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Together with Code SIA 269/1, replaces Guideline SIA 462, 1994 edition

Grundlagen der Erhaltung von Tragwerken
Bases pour la maintenance des structures porteuses
Basi per la conservazione delle strutture portanti

Existing structures – Bases for examination and interventions

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FOREWORD

Code SIA 269 describes the basic principles and the procedure to be followed in the treatment of existing structures and is directed at specialists in engineering activities related to existing structures. In addition, owners of the structures are addressed in the sections on examination and the planning of interventions.

Code SIA 269 forms part of the SIA's structural codes. It is based on the principles set forth in Code SIA 469 *Preservation of constructions* and supplements Code SIA 260 in the area of interventions in existing structures.

Code SIA 269 is the basic code in the field of engineering of existing structures and is supplemented, with respect to actions and the different methods of construction, by the following codes:
- Code SIA 269/1 Existing structures – Actions
- Code SIA 269/2 Existing structures – Concrete structures
- Code SIA 269/3 Existing structures – Steel structures
- Code SIA 269/4 Existing structures – Composite steel and concrete structures
- Code SIA 269/5 Existing structures – Timber structures
- Code SIA 269/6 Existing structures – Masonry structures
- Code SIA 269/7 Existing structures – Geotechnics.

Technical Specification SIA 2018 continues to apply to the examination of existing buildings with respect to earthquakes. However, it is planned to supplement the codes for existing structures with a Code SIA 269/8 *Existing structures – Seismic aspects*.

Codes SIA 269/1 to 269/8 also form part of the SIA's structural codes and supplement the series of Codes SIA 261 to 267.

Together with Code SIA 269/1, Code SIA 269 replaces the guideline SIA 462 (1994) *Assessment of the structural safety of existing structures*.

The application of Code SIA 269 requires a detailed knowledge of Codes SIA 260 and SIA 469. Terms that are already defined in these two codes, in particular the terms relating to existing structures, are not listed again in the section on Terminology.

Code SIA 269 introduces the technical terms "updating", "degree of compliance", "concept of intervention", "design of intervention" and "proportionality of interventions". The technical terms "examination situation" and "examination value" are also used in connection with examination (analogously to the corresponding technical terms for the design of structures). The term "defect" is used in its generally understood sense. Accordingly, "defect" refers to the lack of a technical or physical property, detached from any legal interpretation. A defect does not therefore automatically give rise to any liability regarding defects. The term "defect" does not simply relate to the condition at the time of acceptance of the construction work.

Certain aspects of existing structures are dealt with using a risk-based procedure. The technical terms "efficiency of the interventions" and "safety costs" are defined accordingly in Code SIA 269. Code SIA 269 provides criteria for the application of the methods of reliability theory, for which reason its fundamental terms are also defined under the technical terms. The implementation of these criteria in the definition of the safety level for the purpose of verification of structural safety as well as in judging the proportionality of interventions requires in-depth knowledge.

The project management recognises the importance of a panel of experts in the sense in which it was first introduced in Guideline SIA 462. However, in line with the principle of separation of technical specifications and the assignment of responsibilities to the different responsible parties, the panel of experts is not explicitly addressed in Code SIA 269.

Codes SIA 269 Project Management Team

0 SCOPE

0.1 Limitations

0.1.1 Code SIA 269 establishes the basic principles for the treatment of structures as part of existing construction works, taking into consideration their preservation values.

0.1.2 Code SIA 269 applies to all existing structures in different types of construction in analogy to Code SIA 260.

0.1.3 Code SIA 269 governs the activities and intervention measures in connection with existing structures. It supplements the specifications of Codes SIA 469 and SIA 260 in the case of existing structures.

0.1.4 Code SIA 269 applies in combination with Codes SIA 269/1 to 269/8. The basic principles of Code SIA 269 are to be applied analogously for applications outside of the scope of these codes.

0.1.5 In the case of modifications, in general new structural components shall be treated according to Codes SIA 260 to 267 and existing structural components according to Code SIA 269 together with Codes SIA 269/1 to 269/8. It is permissible to deviate from this rule with respect to the definition of the variable actions if different limitations are appropriate on the basis of specific considerations.

0.1.6 Code SIA 269 may not be used for the design and dimensioning of new structures.

0.2 References

0.2.1 Reference is made to the following Technical Specification. This is also applicable, in full or in part, by way of reference:
– Technical Specification SIA 2017 *Preservation value of construction works*.

0.2.2 Superseded codes and guidelines to which reference is made may not be incorporated in the service criteria agreement or in the basis of design as code-related specifications, but only by way of reference, and only in order to document former design criteria.

0.3 Deviations

0.3.1 Deviations from the present code are permissible provided they are sufficiently well-founded, theoretically or experimentally, or justified by new developments and new knowledge.

0.3.2 Deviations from the code shall be clearly documented in the construction documents together with the reasons for such deviation.

1 TERMINOLOGY

1.1 Technical terms

In addition to the technical terms defined in Codes SIA 260 and SIA 469, the general technical terms defined below are used in the present code. Other specific technical terms are defined in Codes SIA 269/1 to 269/8.

Concept of intervention *Massnahmenkonzept* *concept d'intervention* *concetto dell'intervento*	Concept for the implementation of intervention measures, based on a study of intervention variants over a given period of time and with specific local application.
Degree of compliance *Erfüllungsgrad* *degré de conformité* *grado di conformità*	Numerical statement, expressed in terms of examination values, regarding the extent to which an existing structure fulfils the given structural safety requirements.
Design of intervention *Massnahmenprojekt* *projet d'intervention* *progetto di intervento*	Implementation of the concept of intervention, including the planning of intervention measures.
Deterministic verification *deterministischer Nachweis* *vérification déterministe* *verifica deterministica*	Verification based on the concept of partial factors.
Direct costs *direkte Kosten* *coûts directs* *costi diretti*	Costs within the defined framework.
Efficiency of interventions *Massnahmeneffizienz* *efficacité des interventions* *efficienza degli interventi*	Efficiency of safety-related interventions, expressed as the ratio of risk reduction to safety costs.
Examination situation *Überprüfungssituation* *situation d'examen* *situazione di esame*	Physical circumstances and conditions within the remaining service life for which it is verified, for an existing structure, that the relevant limit states are not exceeded.
Examination value *Überprüfungswert* *valeur d'examen* *valore di esame*	Value determined from a characteristic or another representative value in combination with partial and conversion factors, or possibly also directly defined factors, which is applied in a verification carried out on an existing structure.
Existing structure *bestehendes Tragwerk* *structure porteuse existante* *struttura portante esistente*	Load-bearing part of a completed and accepted structure.
Failure rate *Versagensrate* *taux de défaillance* *tasso di rottura*	Probability in relation to a unit of time (generally 1 year) that a structure or structural component will fail or exceed a serviceability limit.
Intervention *Erhaltungsmassnahme* *intervention de maintenance* *intervento di conservazione*	Operational or structural measure intended to limit hazards and to ensure the existence as well as the material and non-material value of a structure.
Preservation value *Erhaltungswert* *valeur de maintenance* *valore di mantenimento*	Social and cultural values of a structure according to Technical Specification SIA 2017.

Probabilistic verification *probabilistischer Nachweis* *vérification probabiliste* *verifica probabilistica*	Verification explicitly taking into consideration the distribution of probability of the basic variables.
Proportionality of interventions *Verhältnismässigkeit von Erhaltungsmassnahmen* *proportionnalité des interventions de maintenance* *proporzionalità degli interventi di conservazione*	Comparison of costs and benefits of planned interventions with the aim of efficient use of resources.
Reliability index *Zuverlässigkeitsindex* *indice de fiabilité* *indice di affidabilità*	Measure for the failure rate, formulated as its inverse standardised normal distribution.
Remaining service life *Restnutzungsdauer* *durée d'utilisation restante* *durata d'utilizzo rimanente*	Planned period of time during which an existing structure will continue to remain in operation according to the service criteria agreement.
Risk *Risiko* *risque* *rischio*	Product of the probability of occurrence of a damage event in relation to a particular unit of time and the quantified potential consequence in terms of damage to persons, material goods and the environment.
Safety costs *Sicherheitskosten* *coûts de sécurité* *costi per garantire la sicurezza*	Safety-related costs of planned interventions which are written off annually over the remaining service life.
Sensitivity factor *Sensitivitätsfaktor* *facteur de sensibilité* *fattore di sensitività*	Measure for the relative importance of the individual basis variables for the limit state condition.
Strengthening *Verstärkung* *renforcement* *rinforzo*	Measure intended to improve the ultimate resistance and serviceability of a structure or of a structural member.
Updating *Aktualisierung* *actualisation* *attualizzazione*	Process of supplementing existing knowledge with new information.

1.2 Symbols

1.2.1 Latin upper case letters

$A_{d,act}$	examination value of an accidental action
C_{acc}	constant for quantification of risk acceptance
$C_{d,act}$	updated serviceability limit
C_F	direct costs in the event of failure
C_W	costs of rehabilitation of the structure
E	action effect
$E_{d,act}$	examination value of an action effect
$E_{d,dst,act}$	examination value of a destabilising action
$E_{d,stb,act}$	examination value of a stabilising action
$E_{m,act}$	updated expected value of an action effect
EF_M	efficiency of the intervention measure
$G(\ldots)$	limit state function
$G_{k,act}$	updated characteristic value of a permanent action
N_F	estimate of the number of fatalities in the case of a failure event
$P\{\ldots\}$	probability
P_{acc}	probability of fatality for one person
$P_{k,act}$	updated characteristic value of an action due to prestressing
$Q_{k1,act}$	updated characteristic value of the (variable) leading action
R	ultimate resistance
$R_{d,act}$	examination value of the ultimate resistance
$R_{m,act}$	updated expected value of the ultimate resistance
SC_M	safety costs of interventions
$X_{d,act}$	examination value of a construction material or geotechnical property
X_i	basic variable
$X_{k,act}$	updated characteristic value of a construction material or geotechnical property

1.2.2 Latin lower case letters

a_0	constant for the limit state function
ad,act	examination value of a geometrical property
n	degree of compliance
t	time

1.2.3 Greek letters

α_E	sensitivity factor for an action effect
α_R	sensitivity factor for an ultimate resistance
β	reliability index
β_0	target value of the reliability index
$\gamma_{G,act}$	updated load factor for a permanent action

$\gamma_{G,inf,act}$	updated load factor for permanent actions (examination with lower examination values)
$\gamma_{G,sup,act}$	updated load factor for permanent actions (examination with upper examination values)
$\gamma_{M,act}$	updated resistance factor
γ_P	load factor for an action resulting from prestressing
γ_{Q1}	updated load factor for a (variable) leading action
δ_E	parameter of log-normal distribution for an action effect
δ_R	parameter of log-normal distribution for an ultimate resistance
η	conversion factor (with regard to construction material properties)
$v_{E,act}$	updated coefficient of variation for an action effect
$v_{R,act}$	updated coefficient of variation for an ultimate resistance
ρ	coefficient describing the consequences of a structural failure
ψ_0	reduction factor for the occasional value of a variable action
$\psi_{0i}Q_{ki,act}$	occasional value of the updated variable accompanying action *i*
ψ_1	reduction factor for the frequent value of a variable action
ψ_2	reduction factor for the quasi-permanent value of a variable action
$\psi_{2i}Q_{ki,act}$	updated quasi-permanent value of the variable action *i* in combination with an accidental action or the frequent value of the (variable) leading action
ΔR_M	risk reduction as a result of interventions
$\Phi(...)$	standard normal distribution function

2 BASIC PRINCIPLES

2.1 General

2.1.1 Activities related to existing structures shall take into consideration current requirements and needs, in particular with regard to the safety of individuals and society. It shall be economic and environmentally-friendly as well as being culturally and socially acceptable.

2.1.2 In supplementing Code SIA 469 and formulating it more precisely, the following objectives are pursued with regard to the preservation of an existing structure over its remaining service life:
- to fulfil the requirements arising from its use
- to fulfil the legal requirements
- to ensure structural safety and serviceability
- to maintain the preservation value
- to fully exploit the potential of a structure.

2.1.3 The scope and nature of related activities shall be adapted to the importance of the structure, the hazard scenarios and the complexity of the task.

2.1.4 In the case of important interventions, the preservation value of a structure shall be determined.

2.2 Monitoring and maintenance

2.2.1 Monitoring and maintenance shall be carried out according to Code SIA 469 for all types of structure. Changed conditions and new knowledge shall be taken into consideration.

2.2.2 The aim of the monitoring is to verify predictions regarding the structural behaviour and to allow any unforeseen structural behaviour, deterioration mechanisms and hazards to be identified as early as possible.

2.2.3 Maintenance includes the planned activities according to the intervention plan and the remedial action on minor deterioration. These activities are for the most part of a preventive nature.

2.2.4 If damage, defects, unexpected structural behaviour or significant impairment of the ultimate resistance or operating safety is identified, an examination should be instigated. If necessary, urgent safety measures should also be implemented.

2.3 Examination

2.3.1 The purpose of the examination is to verify the structural safety and serviceability of a structure with respect to its specified remaining service life and, where necessary, to suggest interventions.

2.3.2 The service criteria agreement should be checked for validity, adapted if necessary or, if no service criteria agreement exists, it should be drawn up.

2.3.3 The basis of design should be updated according to Codes SIA 269/1 to 269/8 or, if no basis of design exists, it should be drawn up.

2.3.4 The examination takes place on the basis of the updating of actions, construction material and geotechnical properties, structural models and geometrical properties, as well as ultimate resistances and deformation capacity. The updating shall take into consideration all available information and, in particular, the influences of deterioration mechanisms.

2.3.5 In general, the verifications are carried out following the deterministic method according to the basic principles set forth in Code SIA 260.

2.3.6 Probabilistic verifications may be appropriate:

- where a great deal or very little, is known about the structure and its condition
- where the consequences of structural failure would be very serious
- in order to evaluate the efficiency of monitoring and maintenance strategies
- for fundamental decisions concerning a whole group of structures.

3 REQUIREMENTS

3.1 Use

The remaining service life and the service situations of a structure and its components shall be defined during the examination or when planning interventions.

3.2 Structural safety

3.2.1 The structural safety is considered adequate, either if the necessary level of numerically-determined structural safety is maintained, or if the possibility of structural failure is kept under control by means of supplementary or urgent safety measures.

3.2.2 The deterministic verification of structural safety is provided if the conditions according to Section 5.2.1 are fulfilled.

3.2.3 The probabilistic verification is provided if the conditions according to Appendix B are fulfilled.

3.2.4 The structural safety requirements, in terms of reliability theory, are defined in Appendix B.

3.3 Serviceability

3.3.1 In general, if the use of the structure is unchanged, its serviceability is usually verified on the basis of the results of the condition survey. The experiences of the users should be taken into account.

3.3.2 If the use of the structure has changed, serviceability should be verified on the basis of the results of the condition survey as well as with the updated actions and serviceability limits.

3.3.3 The deterministic verification of serviceability is provided if the condition according to Section 5.2.2 is fulfilled.

3.4 Proportionality of interventions

3.4.1 The proportionality of interventions is determined through a comparison of their costs (direct and indirect costs for the fulfilment of the requirements) and benefits (reduction of risks, increase in preservation value and reliability) in relation to the remaining service life.

3.4.2 In general, the proportionality of interventions is assessed empirically. In the case of safety-related interventions the assessment can be supported through verification according to Section 5.4.

3.4.3 If safety-related interventions prove to be disproportionate, either the planned intervention measures should be revised or the service criteria agreement adapted to the changed circumstances. In the case of accidental examination situations, an unsatisfactory situation can be accepted even if conditions according to Section 5.2 are not fulfilled; however, the risk to individuals shall be limited according to Section B.4.

3.4.4 If safety-related interventions prove to be proportionate, they shall be implemented.

4 UPDATING

4.1 General

4.1.1 As a basic rule, the actions, the construction material and geotechnical properties, the structural model, the geometrical properties, the ultimate resistances and the deformation capacity have to be updated.

4.1.2 Among other things, the updating takes into account:
- occurrences affecting structural behaviour during construction and use
- the findings from observations and measurements during previous use
- previous interventions
- the results of condition surveys
- the specified service situations during the remaining service life
- experience gained from the behaviour of comparable structures under comparable use.

4.1.3 The updated values should be documented in the basis of design.

4.2 Updating of actions

4.2.1 In general, updated characteristic values of actions are defined according to Code SIA 269/1.

4.2.2 If statistical distributions for variables of variable actions are available on the basis of a series of measurements or other information, updating can be carried out, whereby
- the characteristic value of the variable action $Q_{k,act}$ is determined according to the fractile value, which depends on the return period, or
- the examination value of an action effect $E_{d,act}$ is determined according to the method given in Appendix C.

4.3 Updating of construction material and geotechnical properties

4.3.1 The construction materials or the ground are identified through study of the construction works documents and during the condition survey. A construction material or geotechnical property $X_{k,act}$ shall be updated according to the specifications of Codes SIA 269/2 to 269/8.

4.3.2 Codes SIA 269/2 to 269/8 contain information on the updating of conversion factors η and on updated resistance factors $\gamma_{M,act}$.

4.4 Updating of structural models and geometrical properties

4.4.1 The chosen structural model shall realistically reflect the structural behaviour and shall be suitable for predicting the structural behaviour in the examination situations under consideration.

4.4.2 The updating of geometrical properties $a_{d,act}$ is based on the existing dimensions as well as deterioration and imperfections identified during the condition survey. Inconsistencies with the construction documents should be clarified.

4.5 Updating of ultimate resistances and deformation capacity

4.5.1 The updating of the ultimate resistance and of the deformation capacity is carried out according to the basic principles set forth in Codes SIA 262 to 267, SIA 266/2 and SIA 269/2 to 269/8. It should be taken into consideration that the actions and the deformation capacity of the structure can influence one another.

4.5.2 The influences of deterioration and defects on the ultimate resistance and deformation capacity shall be quantified and taken into consideration as updated geometrical properties or as updated construction material and geotechnical properties.

4.5.3 If statistical distributions for variables for determining the ultimate resistances or the deformation capacity on the basis of observations and measurements are available, updating may be carried out, whereby:
- the characteristic value of a construction material or geotechnical property $X_{k,act}$ is determined according to Codes SIA 269/2 to 269/8 or
- the examination value of the ultimate resistance $R_{d,act}$ is determined according to the method described in Appendix C.

5 STRUCTURAL ANALYSIS AND VERIFICATIONS

5.1 General

5.1.1 The structural analysis and the verifications are carried out in accordance with the basic principles set forth in Code SIA 260. The corresponding influencing factors shall be taken into account with their updated values.

5.1.2 The failure types of the structure on which the verifications are based shall be assessed. In particular, it shall be assessed whether indications of failure appear before the ultimate resistance is reached.

5.2 Deterministic verifications

5.2.1 Verification of structural safety

5.2.1.1 For the remaining service life under consideration and limit states of type 1, the structural safety is considered verified if the following criterion for the degree of compliance n is fulfilled:

$$n = \frac{E_{d,stb,act}}{E_{d,dst,act}} \geq 1 \tag{1}$$

5.2.1.2 For the remaining service life under consideration and limit states of types 2 to 4, the structural safety is considered verified if the following criterion for the degree of compliance n is fulfilled:

$$n = \frac{R_{d,act}}{E_{d,act}} \geq 1 \tag{2}$$

5.2.1.3 The examination value of the ultimate resistance is determined with updated average cross section and construction material properties according to Codes SIA 269/2 to 269/8:

$$R_{d,act} = \frac{R\{X_{d,act}, a_{d,act}\}}{\gamma_{R,act}} \tag{3}$$

In general, the expression

$$R_{d,act} = \frac{\eta R_{k,act}}{\gamma_{M,act}} \tag{4}$$

can be used in place of (3).

5.2.1.4 For continuing and temporary examination situations, the examination values for an action effect shall be determined as follows:

$$E_{d,act} = E(\gamma_{G,act}G_{k,act}, \gamma_P P_{k,act}, \gamma_{Q1}Q_{k1,act}, \psi_{0i}Q_{ki,act}, X_{d,act}, a_{d,act}) \tag{5}$$

5.2.1.5 The load factor for a permanent action $\gamma_{G,act}$ may be updated according to Table 1 if the updating of the permanent actions is carried out according to Code SIA 269/1.

Table 1: Updated load factors for verification of structural safety

Actions	Load factor	Limite state		
		Type 1	Type 2	Type 3
Permanent actions (incl. soil surcharge)				
– acting unfavourably	$\gamma_{G,sup,act}$	1,05 [1)]	1,20 [1)]	1,00
– acting favourably	$\gamma_{G,inf,act}$	0,95 [1)]	0,90 [1)]	1,00

[1)] $G_{k,act}$ is multiplied either by $\gamma_{G,sup,act}$ or by $\gamma_{G,inf,act}$, depending on whether the overall action is unfavourable or favourable.

5.2.1.6 The load factors according to Code SIA 260 apply for variable actions and actions arising from the ground.

5.2.1.7 The reduction factors ψ_0, ψ_1 and ψ_2 can be taken from Code SIA 260.

5.2.1.8 For accidental examination situations, the examination values of an action effect shall be determined as follows:

$$E_{d,act} = E(G_{k,act}, P_{k,act}, A_{d,act}, \psi_{2i}Q_{ki,act}, X_{d,act}, a_{d,act}) \quad (6)$$

5.2.1.9 For limit states of type 4, the verification of fatigue safety shall be carried out using one of the following methods:
- verification of fatigue strength with the fatigue actions described in Code SIA 269/1
- verification of operating strength as for new structures with partial factors for service loads according to Code SIA 269/1
- verification by calculating the accumulation of damage
- verification by the method of the structural stress concept.

A distinction should be made between the fatigue actions during the previous service life and the remaining service life.

5.2.2 Verification of serviceability

For the examination situation under consideration, the serviceability is considered verified if the following criterion is fulfilled:

$$E_{d,act} \leq C_{d,act} \quad (7)$$

$E_{d,act}$ represents the examination value of the action effect due to the load cases considered in the actual examination situation and $C_{d,act}$ represents the associated updated service limit.

5.3 Probabilistic verifications

If updated distributions of the basic variables are available, the structural safety may be verified using the methods of reliability theory.

5.4 Verification of the proportionality of safety-related interventions

5.4.1 The proportionality of safety-related interventions is assessed on the basis of their efficiency and taking into consideration the following aspects:
- safety requirements with respect to individuals and society
- availability of a structure or installation
- extent of damage to persons, material goods and the environment
- preservation of cultural values.

5.4.2 The efficiency of the interventions is assessed with the coefficient EF_M:

$$EF_M = \frac{\Delta R_M}{SC_M} \quad (8)$$

ΔR_M represents the reduction in risk as a result of interventions (formulated as discounted annual monetary value over the remaining service life) and SC_M represents the safety costs (formulated as discounted annual monetary value over the remaining service life) associated with making the structure safe. An interest rate of 2% can be applied for the discounting.

5.4.3 A safety-related intervention is regarded as proportionate if $EF_M \geq 1{,}0$. In general, a safety-related intervention is regarded as disproportionate if $EF_M < 1{,}0$; however, taking into account the aspects mentioned in Section 5.4.1 can lead to a different assessment.

5.4.4 In determining the reduction of risk, 3 to 10 million Swiss francs can be assumed for a saved human life. If the risk reduction is determined solely taking into account human life, a safety-related intervention is regarded as proportionate if $EF_M \geq 1{,}0$.

6 EXAMINATION

6.1 Procedure

6.1.1 General

6.1.1.1 The examination is carried out in stages, in increasing depth. It consists of the general examination and if necessary one or more detailed examinations. The degree of depth depends on the quality of the information available on the structure and its importance.

6.1.1.2 The results of the examination shall satisfy a plausibility check and be consistent with the observed condition and behaviour of the structure.

6.1.1.3 The results of the examination shall be recorded in a report.

6.1.2 Instigation

6.1.2.1 An examination of an existing structure needs to be performed in the event of a change in use or service requirements or in the event of an alteration.

6.1.2.2 In supplementation of Section 6.1.2.1, there are sufficient grounds for carrying out an examination if:
- significant damage or defects have been identified in the structure
- significant movements or deformations have occurred in the ground or the structure
- accidental or unforeseen actions have occurred
- a structure has not been monitored, or has not been monitored sufficiently, or cannot be monitored
- on the basis of the monitoring, doubts exist concerning the evaluation of the condition
- an investigation of the reliability of the structure appears necessary
- new knowledge is available concerning actions or properties of the structure.

6.1.3 General examination

6.1.3.1 The general examination applies to the entire structure including all structural members, whose failure would represent a hazard to persons, valuable material goods and the environment.

6.1.3.2 The scope of the general examination and the identification of the structural members that are to be examined have to be defined object-specifically.

6.1.3.3 Usually, the general examination takes place in stages according to Appendix A.

6.1.4 Detailed examination

6.1.4.1 A detailed examination shall be carried out if fulfilment of the requirements cannot be verified in the general examination and if the anticipated benefits justify the associated costs.

6.1.4.2 In general, the detailed examination is limited to selected parts of a structure and can take place in several stages, and in increasing depth (see Appendix A).

6.2 Condition survey

6.2.1 General

6.2.1.1 The condition survey forms the basis for the condition evaluation and the recommendation of interventions. It is based on the service criteria agreement and the basis of design and takes into consideration inspection and examination reports as well as the experiences of the users.

6.2.1.2 The aim of the condition survey is
- to obtain indications of hazard scenarios, information on actions and data on the exposure of the structure
- to determine the condition of the structure, as well as any deterioration and defects, and document these for the condition evaluation.

6.2.1.3 Each condition survey should include an evaluation of the reliability and plausibility of the results.

6.2.1.4 The main focus of the condition survey is on obtaining information regarding:
- the structure and structural behaviour
- the hazard scenarios and service situations as well as actions and the effects of these actions
- the condition of parts of the structure, in particular those exposed to severe environmental influences
- the construction method and the construction materials with their present properties and those expected in the future.

6.2.1.5 In general, preparations for the condition survey of the structure include:
- the objective, stating why particular information is sought
- the investigation programme with details of any restrictions on use during the condition survey
- description of and reasons for choice of investigation methods
- nature and expected results of investigations of the structure and of laboratory tests
- information concerning the representativeness of the investigations and the expected results
- information concerning rehabilitation work in which sample-taking and probing are necessary.

6.2.2 Investigations

6.2.2.1 In general, the investigations of the structure include:
- the structural system
- the relevant dimensions of the structural components, their structural design and consistency with the construction documents
- the construction materials and their properties
- the equipment components that are of importance to the structural behaviour.

6.2.2.2 In defining the structural model, the static and kinematic boundary conditions such as fixed connections, support conditions and the freedom of movement within joints should be recorded. In particular, the interaction between structure and the ground as well as the stability of the system as a whole and the individual structural components should be investigated.

6.2.2.3 The investigation shall include those structural members which influence the structural behaviour of the structure.

6.2.2.4 In the case of structures subject to fatigue, the structural design shall be examined in order to identify design details subject to fatigue and the fatigue strengths determined according to Codes SIA 269/2 to 269/5.

6.2.3 Determination of the structural behaviour with the aid of testing

6.2.3.1 Investigating the structural behaviour using static or dynamic stress tests may be carried out:
- if insufficient knowledge and information about the structure and its structural behaviour is available
- in order to verify elastic structural behaviour
- in order to calibrate structural models for the structural analysis
- before applying higher live loads, if verification through calculation is not possible
- as part of a special inspection.

6.2.3.2 In loading tests, the behaviour of the structure and the structural components is determined and it is established whether, under certain stresses, the deformations of the structure are reversible and no excessive formation of cracks, vibrations or displacements occur.

6.2.3.3 The results of loading tests should be interpreted on the basis of structural models. Particular attention should be paid to the influences that cannot be modelled, or cannot be modelled satisfactorily.

6.3 Condition evaluation

6.3.1 General

6.3.1.1 The condition evaluation evaluates the condition of the structure as a whole or of individual structural members in terms of structural safety, serviceability and durability. It includes an estimate of the further development of the condition.

6.3.1.2 The structure should also be assessed in terms of its robustness. The consequences of deterioration as a result of accidental actions or environmental influences on the resistance and the stability of the structure should be investigated using hazard scenarios and corresponding failure scenarios.

6.3.1.3 In the failure scenarios, a distinction should be made between load, force or deformation-induced processes that may occur before the ultimate resistance is reached at varying degrees of deformation. It shall be established whether a process leading to failure can be identified in good time.

6.3.1.4 Structures or structural components that cannot be inspected and cannot be directly tested should be evaluated on the basis of indirect evidence.

6.3.1.5 If a condition evaluation is not possible with adequate reliability, the planning of intervention measures can be carried out by applying of the observation method according to Codes SIA 260 and 267.

6.3.1.6 The condition evaluation should, if possible, be based on a quantitative analysis, otherwise on an empirical analysis.

6.3.2 Quantitative analysis

6.3.2.1 In the quantitative analysis of structural safety and serviceability, it should be determined whether the corresponding verifications are fulfilled. The degree of compliance in terms of structural safety should be demonstrated.

6.3.2.2 Model uncertainties and the importance of the relevant examination values can be investigated on the basis of a sensitivity analysis.

6.3.2.3 If adequate structural safety cannot be verified, the choice of structural model and the influence of the relevant parameters on the result of the verification of structural safety should be assessed. It should be determined whether the relevant failure mechanism is manifested before the ultimate resistance is reached. It should also be estimated whether an additional detailed examination can provide new knowledge.

6.3.2.4 If the limit states of type 4 cannot be verified, it should be estimated whether an additional detailed examination can provide new knowledge. This includes, individually or in combination:
- a refined evaluation of the previous and future fatigue actions taking into consideration the remaining service life
- a refined structural analysis or loading tests for more precise determination of the fatigue-relevant stress values
- a refined evaluation of the fatigue resistance, if necessary on the basis of tests
- application of the methods of reliability theory in order to determine the probability of failure.

6.3.3 Empirical analysis

6.3.3.1 An empirical analysis should be carried out, in particular, if the structural safety cannot be verified, or cannot be verified reliably, according to Section 5.2.1 or 5.3.

6.3.3.2 In an empirical analysis, adequate structural safety may be assumed if all the following conditions are fulfilled:
- No deterioration or defects can be identified that impair the resistance.
- The structure has displayed satisfactory structural behaviour over a relatively long service life.
- Similar experiences with the structural behaviour of comparable structures are available.
- No changes in use are planned for the remaining service life.
- The risk of a structural failure and its consequences can be classed as acceptable.

6.3.3.3 If adequate structural safety is anticipated on the basis of an empirical analysis, supplementary safety measures according to Section 7.5 should be implemented.

6.3.4 Prediction of the development of the condition

6.3.4.1 The prediction of the development of the condition includes statements regarding the anticipated development of the structure's condition as well as its structural safety and serviceability.

6.3.4.2 The foreseeable changes in the actions, the ultimate resistance and the structural behaviour, including possible deterioration mechanisms, are taken into account in the prediction of the development of the condition.

6.3.4.3 Qualitative statements concerning the development of the condition are based on the condition survey as well as on experience from comparable structures.

6.3.4.4 Quantitative statements concerning the development of the condition are based on the modelling of time-dependent actions, deterioration mechanisms and other time-dependent processes.

6.3.4.5 The prediction of the development of the condition should be compared with the remaining service life as defined in the service criteria agreement.

6.4 Recommendation of intervention measures

6.4.1 The recommendation of intervention measures forms the basis for the fundamental decision by the owner of the structure regarding further action.

6.4.2 The recommendation of intervention measures can include the following options:
- acceptance of the existing condition
- immediate correction of the existing condition by means of urgent safety measures
- supplementary safety measures
- performance of a (further) detailed examination
- change in monitoring and maintenance procedures
- rehabilitation, renewal and/or modification
- replacement of the entire structure or individual parts thereof
- decommissioning
- dismantlement.

6.4.3 If the limit states of type 4 cannot be verified, supplementary safety measures are the first options to be considered. Modification of the structure is only necessary if these prove inadequate.

7 INTERVENTIONS

7.1 General

7.1.1 The planning of intervention measures is based on the fundamental decision by the owner of the structure regarding the proposed use of the structure and further action.

7.1.2 Operational and/or structural interventions geared to the remaining service life are to be defined in the course of the planning of interventions.

7.1.3 The interaction of the existing structure or part of the structure with other existing structural members, with adjacent structures and with the ground shall be taken into consideration.

7.1.4 The influence of an intervention on integration, configuration and cultural values as well as, in the case of historical buildings, on the conservation of the original substance should be demonstrated.

7.1.5 The functional principle and the anticipated effectiveness of the intervention in ensuring durability during the remaining service life should be substantiated.

7.1.6 Following the implementation of interventions, the service criteria agreement should be confirmed, the basis of design updated and the service instructions implemented.

7.1.7 Following the execution of interventions, these should be monitored for effectiveness. The checks necessary for this purpose should be included in the monitoring plan.

7.2 Rehabilitation and modifications

7.2.1 General

7.2.1.1 The rehabilitation of a structure includes measures which, in general, comprise a combination of the following objectives:
- eliminating the causes of deterioration
- retarding or preventing deterioration mechanisms
- rectifying deterioration and defects
- protecting the structure or structural components.

7.2.1.2 When planning interventions, the risks of execution and the factors required to overcome them shall be taken into consideration.

7.2.1.3 In evaluating the proportionality of interventions, particular attention shall be paid to the influence on cultural values.

7.2.2 Concept of intervention

7.2.2.1 The concept of intervention corresponds in content and scope to the preliminary stage of the project.

7.2.2.2 The concept of intervention is chosen on the basis of an optimisation of variants.

7.2.2.3 The basis for the choice of variants is provided by the results of the examination, the aims of the management of the structure, the current and future use, the remaining service life, the preservation value as well as the legal requirements.

7.2.2.4 The concept of intervention is documented in the form of a report.

7.2.3 **Design of intervention**

7.2.3.1 The design of intervention corresponds in content and scope to the preliminary stage of the project.

7.2.3.2 In the design of intervention, the quality assurance, consisting of quality requirements, test methods and acceptance criteria, should be defined. The consequences of failure to fulfil the quality requirements should be described.

7.2.3.3 The design of intervention has to be documented in the form of a report.

7.3 Monitoring and maintenance

7.3.1 Monitoring and maintenance are carried out according to the updated monitoring and maintenance plan.

7.3.2 If serious deterioration cannot be eliminated, more intensive monitoring should be introduced as a supplementary safety measure.

7.4 Urgent safety measures

7.4.1 If the structural safety or safety in operation is clearly not ensured, urgent safety measures for the protection of persons, material goods and the environment should be implemented.

7.4.2 The following urgent safety measures should be considered:
- limitations on use
- urgent structural safety measures, for example shoring and underpinning of the structure
- intensification of the monitoring
- decommissioning and cordoning-off of the structure
- alarming of endangered persons
- evacuation of endangered persons and material goods.

7.4.3 Urgent safety measures may neither prejudice nor hinder supplementary safety measures.

7.5 Supplementary safety measures

7.5.1 Supplementary safety measures shall be defined object-specifically according to the following criteria:
- importance of the structure and damage potential
- nature of the structural failure (with/without prior warning)
- possibility of monitoring the structural behaviour
- possibility of controlling use
- costs-risk considerations
- various possibilities of damage limitation.

7.5.2 The following supplementary safety measures can be considered:
- limitation of the use and limitation of the remaining service life
- limitation of live loads (possibly through structural design measures)
- monitoring of the structural behaviour (control measurements, interim inspection)
- permanent or periodic monitoring of use
- installation of automatic warning and safety equipment
- preparation of emergency measures
- drafting of alarm dispositions
- introduction of evacuation plans.

APPENDIX A (normative)

STEP-BY-STEP EXAMINATION PROCEDURE

General examination

Section 6.1.3

Basis	
Study of construction documents	
Updating of service criteria agreement	Sect. 3 + 4
Updating of the basis of design	Sect. 3 + 4

Condition survey Section 6.2
– visual checks – simple, generally non-destructive investigations

Structural analysis and verifications Section 5	
Approx. deterministic verifications	Section 5.2
– evaluation of the structural concept – mechanisms and nature of possible structural failure – identification of key areas of the structure	

Condition evaluation Section 6.3
– quantitative – empirical – prediction of the development of the condition

Recommendation of intervention measures Section 6.4
– detailed examination – monitoring and maintenance – urgent safety measures – supplementary safety measures – rehabilitation, modifications, replacement – etc.

Detailed examination

Section 6.1.4

Basis	
Results of general examination	
Supplementary study of construction documents	
Updating of service criteria agreement	Sect. 3 + 4
Updating of the basis of design	Sect. 3 + 4

Condition survey Section 6.2
– in-depth investig. of relevant structural members – investigations through measurement – laboratory tests

Structural analysis and verifications Section 5	
Deterministic verifications	Section 5.2
Probabilistic verifications	Section 5.3
– in general, only key parts of a structure – refined structural analysis – in-depth determination of actions and action effects	

Condition evaluation Section 6.3
– quantitative – empirical – prediction of the development of the condition

Recommendation of intervention measures Section 6.4
– further detailed examination – monitoring and maintenance – urgent safety measures – supplementary safety measures – rehabilitation, modifications, replacement – etc.

APPENDIX B (normative)

STRUCTURAL SAFETY REQUIREMENTS

B.1 The requirement in terms of structural safety is defined through the target value of the reliability index or through the individual risk.

B.2 The target value of the reliability index β_0 is dependent on the consequences of structural failure. These are estimated with the aid of the coefficient ρ.

$$\rho = \frac{C_F}{C_W} \tag{9}$$

C_F refers to all direct costs in the event of failure, C_W to the costs of restoration of the structure following failure.

In the case of consequences $\rho > 10$ or high consequential costs in the event of failure, the necessary level of structural safety should be defined on the basis of a risk analysis.

B.3 The target value of the reliability index β_0 is defined in Table 2.

Table 2: Target value of the reliability index β_0 with a reference period of 1 year

Efficiency of the interventions EF_M according to Section 5.4	Consequences of structural failure according to (9)		
	minor $\rho < 2$	moderate $2 < \rho < 5$	serious $5 < \rho < 10$
Low: $EF_M < 0{,}5$	3,1	3,3	3,7
Medium: $0{,}5 \le EF_M \le 2{,}0$	3,7	4,2	4,4
High: $EF_M > 2{,}0$	4,2	4,4	4,7

If the efficiency of safety-related interventions cannot be determined during the examination phase, $EF_M = 1$ should be applied.

B.4 The acceptable individual risk is 10^{-5} per year.

APPENDIX C (normative)
EXAMINATION VALUES

C.1 If updated probability distributions of basic variables (action effects and ultimate resistances) are available, examination values may be determined according to the following semi-probabilistic method. In general, the following assumptions apply:
- action effects as a result of permanent actions exhibit a normal distribution
- action effects as a result of variable or accidental actions exhibit a Gumbel distribution
- variables of the ultimate resistance exhibit normal or log-normal distributions
- stiffnesses are normally distributed.

C.2 The examination value of normally distributed effects of an action (E), variables of ultimate resistance (R) and stiffness may be determined as follows:

$$E_{d,act} = E_{m,act} (1 + \alpha_E \beta_0 v_{E,act}) \quad (10)$$

$$R_{d,act} = R_{m,act} (1 + \alpha_R \beta_0 v_{R,act}) \quad (11)$$

$E_{m,act}$ and $R_{m,act}$ are updated estimates, $v_{E,act}$ and $v_{R,act}$ are updated coefficients of variation and α_E and α_R are sensitivity factors.

β_0 is the target value of the reliability index and can be taken from Table 2.

C.3 The examination value of log-normally distributed effects of an action (E) and variables of the ultimate resistance (R) may be determined as follows:

$$E_{d,act} = E_{m,act}\, e^{(\alpha_E \beta_0 \delta_E - 0{,}5\,\delta_E^2)} \quad (12)$$

$$R_{d,act} = R_{m,act}\, e^{(\alpha_R \beta_0 \delta_R - 0{,}5\,\delta_R^2)} \quad (13)$$

where:

$$\delta_E^2 = \ln (v_{E,act}^2 + 1) \quad (14)$$

$$\delta_R^2 = \ln (v_{R,act}^2 + 1) \quad (15)$$

$E_{m,act}$ and $R_{m,act}$ are updated estimates, $v_{E,act}$ and $v_{R,act}$ are updated coefficients of variation, α_E and α_R are sensitivity factors and δ_E and δ_R are parameters of the log-normal distribution.

C.4 The examination value of Gumbel-distributed effects of an action (E) may be determined as follows:

$$E_{d,act} = E_{m,act} [1 - v_{E,act}(0{,}45 + 0{,}78 \ln\{-\ln [\Phi(\alpha_E \beta_0)]\}] \quad (16)$$

C.5 If sensitivity factors cannot be updated with the aid of FORM analyses (First Order Reliability Method), the following factors can be used for simplified calculation:
- $\alpha_E = 0{,}7$ for the effects of leading actions
- $\alpha_E = 0{,}3$ for the effects of accompanying actions
- $\alpha_R = -0{,}8$ for ultimate resistances, which are of key importance in the verification of structural safety
- $\alpha_R = -0{,}3$ for ultimate resistances, which are of secondary importance in the verification of structural safety.

Abbreviations for the organisations represented in the commission SIA 260

Empa	Swiss Federal Laboratories for Materials Science and Technology
EPFL	Swiss Federal Institute of Technology, Lausanne
ETH Zürich	Swiss Federal Institute of Technology, Zurich
FEDRO	Federal Roads Office
FOT	Federal Office of Transport

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