial structures, etc.) based on the principles of structural reliability and consequences of failure. It is based on ISO 2394.

It is applicable to the assessment of any type of existing structure that was originally designed, analysed and specified based on accepted engineering principles and/or design rules, as well as structures constructed on the basis of good workmanship, historic experience and accepted professional practice. The assessment can be initiated under the following circumstances:

— an anticipated change in use or extension of design working life;

— a reliability check (e.g. for earthquakes, increased traffic actions) as required by authorities, insurance companies, owners, etc.;

— structural deterioration due to time-dependent actions (e.g. corrosion, fatigue);

— structural damage by accidental actions (see ISO 2394).

This International Standard is also applicable to heritage structures provided additional considerations shown in Annex I are taken into account.

This International Standard is applicable to existing structures of any material, although specific adaptation can be required depending on the type of material, such as concrete, steel, timber, masonry, etc.

This International Standard provides principles regarding actions and environmental influences. Further detailed considerations are necessary for accidental actions such as fire and earthquake.

NOTE Fire resistance requires properties different from those for structural safety and integrity. Also fire hazards can be created by change in use. Special requirements are necessary for seismic hazards taking the dynamic action and structural response into account.

This International Standard is intended to serve as a basis for preparing national standards or codes of practice in accordance with current engineering practice and the economic conditions.

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*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2394 and the following apply.

NOTE See also Annex A.

3.1
assessment
set of activities performed in order to verify the reliability of an existing structure for future use

3.2
damage
unfavourable change in the condition of a structure that can affect structural performance

3.3
deterioration
process that adversely affects the structural performance, including reliability over time due to

— naturally occurring chemical, physical or biological actions,

— repeated action such as those causing fatigue

— normal or severe environmental influences

— wear due to use, or

— improper operation and maintenance of the structure.

3.4
deterioration model
mathematical model that describes structural performance as a function of time, taking deterioration into account

3.5
inspection
on-site non-destructive examination to establish the present condition of the structure

3.6
investigation
collection and evaluation of information through inspection, document search, load testing and other testing

3.7
load testing
test of the structure or part thereof by loading to evaluate its behaviour or properties, or to predict its load bearing capacity

3.8
maintenance
routine intervention to preserve appropriate structural performance

3.9
material properties
mechanical, physical or chemical properties of structural materials

3.10
monitoring
frequent or continuous, normally long-term, observation or measurement of structural conditions or actions

3.11
reference period
chosen period of time which is used as a basis for assessing values of variable actions, time-dependent material properties, etc.

NOTE The remaining working life or the minimum standard period for safety of an existing structure can be taken as a reference period (see Annex F).

3.12
rehabilitation
work required to repair, and possibly upgrade, an existing structure

3.13
remaining working life
period for which an existing structure is intended/expected to operate with planned maintenance

3.14
repair, verb
<of a structure> improve the condition of a structure by restoring or replacing existing components that have been damaged.

3.15
safety plan
plan specifying the performance objectives, the scenarios to be considered for the structure, and all present and future measures (design, construction, or operation such as monitoring) to ensure the safety of the structure

3.16
structural performance
qualitative or quantitative representation of the behaviour of a structure (e.g. load bearing capacity, stiffness) in terms of its safety and serviceability

3.17
target reliability level
level of reliability required to ensure acceptable safety and serviceability

3.18
upgrading
modifications to an existing structure to improve its structural performance

3.19
utilization 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

4 General framework of assessment

4.1 Objectives

The objective of the assessment of an existing structure in terms of its required future structural performance shall be specified in consultation with the client (the owner, the authority, insurance companies, etc.) based on the following performance levels:

a) safety performance level, which provides appropriate safety for the users of the structure;

b) continued function performance level, which provides continued function for special structures such as hospitals, communication buildings or key bridges in the event of an earthquake, impact, or other foreseen hazard;

c) special performance requirements of the client related to property protection (economic loss) or serviceability. The level of this performance is generally based on life cycle cost and special functional requirements.

4.2 Procedure

The procedure depends on the assessment objectives (see 4.1), and on specific circumstances (e.g. the availability of the design documents, the observation of damage, the use of the structure). A site visit is recommended prior to initiating the procedure.

The assessment is carried out taking into account the actual conditions of the structures (see the flowchart in Annex B) and is composed in general of steps a) to f):

a) specification of the assessment objectives;

b) scenarios;

c) preliminary assessment:

   1) study of documents and other evidence,

   2) preliminary inspection,

   3) preliminary checks,

   4) decisions on immediate actions,

   5) recommendation for detailed assessment;

d) detailed assessment:

   1) detailed documentary search and review,

   2) detailed inspection and material testing,

   3) determination of actions,

   4) determination of properties of the structures,

   5) structural analysis,

   6) verification;

e) results of assessment:

   1) report,

   2) conceptual design of construction interventions,

   3) control of risk;

f) repetition of the sequence if necessary.

The procedure outlined above may be applied to both the assessment of one specific structure and the assessment of a group of structures.

4.3 Specification of the assessment objectives

At the outset, the objective of the assessment of the structure shall be clearly specified in terms of its future performance in an agreement between the client, the authorities when relevant and the assessing engineer (see 4.1). The required future performance shall be specified in the utilization plan and safety plan.

4.4 Scenario

Scenarios related to a change in structural conditions or actions should be specified in the safety plan in order to identify possible critical situations for the structure. Each scenario is characterized by a predominant process or action and, where appropriate, by one or more accompanying processes or actions. The identification of scenarios represents the basis for the assessment and design of interventions to be taken to ensure structural safety and serviceability.

4.5 Preliminary assessment

4.5.1 Study of documents and other evidence

Design and inspection documents contain important information that is necessary for a thorough assessment of an existing structure. It shall be verified that the documents are correct and, in that context, they are updated to include information of any previous intervention to the structure. Other evidence, such as the occurrence of significant environmental or seismic actions, large actions, changes in soil conditions, corrosion, and misuse of the structure, shall be recorded and documented.

4.5.2 Preliminary inspection

The aim of a preliminary inspection is to identify the structural system and possible damage of the structure by visual observation with simple tools. The information collected is related to aspects such as surface characteristics, visible deformations, cracks, spalling, corrosion, etc. The results of the preliminary inspection are expressed in terms of a qualitative grading of structural conditions (e.g. none, minor, moderate, severe, destructive, unknown) for possible damage.

4.5.3 Preliminary checks

The purpose of the preliminary checks is to identify the critical deficiencies related to the future safety and serviceability of the structure with a view to focussing resources on these aspects in subsequent assessment. Based on these results, it is then judged whether or not a further investigation is necessary.

4.5.4 Decisions on immediate actions

When the preliminary inspections and/or checks clearly indicate that the structure is in a potentially dangerous condition, it is necessary to report to the client that interventions should be taken immediately to reduce the danger with respect to public safety. If there is uncertainty, the critical deficiencies should be assessed immediately and actions taken, if necessary.

4.5.5 Recommendations for detailed assessment

The preliminary checks may clearly show the specific deficiencies of the structure, or that the structure is reliable for its intended use over the remaining working life, in which case a detailed assessment is not required. Where there is uncertainty in the actions, action effects or properties of the structure, a detailed assessment should be recommended in accordance with 4.6.

4.6 Detailed assessment

4.6.1 Detailed documentary search and review

The following documents, if available, should be reviewed:

— drawings, specifications, structural calculations, construction records, inspection and maintenance records, details of modifications;

— regulations and by-laws, codes of practice and standards that were used for constructing the structure;

— topography, subsoil conditions, groundwater level at the site.

4.6.2 Detailed inspection and material testing

The details and dimensions of the structure as well as characteristic values of material properties can be obtained from design documents, provided that the documents exist and that there is no reason for doubt. In case of any doubts, details and dimensions of components and properties of materials assumed for the analysis shall be determined from a detailed inspection and material testing. The planning of such an inspection is based on information that is already available. The detailed quantitative inspection results in a set of updated values or distributions for certain relevant parameters that affect the properties of the structure (see Annex C).

4.6.3 Determination of action

Actions and in particular environmental actions on structures shall be determined by analysis in accordance with ISO 2394, taking into account provisions laid down in the safety plan and utilisation plan.

4.6.4 Determination of properties of the structures

Testing of the structure is used to measure its properties and/or to predict a load bearing capacity when other approaches such as detailed structural analysis or inspection alone do not provide clear indication or have failed to demonstrate adequate structural reliability (see Annex D).

4.6.5 Structural analysis

Structural analysis in accordance with ISO 2394 shall be carried out to determine the effects of the actions on the structure. The capacity of structural components to resist action effects shall also be determined. The deterioration of an existing structure shall be taken into consideration. When deterioration of an existing structure is observed, the reliability assessment of the structure becomes a time-dependent deterioration problem as described in ISO 2394, and an appropriate analysis method shall be used. In the case of deteriorated structures, it is essential to understand the causes for the observed damage or malfunction.

Some examples of appropriate analysis methods to assess time-dependent reliability can be found in Annex E.

NOTE For deterioration, it is often more practical to use service-life predictors (such as S-N curves for fatigue or time-to spalling models for corrosion of reinforcement) based on test data.

4.6.6 Verification

The verification of an existing structure should normally be carried out to ensure a target reliability level that represents the required level of structural performance (see 4.1 and Annex F). Current codes or codes equivalent to ISO 2394 that have produced sufficient reliability over a long period of application may be used. Former codes that were valid at the time of construction of an existing structure should be used as informative documents. Alternatively, verification may be based on satisfactory past performance (see Clause 8).

4.7 Results of assessment

4.7.1 Report

The results of assessment shall be documented in a report (see Annex G for example).

4.7.2 Conceptual design of construction interventions

If the structural safety or serviceability is shown to be inadequate, the results of the assessment should be used to recommend construction interventions for repair, rehabilitation or upgrading of the structure to perform in accordance with the objective of the assessment for its remaining working life (see Annex H).

4.7.3 Control of risk

An alternative approach to construction interventions, which may be appropriate in some circumstances, is to control or modify the risk. Various measures to control the risk environment include imposing load restrictions, altering aspects of the use of the structure, and implementing some form of in-service monitoring and control regime.

5 Data for assessment

5.1 General

Data for assessment should be related to the material properties, structural properties, dimensions, and other conditions as actually established for the existing structure, and to previous and/or future actions to the structure.

NOTE Current codes are normally design codes and therefore they may not be appropriate for use directly for assessment of existing structures. However they should be considered for the assessment. As discussed in Clause 7 and Annex F, reduced service life and target reliability level may be considered for an existing structure. Furthermore, refined analyses, testing and a consideration of the actual behaviour of a structure may help in this respect.

5.2 Actions and environmental influences

5.2.1 Actions

Actions shall be determined in accordance with current codes. Changes of actions caused by the change in use or modification of an existing structure shall be taken into consideration.

5.2.2 Environmental influences

Environmental influences of a physical, chemical or biological nature that may have an effect on the material properties of an existing structure shall be taken into account. Changes in environmental influences as a result of change in use or modification of an existing structure shall be taken into consideration.

5.2.3 Original drawings and design specifications

The actions and environmental influences for which the structure was originally designed may be determined from drawings and design specifications when there is no uncertainty about their validity.

5.2.4 Inspection

Environmental influences should be determined by inspection in cases of uncertainty. In such cases, some types of actions may also be determined by inspection.

5.2.5 Site-specific data

It can be advantageous to consider the specific characteristics of a structure or its surrounding or to observe actions when determining actions and environmental influences. It is important to adjust for long-term and extreme effects that cannot be measured directly when collecting information on actions and environmental influences.

5.3 Material properties

5.3.1 Actual material properties

Material properties used in the assessment shall be the estimated actual material properties of the existing structure, not material properties specified in the original design of the structure or in a code or standard. The material properties shall be assessed by considering deterioration and possible influences of actions (e.g. fire) during the history of the structure.

5.3.2 Original drawings and design specifications

Material properties may be determined from drawings and design specifications when there is no uncertainty about their validity.

5.3.3 Material testing

In cases of uncertainty, material properties should be determined by testing, including non-destructive or destructive material testing. The testing should be planned to produce data which is of direct concern to the required safety and serviceability of the structure as shown by structural analysis. The use of the structure and the environmental influences on the structure shall be taken into account.

5.3.4 Sampling and testing procedure

Sampling and testing methods should be in accordance with the relevant International Standards. Sampling locations and methods that can jeopardize structural reliability shall be avoided. Repair and/or reinforcement shall be carried out immediately after sampling.

5.3.5 Analysis of test results

When samples are tested, the material properties of the structure shall be determined, statistically if possible, from the test results.

5.4 Properties of the structure

5.4.1 Testing for static and dynamic properties of structure

If the properties of the structure are not sufficiently understood or if it is not feasible to establish the required dimensions and material properties by measurement, testing of the structure can be required to define structural properties. Dynamic testing shall be carried out if the dynamic properties of an existing structure are required and are not available from other sources (see Annex D).

5.4.2 Geotechnical investigation

Geotechnical and subsoil influences on structural behaviour shall be investigated.

5.5 Dimensions

5.5.1 Actual dimensions

In determining dimensions of components in an existing structure, the actual dimensions should be used.

5.5.2 Determination of dimensions

Dimensions may be determined from drawings and design specifications when there is no uncertainty about their validity. In cases of uncertainty, dimensions should be determined by inspection and measurement.

6 Structural analysis

6.1 Models

Structural performance shall be analysed using models that reliably represent the actions on the structure, the behaviour of the structure, and the resistance of its components. The analytical model should reflect the actual condition of the existing structure.

6.2 Limit states

The structure shall be analysed for the ultimate limit states and serviceability limit states, using the basic variables and taking account of relevant deterioration processes.

6.3 Basic variables

The following basic variables for use in structural analysis shall be determined by updating information about the actual condition of the structure:

a) actions;

b) material properties and geotechnical conditions;

c) dimensions of the structural components and subsoil geometry;

d) model uncertainties.

6.4 Model uncertainties

The uncertainty associated with the validity and accuracy of the models should be considered during assessment, either by adopting appropriate partial factors in deterministic verifications or by introducing additional random variables representing model uncertainties in reliability analyses.

6.5 Conversion factors

Conversion factors reflecting the influence of shape and size effect of specimens, temperature, moisture, duration-of-load effects, etc., shall be taken into account.

6.6 Uncertainty about the condition of components

When an existing structure is analysed, the level of knowledge about the condition of components shall be taken into account. This may be achieved by adjusting the assumed variability in either the load carrying capacity of the components or the dimensions of their cross sections, depending on the type of structure.

6.7 Deterioration models

When deterioration of an existing structure is observed, the deterioration mechanisms shall be identified and a deterioration model predicting the future performance of the structure shall be determined on the basis of theoretical or experimental investigation, inspection, and experience.