JRC SCIENCE AND POLICY REPORT

New European Technical Rules for the Assessment and Retrofitting of Existing Structures

Policy Framework
Existing Regulations and Standards
Prospect for CEN Guidance

Support to the implementation, harmonization and further development of the Eurocodes

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Abstract

The consideration of sustainability aspects in the construction sector jointly with considerable economic interests have been the main impulse to include the work item of assessment and retrofitting of existing structures in the Mandate M/515 with a high priority. The new European technical rules will be developed using the existing organization of CEN/TC250.

The present report has been worked out in the frame of CEN/TC250/WG2 activities. The report encompasses:

- Part I introduces the policy framework and the CEN/TC250 initiative.
- Part II is a collation of the different existing National regulations and standards in Europe with regard to existing structures.
- Part III gives a prospect for CEN guidance for the assessment and retrofitting of existing structures.

Having in mind the stepwise procedure for preparation of CEN Technical Documents, the contents of Part III is broader, covers more aspects, and includes more information than the normative technical recommendations. In particular, key issues are identified that require resolution and a summary of different national perspectives is provided rather than seeking to resolve all difficult technical issues during the first work step. The report presents scientific and technical background intended to stimulate debate and serves as a basis for further work to achieve a harmonized European view on the assessment and retrofitting of existing structures.

Foreword

The **construction sector** is of strategic importance to the EU as it delivers the buildings and infrastructure needed by the rest of the economy and society. It represents more than **10% of EU GDP and more than 50% of fixed capital formation**. It is the largest single economic activity and it is the biggest industrial employer in Europe. The sector employs directly almost 20 million people. Construction is a key element not only for the implementation of the **Single Market**, but also for other construction relevant EU Policies, e.g. **Sustainability**, **Environment and Energy,** since 40-45% of Europe's energy consumption stems from buildings with a further 5-10% being used in processing and transport of construction products and components.

The **EN Eurocodes** are a set of **European standards** which provide common rules for the design of construction works, to check their strength and stability against extreme live loads such as fire and earthquakes. In line with the EU's strategy for smart, sustainable and inclusive growth (EU2020), **Standardisation** plays an important part in supporting the industrial policy for the globalization era. The improvement of the competition in EU markets through the adoption of the Eurocodes is recognized in the "Strategy for the sustainable competitiveness of the construction sector and its enterprises" - COM (2012)433, and they are distinguished as a tool for accelerating the process of convergence of different national and regional regulatory approaches.

With the publication of all the 58 Eurocodes Parts in 2007, the implementation in the European countries started in 2010 and now the process of their adoption internationally is gaining momentum. The Commission Recommendation of 11 December 2003 stresses the importance of training in the use of the Eurocodes, especially in engineering schools and as part of continuous professional development courses for engineers and technicians, which should be promoted both at national and international level. It is recommended to undertake research to facilitate the integration into the Eurocodes of the latest developments in scientific and technological knowledge.

In May 2010 **DG ENTR issued the Programming Mandate M/466 EN to CEN concerning the future work on the Structural Eurocodes**. The purpose of the Mandate was to initiate the process of further evolution of the Eurocode system. M/466 requested CEN to provide a programme for standardisation covering:

- Development of **new standards or new parts** of existing standards, e.g. a new construction material and corresponding design methods or a new calculation procedure;

- Incorporation of **new performance requirements and design methods** to achieve further harmonisation of the implementation of the existing standards.

Following the answer of CEN, in December 2012 DG ENTR issued the Mandate M/515 EN for detailed work programme for amending existing Eurocodes and extending the scope of structural Eurocodes. In May 2013 CEN replied to M/515 EN. Over 1000 experts from across Europe have been involved in the development and review of the document. The CEN/TC250 work programme encompasses all the requirements of M/515 EN, supplemented by requirements established through extensive consultation with industry and other stakeholders. Publishing of the complete set of new standards is expected by 2020.

The standardisation work programme of CEN/TC250 envisages that the new pre-normative documents will first be published as JRC Science and Policy Reports, before their publication as CEN Technical Specifications. After a period for trial use and commenting, CEN/TC 250 will decide whether the Technical Specifications should be converted into ENs.

This pre-normative document is published as a part of the JRC Report Series "Support to the implementation, harmonization and further development of the Eurocodes" and presents preliminary proposals relating to **New European Technical Rules for the Assessment and Retrofitting of Existing Structures. It was developed by CEN/TC250 Working Group (WG) 2 on assessment and retrofitting of existing structures**. The purpose of its work is to start to bring together the different national approaches to a broadly accepted and coherent set of harmonised European technical rules for the assessment and retrofitting of existing structures complementing those for the design of new structures.

This JRC Science and Policy Report presents scientific and technical background intended to stimulate debate and serves as a basis for further work to achieve a harmonized European view on the assessment and retrofitting of existing structures. The report is subdivided into three parts:

- Part I introduces the policy framework and the CEN/TC250 initiative.
- Part II is a collation of the different existing National regulations and standards in Europe with regard to existing structures.
- Part III gives a prospect for CEN guidance for the assessment and retrofitting of existing structures.

The editors and authors have sought to present useful and consistent information in this report. However, users of information contained in this report must satisfy themselves of its suitability for the purpose for which they intend to use it.

The report is available to download from the "Eurocodes: Building the future" website (http://eurocodes.jrc.ec.europa.eu).

Ispra, February 2015

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Report Series "Support to the implementation, harmonization and further development of the Eurocodes"

In the light of the Commission Recommendation of 11 December 2003, DG JRC is collaborating with DG ENTR and CEN/TC250 "Structural Eurocodes", and is publishing the Report Series "**Support to the implementation, harmonization and further development of the Eurocodes"** as JRC Science and Policy Reports. This Report Series includes, at present, the following types of reports:

1. **Policy support documents**, resulting from the work of the JRC in cooperation with partners and stakeholders on "Support to the implementation, promotion and further development of the Eurocodes and other standards for the building sector";

2. **Technical documents**, facilitating the implementation and use of the Eurocodes and containing information and practical examples (Worked Examples) on the use of the Eurocodes and covering the design of structures or its parts (e.g. the technical reports containing the practical examples presented in the workshop on the Eurocodes with worked examples organized by the JRC);

3. **Pre-normative documents**, resulting from the works of the CEN/TC250 and containing background information and/or first draft of proposed normative parts. These documents can be then converted to CEN technical specifications;

4. **Background documents**, providing approved background information on current Eurocode part. The publication of the document is at the request of the relevant CEN/TC250 Sub-Committee;

5. **Scientific/Technical information documents**, containing additional, non-contradictory information on current Eurocode part, which may facilitate its implementation and use, or preliminary results from pre-normative work and other studies, which may be used in future revisions and further developments of the standards. The authors are various stakeholders involved in Eurocodes process and the publication of these documents is authorized by relevant CEN/TC250 Sub-Committee or Working Group.

Editorial work for this Report Series is **performed by the JRC** together with partners and stakeholders, when appropriate. The publication of the reports type 3, 4 and 5 is made after approval for publication by CEN/TC250, or the relevant Sub-Committee or Working Group.

The publication of these reports by the JRC serves the purpose of implementation, further harmonization and development of the Eurocodes. However, it is noted that neither the Commission nor CEN are obliged to follow or endorse any recommendation or result included in these reports in the European legislation or standardisation processes.

The reports are available to download from the "Eurocodes: Building the future" website (http://eurocodes.jrc.ec.europa.eu).

Acknowledgements

This report has been prepared for the development of a future European guidance for the assessment and retrofitting of existing structures under the aegis of CEN/TC250. Both CEN/TC250 and JRC acknowledge the substantial contribution of the many international experts of CEN/TC250/WG2 and others, who have supported the works by their essential input and reviews, notably:

Editorial Panel: Gerrie Dieteren; Stuart Matthews; Peter Tanner

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Reference to the front pictures:

Dock B at Zurich Airport: Assessment and integration of the existing structure into the expanded new Dock-Building

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Part II: Existing National Regulations and Standards in Europe

Part III: Prospect for CEN Guidance

NEW EUROPEAN TECHNICAL RULES FOR THE ASSESSMENT AND RETROFITTING OF EXISTING STRUCTURES

PART I: POLICY FRAMEWORK

Contents Part I

1 Purpose, justification, and benefits

1.1 Introduction

CEN/TC250 has taken the initiative to prepare a document addressing the purpose and justification for new European technical rules and associated standards for the assessment and retrofitting of existing structures. The corresponding report [01] was drafted by a former chairman's advisory panel (CAP). The continuous discussions in CEN/TC250 reflected the need of the formation of a CEN Working Group WG2 to further develop the work item. The preliminary dialogue within CEN/TC250/WG2 resulted in a Project Proposal [02] as basis for the future work programme.

The CEN/TC250 initiative was motivated by the expanding and extensive construction activities in assessing and retrofitting buildings and engineering works that aligns with the new strategy for sustainable construction. The strategy recognises the importance of extending the life of existing assets thereby delivering environmental, economic and socio-political benefits.

The analysis of the present situation in the construction sector and the identification of the design concepts provided by the current structural design codes and trends in the construction market are the bases for the perspective of the future generation of codes for the design as well as for the assessment of existing structures.

1.2 Design concepts at present

During the past 25 years an alignment of the generally used design procedures can be observed worldwide. Most design procedures at present refer to the fundamental requirements to be met. According to the fundamental requirements a structure should be designed, executed and maintained in such a way that it will, during its intended life, with appropriate degrees of reliability:

- sustain all actions likely to occur during execution and use
- remain fit for the use for which it is required.

These fundamental requirements stipulate the concept of the limit state design, which is differentiating:

- ultimate limit state referring to the structural safety
- serviceability limit states.

The structural safety includes:

- loss of equilibrium
- failure of structure
- failure caused by fatigue.

The serviceability includes considerations with regard to:

- function of the structure
- comfort of the user
- appearance of the structure.

It is to be noted that these fundamental requirements are mainly restricted to the mechanical characteristics and behaviour of a structure and its parts.

Most current structural design codes are based on semi-probabilistic methods describing the design values with appropriate partial factors.

The EN Eurocodes are an example of a consistent and coherent set of structural design codes. They cover all main construction materials, all major fields of structural engineering, and a wide range of types of structures. The EN Eurocodes have been developed in a long process of discussions between experts of all European countries with the objective of harmonizing design procedures.

The general appreciation of design concepts leads to a common understanding among professionals and to mutual recognition of different design cultures. The harmonization of the different design procedures allows for the exchange of experiences and engineering services.

1.3 Trends in the construction sector

1.3.1 Design concepts

The concepts of future urban planning will be based on new social, economic and technological ideals focussed on improving the quality of life. To attain this main objective, architects and engineers must improve the quality of buildings and engineering works and establish new principles of building concepts.

The future of construction works will be closely governed by the sustainable development of urban and industrial areas and infrastructures, which results in modifications or substitutions or extensions of existing buildings and engineering works. The requirements in terms of structural safety are defined through the target value of reliability index, acceptable probability of failure or the acceptable level of risk.

1.3.2 Sustainable development

After adopting the Kyoto protocol in 1997, the sustainable development is a long term goal of the global policy. The building and construction sector plays an important role in sustainable development. The environmental impact of construction sector is considerable:

- total energy consumption: ~40%
- consume of raw materials: ~50%
- waste streams: 40 – 50%

Thus the construction sector is one of the largest industrial sectors with all aspects of economic importance and environmental impact. In this context the assessment and retrofitting of existing structures is a leading branch in the construction sector. The rate is increasing steadily during the last 30 years and it will continue increasing in future (Figure 1.1).

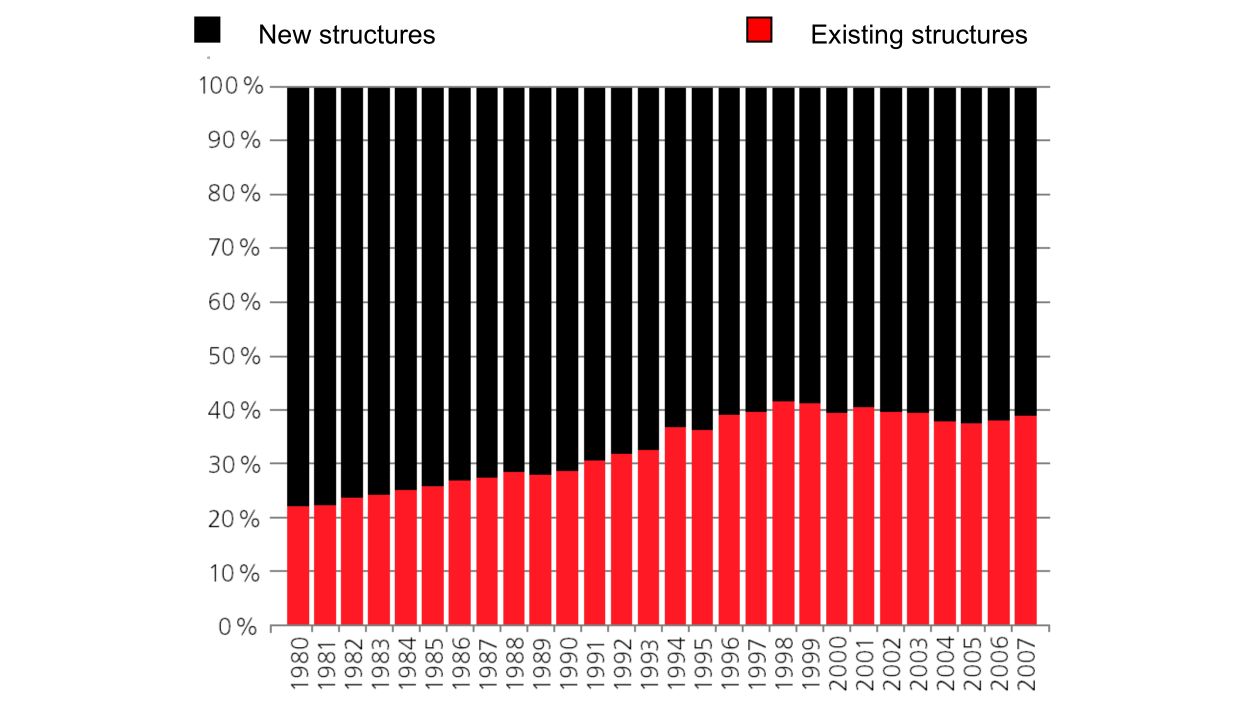

Figure 1.1: Increasing rate of retrofitting existing building and engineering works [03]

1.3.3 Integrated design and construction process

The complexity of design practice requires an integrated and concerted planning process. The consideration of all aspects of sustainability leads to integrated design procedures of structures that do not meet only the traditional requirements with regard to mechanical characteristics. More general requirements have to be respected. In this sense the Construction Products Regulation [04] identifies in its Annex I the following basic requirements for construction works:

1. mechanical resistance and stability
2. safety in case of fire
3. hygiene, health and environment
4. safety and accessibility in use
5. protection against noise
6. energy economy and heat retention
7. sustainable use of natural resources.

As various requirements may lead to conflicting directions for design of structures, concerted actions are necessary to develop consistent code and standard families in future.

The need of concerted actions in the sense of an integrated design process for buildings and engineering works is broadly acknowledged by all involved parties in the construction sector.

In parallel to the development of the engineering services and construction market the future generation of structural design codes will highlight new and advanced concepts for the design of new structures as well as for the assessment and retrofitting of existing structures.

2 Assessment and retrofitting of existing structures

2.1 Existing structures and sustainability

A sustainable development for construction will not simply respond to new needs by adding new buildings to the existing building stock or demolish old buildings and simply substitute them by new ones. It will analyse existing structures to identify their possibilities for meeting sustainability goals.

An assessment of existing structures may be necessary in case of:

- adequacy checking in order to establish whether the existing structure can resist loads associated with the anticipated change in use of the facility, operational changes or extension of its design working life

- repair of an existing structure, which has deteriorated due to time dependent environmental effects or which has suffered damage from accidental actions for example due to impact, explosion, fire or earthquake

- doubts concerning the actual reliability of the structure

- rehabilitation of an existing building structure in connection with retrofitting the building services

- requirements from authorities, insurance companies or owners or from a maintenance plan.

Figure 1.2: Example for the assessment and retrofitting of an existing building [05]

Figure 1.2 illustrates an example for the assessment and retrofitting of an existing office building. The left-hand picture shows the original building as inaugurated in 1971; the right-hand picture shows the same building after rehabilitation in 2008. The main reason for the rehabilitation of this building was the replacement of the building techniques system and of the façade construction respecting the needs of energy efficiency. However, the main structural system consisting of reinforced concrete floor slabs supported by steel columns proved to be still in good condition. Thus the assessment of the structure was focussed on the reliability with regard to seismic actions.

Owners of existing buildings, real estate agents and other partners interested in the technical performance of the structure are interested to profit from a successful assessment or retrofitting in achieving a higher value on the real estate or rent market.

With respect to bridges the situation is slightly different from that for buildings. Especially the reasons for assessing bridges and the impulse for maintenance intervention are different; however the principles are the same and the methodologies are comparable.

Due to the demand for freight volume on rail and road, traffic has increased significantly leading to increasing number of heavy vehicles in the traffic flows. Because of environmental considerations there is also a tendency to further enhance the admissible loads in the design of new heavy vehicles. In addition to the change of the traffic flows the exposure to climate actions and extreme emissions may impair the long term behaviour of a structure. This all may affect the safety, serviceability and durability of existing bridges. Bridge authorities are therefore interested in agreed methods to assess the safety, and durability of existing bridges and to make appropriate provisions for more refined methods for the evaluation and maintenance.

Hence, in case of assessment of bridges additional aspects and activities may be become important:

- consider and reduce the environmental impact by means of a life cycle analysis
- estimate and optimise the overall cost by means of life cycle cost calculation
- take into account maintenance and management concepts
- perform risk analysis.

2.2 Main growth drivers

The new strategy taking account of continued use of existing structures is of great significance due to environmental, economic and socio-political assets. Growing larger every year it will be a new challenge for architects and engineers and a new focus for the construction industry with a new technical basis and a change of market as well as of the main activities.

The main growth drivers that could influence further assessment and retrofitting of existing buildings are listed in Table 1.1.

Table 1.1: Possible growth drivers for the assessment and retrofitting of existing buildings

Structure	Demand	Growth drivers
Building	Sustainable development	Re-use of buildings in urban development
	Energy saving (heating)	Energy saving legislation and building regulations, reducing of energy loss of building, activation of structure for heat retention
	Energy saving (cooling)	Energy saving legislation, reduction of air-conditioning load in buildings. Preventing non air-conditioned buildings from overheating.
	Fire protection	Legislation in view of evacuation, spread of fire, structural behaviour
	Safety	Adaptation to new occupancies and uses, accounting for accidental loads or seismic loads. Requirements for robustness
	Serviceability and security	Improving of vibration behaviour, use of daylight, elevators
	Acoustic	Legislation against noise from outdoor of from the building

Whereas the growth drivers for bridges are different from those for buildings the principles of assessment and retrofitting remain the same for both types of structures. The main growth drivers that could influence further assessment and retrofitting of existing bridges are listed in Table 1.2.

Table 1.2: Possible growth drivers for the assessment and retrofitting of existing bridges

Structure	Demand	Growth drivers
Bridges	Sustainable development	Using existing lines and crossings
	Security of use	Operational requirements for dimensions of bridges, clearances, etc., no disruption of traffic by maintenance and repair
	Safety	Load carrying capacity, resistance to accidental situations, seismic resistance
	Durability	Reduction of maintenance costs, enhancement of residual life

2.3 Potential for future development

General principles of sustainable development regularly lead to the need for extension of the life of the structure, in majority of practical cases in conjunction with severe economic constraints.

The approach for the assessment of existing structures is in many aspects different from that for designing new structures. The direct application of design-orientated methods to the assessment of existing structures often leads to a high degree of conservatism.

This is why the assessment of existing structures often requires the application of sophisticated methods, as a rule beyond the scope of design codes for new structures. New technical guidelines for the assessment and retrofitting of existing structures will provide the basis and give tools to master this new challenge.

2.4 Main topics for assessment

The fundamental requirements with regard to safety and serviceability and the principles of limit states for the design of new structures apply also for the existing structures. However the technical rules for the design often are not appropriate for the assessment. Whereas the design is taking into account uncertainties in the anticipated use of a structure, the assessment considers the history of a structure and the future use equally.

Design uncertainties arise from the prediction of load and resistance parameters of a new structure. These uncertainties represent the variability of a large population of structures caused by the unequal qualities of material and the different construction practices.

For the assessment of existing structures however, the effects of the construction process and subsequent life of the structure, during which it may have undergone alteration, deterioration, misuse and other changes to its as-built (as-designed) state, must be taken into account. It follows that inspections, examinations, and evaluations of existing structures will be an essential part of the assessment. The updating of information and data is one of the major tasks.

The main topics to be considered are therefore:

- methodology of collecting, evaluating and updating data
- recommendations for application of partial factor method and direct use of probabilistic methods consistent with those for new structures
- target reliability level of existing structures taking into account residual working life time, consequences and costs of safety measures
- assessment based on satisfactory past performance
- resistance models for the assessment of structural elements constructed with different material, detailing provisions and tolerance than those assumed in design standards.

Former editions of codes valid in the period when the structure was originally designed can be helpful as guidance documents to identify possible hot spots.

2.5 Main topics for the retrofitting

New technologies in retrofitting offer very efficient methods for improving the quality of existing structures in a general view and for upgrading their behaviour with regard to sustainability in particular. The design of remedial intervention is based on a strategic decision of the owner of an existing structure. Maintenance interventions have to consider technical, operational, and economic criteria.

Basic principles for retrofitting equal to any type of material and way of construction are:

- compatibility of structural components and materials of the old structure and the new structure in view of structural behaviour and durability, which leads to optimisation with synergic action
- as far as historic structures under protection of monuments are concerned: reversibility of the structural intervention so that future generations can modify the technology without any damage to the features of the historic construction.

Specific assessment and retrofitting methods are linked with regional peculiarities reflecting shortcomings in old national design or execution standards or the use of particular materials or building techniques.

Figure 1.3: Example for retrofitting of an existing bridge [06]

Figure 1.3 illustrates an example for the assessment and retrofitting of an existing motorway bridge after 35 years in use. The assessment and retrofitting was based on a detailed examination and updating of information (Figure 1.3, left). Corrosion of the reinforcement induced by deicing agents made the rehabilitation of the bridge deck necessary (Figure 1.3, right). Furthermore the frame structure was strengthened by external prestressing tendons to allow for the heavier traffic loads to be taken into account.

This bridge was one object of a series of about 220 bridges along a section of a motorway crossing the Swiss Alps, the condition of which has been systematically evaluated.

3 CEN/TC250 initiative / Mandate 515

3.1 Background and justification of the work with high priority

The CEN/TC250 initiative is motivated by the lack of an applicable set of European-wide technical rules to deal with the enormously expanding construction activities in assessing and retrofitting buildings and engineering works.

The approach to the assessment of an existing structure is in many respects different from that in designing new structures. The effects of the construction process and subsequent life of the structure, during which it may have undergone alteration, deterioration, misuse and other changes to its as-built (as-designed) state, need to be taken into account.

It is thus possible to obtain and gain more or less detailed information on a specific structure. This is one of the fundamental differences with respect to the methodology used for the design of new structures where uncertainties are dealt with by relying on information gained from experience.

In this respect the evaluation and updating of information with regard to the actions as well as with regard to the mechanical resistance is one of the key issues when assessing existing structures in order to reduce uncertainty.

The target reliability level for existing structures has to be examined taking into account the remaining service life time and the proportionality of interventions.

Concepts of interventions include long-term considerations and are obtained by optimisation of intervention variants as derived from the results of the examination and assessment.

The new strategy of continuing to use existing structures is of great significance due to environmental, economic and socio-political assets. It will be a new challenge, growing larger every year, for architects and engineers and a new focus for the construction industry with a new technical basis and a change of market and of the main activities.

This is why the assessment of existing structures often requires the application of refined methods that are beyond the scope of design codes for new structures. That is the reason that over the last 20 years, methodologies inherent to existing structures have evolved in many countries and applied on a national level. However they have not yet been generally adopted in broad practice. Therefore it is an urgent need for bringing together the different national approaches to a broadly accepted, coherent and harmonised set of rules for existing structures complementing those for the design of new structures.

The broad interest in the development of a European-wide harmonised and acknowledged coherent set of technical specifications (TS) or Eurocode parts for the assessment and retrofitting of existing structures is demonstrated by the impressive number of 41 highly motivated members in CEN/TC250/WG2 bringing in their specific expertise.

The general part of the set of new European technical rules for the assessment and retrofitting of existing structures is expected to serve as the basis for the development of the whole set implementing coherent rules for all types of structures and all materials.

3.2 Benefits of work items

The future of construction works should be closely governed by the sustainable development of urban and industrial areas and infrastructure, which results in modifications, replacement or extension of existing buildings and civil engineering works.

The retrofitting of structures offers very efficient ways for improving existing building envelopes and the creation of new, energy efficient ones with the introduction of new technologies for upgrading the quality of existing business, industrial and residential buildings.

The application of design-orientated methods to the assessment of existing structures often leads to a high degree of conservatism. This conservatism has severe economic, environmental and socio-political consequences when it results in satisfactory structures being condemned as unsafe, thereby leading to an unnecessary investment of resources in replacement or retrofitting, with its associated disruption.

Owners of existing structures, real estate agents and other partners interested in the technical performance of the structure ask questions about the reliability e.g. related to permissible loading. Bridge authorities are interested in agreed methods to assess the safety, and durability of existing bridges and to make appropriate provisions for more refined methods for evaluation and maintenance.

The consideration of sustainability aspects in the construction sector and joined with the considerable economic interests have been the main impulse to include in the European Commission Mandate [07] the work item of assessment and retrofitting of existing structure with a high priority.

3.3 Interface to the EN Eurocodes for structural design

The proposed new European technical rules for existing structures are related to the principles and fundamental requirements of the EN Eurocodes.

Thus, the technical rules for existing structures are not self-standing rules but they complement rules of the relevant EN Eurocodes (Figure 1.4) by identifying and distinguishing the differences between the design of new structures and the assessment and retrofitting of existing structures.

It is recommended that the part for the basis of assessment, complementary to the current EN 1990 for design, should address to the following items:

- General (scope, references, assumptions, terms and definitions)
- Requirements
- Updating information (general, actions, material properties, geometrical properties, structural models, resistances and deformations)
- Structural analysis and verifications (verification by partial factors, verification by probabilistic methods, risk analysis)
- Examination (procedures, condition survey, condition evaluation, concept of interventions)
- Interventions (retrofitting and modification, survey and monitoring, maintenance, immediate safety interventions).

It is recommended that the part interfacing EN 1991 for actions on structures should give methods for updating actions and describe specific load models for existing structures taking into account the future use of the structures.

It is recommended that the parts related to EN 1992 to 1997 and EN 1999 should give diversified methods and rules for updating specific material properties. In addition they may describe refined models for the analysis of the structural behavior and for the calculation of the structural resistance.

It is suggested that the standards for the different type of structures such as concrete, steel, composite steel and concrete, timber, masonry and aluminium structures should, where possible and reliable, provide provisions regarding characteristic values of building materials from the past as well as connections and structural details frequently used in existing structures.

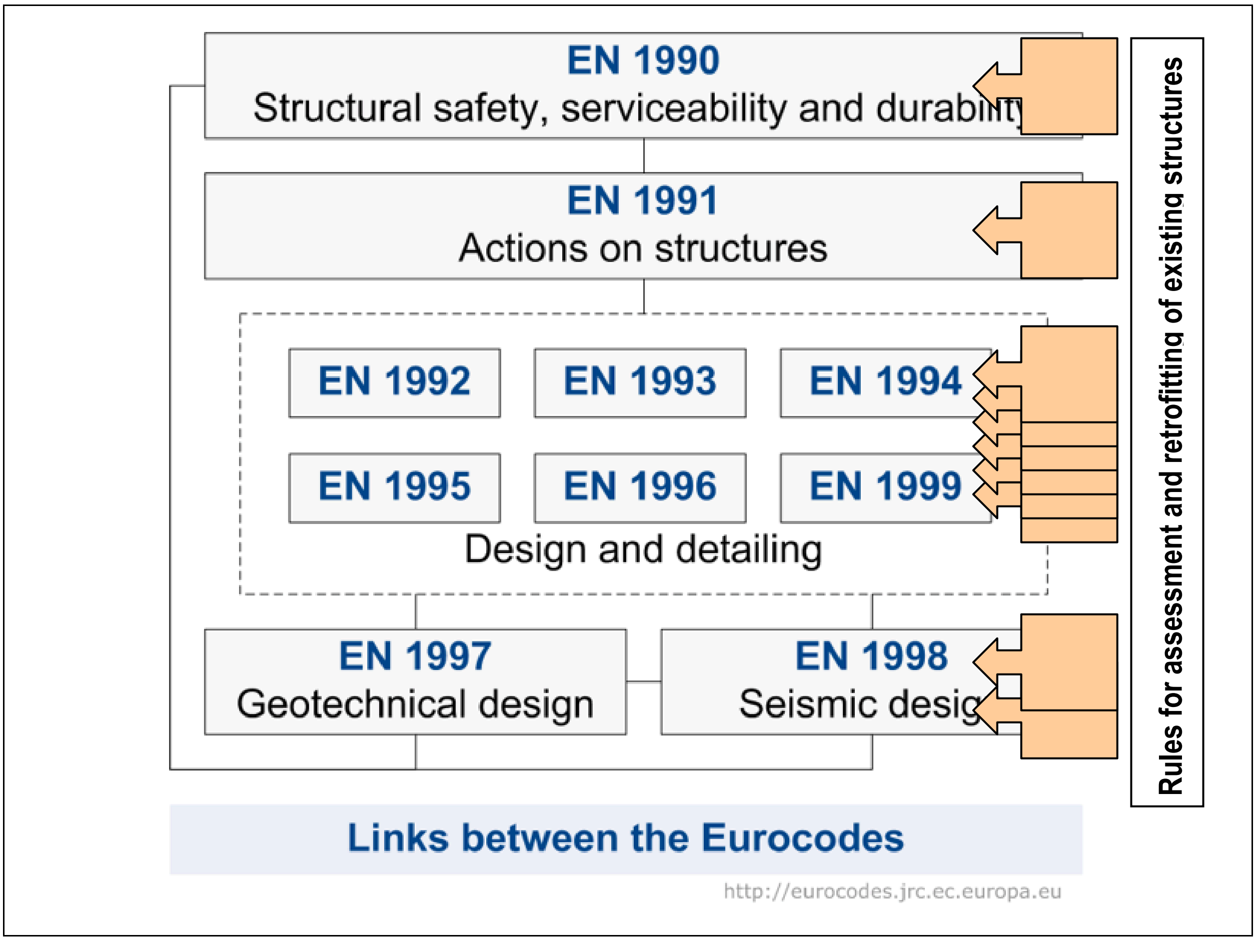

Figure 1.4: Links between the Eurocodes [07]

The material oriented parts should focus on the specific rules for updating information of material properties as well as on refined models for them.

In addition they may describe refined models for the analysis of the structural behavior at ultimate and serviceability limit states and for the calculation of the structural resistance.

The main issue of material oriented rules concerns the methodologies for concepts of interventions including retrofitting and strengthening existing structures.

4 Approach to execution of the Mandate

4.1 Work packages

The purpose of the Mandate M/515 [08] was to initiate the process of further development of the Eurocode system, incorporating both new and revised Eurocodes. The Mandate M/515 identifies two work packages. Package I is concerned with standards of general relevance and the production of a technical report on requirements for climate change. Package II is concerned with material specific standards, including new Eurocodes.

With regard to the new European technical rules for assessment and retrofitting of existing structures package I will include the general rules complementing EN1990 bases of structural design and those for actions complementing EN 1991 actions on structures.

The new European technical rules for the different type of structures such as concrete, steel, composite steel and concrete, timber, masonry and aluminium structures will be a subject of package II.

The specific aspects of assessment and retrofitting of existing structures exposed to seismic actions is the scope of Part 3 of EN 1998. Therefore the aspects with regard to seismic design are not treated in this work item.

4.2 Step-by-step development

The works of the future generation of Eurocodes will be performed in several steps:

- Step 1: Preparation and publication of a "Science and Policy Report", subject to agreement of CEN/TC250.
- Step 2: After agreement of CEN/TC250, preparation and publication of CEN Technical Specifications (previously known as ENV).
- Step 3: After a period for trial use and commenting, CEN/TC250 will decide whether the CEN Technical Specifications should be converted into Eurocode Parts.

As a conclusion, the procedure in several steps does not predetermine to draft immediately new Eurocodes or new Eurocode Parts. In fact the procedure allows for a progressive development, agreed by CEN/TC250, in order to take into account observations from national experts and users.

The production of Science and Policy Reports is declared as pre-normative work and as such will not be funded under Mandate M/515.

The preparation of the new European technical rules in step 2 could be initiated by CEN/TC250 after launching the Mandate M/515.

4.3 Organisation of work

4.3.1 Liaisons within CEN/TC250 family

In document [09] CEN/TC250 replies to the Mandate M/515 setting a detailed work programme together with additional supporting information.In this context the new European technical rules for the assessment and retrofitting of existing structures will be developed using the existing organization of CEN/TC250 (Figure 1.5).

The works are initiated and carried out by the Working Group WG2 "Assessment and retrofitting for existing structures" and supervised by CEN/TC250. The Working Group WG 2 will develop general rules for the assessment and retrofitting of existing structures on the one hand and it will provide guidelines for the different types of construction on the other hand.

The contributions of the subcommittees SC1 to SC9 could be developed if needed in subsidiary Working Groups (WG) of the relevant Subcommittees (SC) and coordinated within the CG (Coordination Group).

Thus in a first phase Working Group WG2 is acting as a Working Group in the sense of the CEN rules. In a later phase Working Group WG2 adapts the function of a Horizontal Group according to the definition of CEN/TC250.

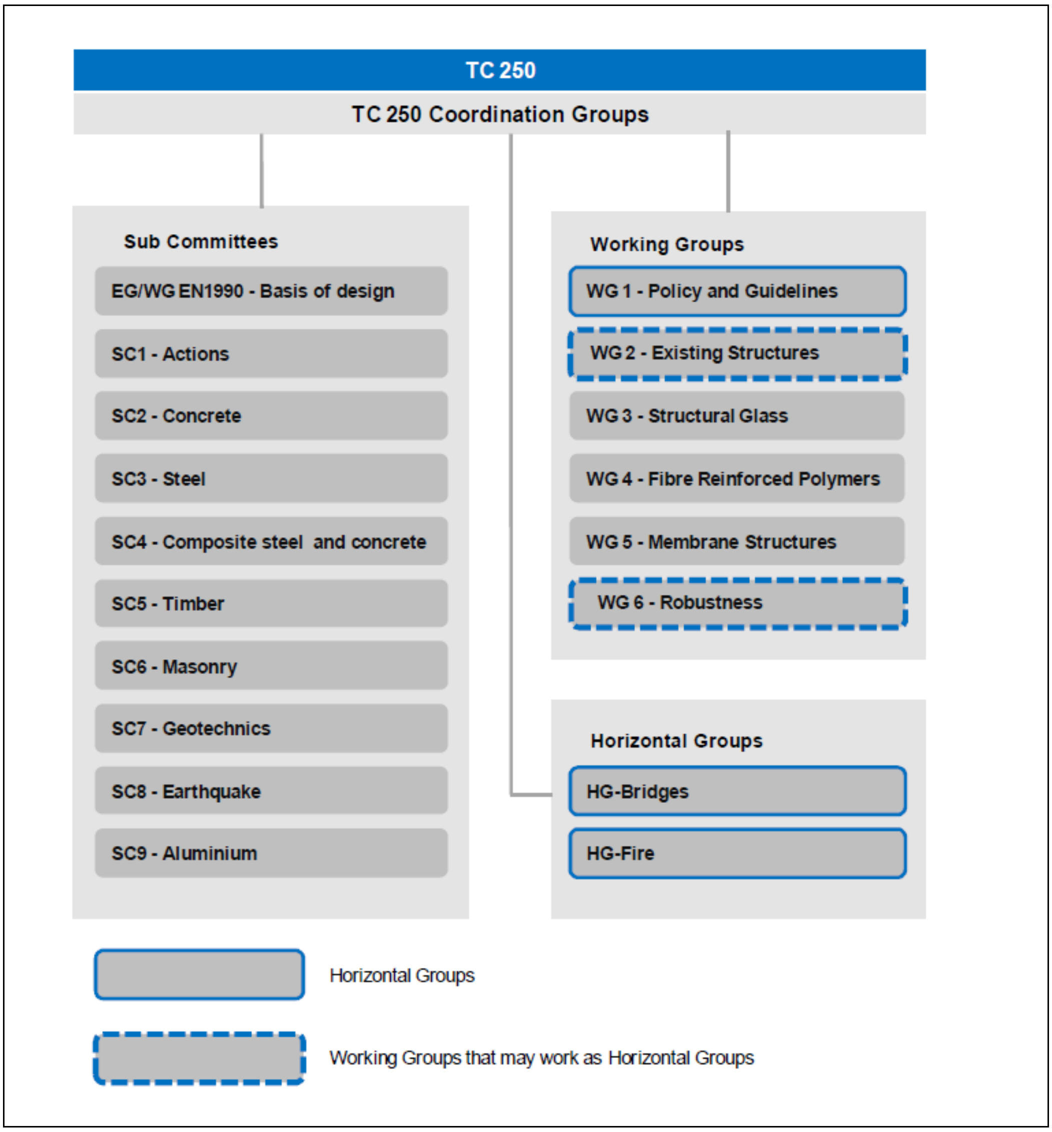

Figure 1.5: Diagram showing the CEN/TC250 structure [09]

4.3.2 Liaisons with other organisations

The main task of CEN/TC250/WG2 is not to undertake research work. In fact CEN/TC250/WG2 will be in close contact with scientific organisations. In consequence CEN/TC250 is responsible for implementation of results of research in codes of practice

In particular with regard to the new European technical rules for the assessment and retrofitting of existing structures, the following organizations as stakeholders will be involved and consulted:

- National Standardisation Bodies
- CEN Committees for construction products, construction materials, execution and testing
- ISO in their development of ISO 13'822 Bases for design of structures - Assessment of existing structures

- Government organizations involved in Building and Construction Regulations, and trade relating to construction.
- Professional Bodies (e.g. National and European Associations representing Consulting Engineers, Designers and Contractors)
- International Scientific and Technical Organisations (e.g. fib, ECCS, JCSS, IABSE, etc.)
- EOTA
- Certification bodies
- Producers of construction products and materials who rely on existing structures for their structural parameters
- And others.

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NEW EUROPEAN TECHNICAL RULES FOR THE ASSESSMENT AND RETROFITTING OF EXISTING STRUCTURES

PART II: EXISTING NATIONAL REGULATIONS AND STANDARDS IN EUROPE

Contents Part II

MEMBER STATE	CYPRUS (CY)
Title	CYS EN 1998-3 Assessment and Retrofitting of Buildings
Status	Compulsory implementation through the Buildings and Streets Law and Regulations
Year of implementation	1 January 2012

1 Executive summary

Cyprus is located in a seismically active zone, therefore it is required that structures are designed to resist earthquake forces. In spite of this fact, many structures have been designed for gravity loads only, since the first earthquake design guidelines were introduced in 1986 and the first Seismic Design Code was implemented on a voluntary and compulsory basis in 1992 and 1994, respectively. Therefore, more than 70% of the building stock was designed for gravity loads only and retrofitting of these structures is required.

On January 1st 2012, all Eurocodes were introduced in Cyprus as compulsory Standards through the Buildings and Streets Law and Regulations, including CYS EN 1998-3 Assessment and Retrofitting of Buildings, along with the associated National Annexes in which the National Choices for the Nationally Determined Parameters are specified for each code part. The design for any building that is now retrofitted needs to follow the provisions of CYS EN 1998-3. It should be noted that these provisions apply to buildings only and that there are no codes or guidelines for other types of structures such as bridges etc.

2 General

The scope of CYS EN 1998-3 is

- To provide criteria for the evaluation of the seismic performance of existing individual building structures.
- To describe the approach in selection necessary corrective measures.
- To set forth criteria for the design of retrofitting measures (i.e. conception, structural analysis including intervention measures, final dimensioning of structural parts and their connections to existing structural elements). It is noted that for the purposes of this standard, retrofitting covers both the strengthening of undamaged structures and the repair of earthquake damaged structures

This standard covers the seismic assessment and retrofitting of buildings made of the more commonly used structural materials: concrete, steel and masonry through Annexes A, B and C, respectively. It is stated in the standard that although its provisions are applicable to all categories of buildings, the seismic assessment and retrofitting of monuments and historical buildings often requires different types of provisions and approaches, depending on the nature of the monuments.

It is also stated, that since existing structures: i) reflect the state of knowledge at the time of their construction, ii) possibly contain hidden gross errors, iii) may have been submitted to previous earthquakes or other accidental actions with unknown effects, structural evaluation and possible structural intervention are typically subjected to a different degree of uncertainty (level of knowledge) than the design of new structures. Different sets of material and structural safety factors are therefore required, as well as different analysis procedures, depending of the completeness and reliability of the information available.

3 Basic requirements
The fundamental requirements refer to the state of damage in the structure, which in the code are defined through three Limit States (LS, namely Near Collapse (NC), Significant Damage (SD), and Damage Limitation (DL):

- LS of Near Collapse (NC). The structure is heavily damaged, with small residual strength and stiffness, although vertical elements are still capable of sustaining vertical loads. Most non-structural components have collapsed. Large permanent drifts are present. The structure is near collapse and would not survive another earthquake, even of moderate intensity.
- LS of Significant Damage (SD). The structure is significantly damaged, with some residual strength and stiffness, and vertical elements are capable of sustaining vertical loads. Non-structural components are damaged, although partitions and infills have not failed out-of-plane. Moderate permanent drifts are present. The structure is likely to be uneconomic to repair.
- LS of Damage Limitation (DL). The structure is only lightly damaged, with structural elements prevented from significant yielding and retaining their strength and stiffness properties. Non-structural components, such as partitions and infills, may show a diffused state of cracking that could however be economically repaired.

According to the National Annex of CYS EN 1998-3Buildings of importance class IV (as defined in Table 4.3 of CYS EN 1998-1:2004) should be checked for all three Limit States defined in 2.1(1)P of CYS EN 1998-3:2005. For the other importance classes the number of limit states to be checked shall be agreed between the owner and the designer.

In addition, in the National Annex it is stated that the return periods specified for the various Limit States shall be agreed between the owner and the designer. The protection normally considered appropriate for ordinary new buildings is considered to be achieved by selecting the following values for the return periods: 2.475 years, corresponding to a probability of exceedance of 2% in 50 years for the LS of Near Collapse (NC), 475 years, corresponding to a probability of exceedance of 10% in 50 years for the LS of significant Damage (SD), and 225 years, corresponding to a probability of exceedance of 20% in 50 years for the LS of Damage Limitation (DL).

4 Framework of assessment and retrofitting
According to EC8 part 3, in In assessing the earthquake resistance of existing structures, taking also into account the effects of actions in other design situations, the input data shall be collected from available records, relevant information, field investigations and, in most cases, from in-situ and/or laboratory measurements and tests. In general, the information for structural evaluation should cover the following points:

a) Identification of the structural system and of its compliance with the regularity criteria in 4.2.3 of EN 1998-1. The information should be collected either from onsite investigation or from original design drawings, if available. In this latter case, information on possible structural changes since construction should also be collected.
b) Identification of the type of building foundations.
c) Identification of the ground conditions as categorized in 3.1 of EN 1998-1.
d) Information about the overall dimensions and cross-sectional properties of the building elements and the mechanical properties and condition of constituent materials.
e) Information about identifiable material defects and inadequate detailing.
f) Information on the seismic design criteria used for the initial design, including the value of the force reduction factor (*q*-factor), if applicable.
g) Description of the present and/or the planned use of the building (with identification of its importance category, as described in 4.2.5 of EN 1998-1).

h) Re-assessment of variable loads considering the use of the building.
i) Information about the type and extent of previous and present structural damages, if any, including earlier repair measures.

Depending on the amount and quality of the information collected on the points above, different types of analysis and different values of the partial safety factors are adopted.

5 Updating information

According to EC8 part 3 a knowledge level (KL) has to be determined, which controls the type of analysis that can be used and the confidence factor (CF). The knowledge level depends on the available information for the structure, the extent of inspection of the geometry and the details, as well as on the extent of testing for obtaining the material properties. These are summarized in Table 3.1 of EC8 part 3.

Knowledge Level	Geometry	Details	Materials	Analysis	CF
KL1	From original outline construction drawings with sample **visual** survey ***or*** from **full** survey	Simulated design according to relevant practice ***and*** from **limited** *in-situ* inspection	Default values according to standards of the time of construction ***and*** from **limited** *in-situ* testing	LF-MRS	CF_{KL1}
KL2		From incomplete original detailed construction drawings with **limited** *in-situ* inspection ***or*** from **extended** *in-situ* inspection	From original design specifications with **limited** *in-situ* testing ***or*** from **extended** *in-situ* testing	All	CF_{KL2}
KL3		From original detailed construction drawings with **limited** *in-situ* inspection ***or*** from **comprehensive** *in-situ* inspection	From original test reports with **limited** *in-situ* testing ***or*** from **comprehensive** *in-situ* testing	All	CF_{KL3}

NOTE The values ascribed to the confidence factors to be used in a country may be found in its National Annex. The recommended values are CF_{KL1} = 1,35, CF_{KL2} = 1,20 and CF_{KL3} = 1,00.

The recommended values for the CF for each of the knowledge levels (KL) are adopted in the Cyprus National Annex.
The recommended minimum requirements for different levels of inspection and testing, which are adopted in the Cyprus National Annex, are given in table 3.2 of EC8 part 3.

	Inspection (of details)	Testing (of materials)
	For each type of primary element (beam, column, wall):	
Level of inspection and testing	Percentage of elements that are checked for details	Material samples per floor
Limited	20	1
Extended	50	2
Comprehensive	80	3

According to the code, mean values of material properties shall be used in the structural model.

6 Structural analysis and verifications

The seismic action effects, to be combined with the effects of the other permanent and variable loads in accordance with the seismic combination, may be evaluated using one of the following methods:

- lateral force (LF) analysis (linear),
- multi-modal response spectrum (MRS) analysis (linear),
- non-linear static (pushover) analysis,
- non-linear time history dynamic analysis
- q-factor approach

Limitations in the use of each of the above methods are specified in the code.

Table 4.3 of the code summarises:

- The values of the material properties to be adopted in evaluating both the demand and capacities of the elements of all types of analysis.
- The criteria that shall be followed for the safety verification of both ductile and brittle elements for all types of analysis.

Type of element or mechanism (e/m)		Linear Model (LM) Demand	Linear Model (LM) Capacity	Nonlinear Model Demand	Nonlinear Model Capacity	q-factor approach Demand	q-factor approach Capacity
	Ductile	Acceptability of Linear Model (for checking of $\rho_i = D_i/C_i$ values): From analysis. Use mean values of properties in model.	In terms of strength. Use mean values of properties.	From analysis. Use mean values of properties in model.	In terms of strength. Use mean values properties divided by CF and by partial factor. In terms of deformation. Use mean values of properties divided by CF		In terms of strength. Use mean values of properties divided by CF and by partial factor.
		Verifications (if LM accepted): From analysis.	In terms of deformation. Use mean values of properties divided by CF.				
	Brittle	Verifications (if LM accepted): If $\rho_i \leq 1$: from analysis. If $\rho_i > 1$: from equilibrium with strength of ductile e/m. Use mean values of properties multiplied by CF.	In terms of strength. Use mean values of properties divided by CF and by partial factor.		In terms of strength. Use mean values of properties divided by CF and by partial factor	In accordance with the relevant Section of EN1998-1: 2004.	

7 Interventions

On the basis of the conclusions of the assessment of the structures and/or the nature and extent of the damage, decisions are taken of the intervention. The selection of the type, technique, extent and urgency of the intervention is based on the structural information collected during the assessment of the building.

An intervention may be selected from the following indicative types; one or more types in combination may be selected. In all cases, the effect of structural modifications on the foundation shall be considered.

a) Local or overall modification of damaged or undamaged elements (repair, strengthening or full replacement), considering their stiffness, strength and/or ductility of these elements.
b) Addition of new structural elements (e.g. bracings or infill walls; steel, timber or reinforced concrete belts in masonry construction; etc).
c) Modification of the structural system (elimination of some structural joints; widening of joints; elimination of vulnerable elements; modification into more regular and/or more ductile arrangements)
d) Addition of a new structural system to sustain the entire seismic action.
e) Possible transformation of existing non-structural elements into structural elements.
f) Introduction of passive protection devices through either dissipative bracing or base isolation.
g) Mass reduction.
h) Restriction or change of use of the building.
i) Partial demolition

In all cases, the documents relating to retrofit design shall include the justification of the type of intervention selected and the description of its expected effect on the structural response, which should be made available to the owner.

The retrofit design procedure shall include the following steps: a) Conceptual design, b) Analysis, c) Verifications.

MEMBER STATE	CZECH REPUBLIC (CZ)
Title	ČSN ISO 13822 Bases of design – Assessment of existing structures ČSN 73 0038 Assessment and verification of existing structures – Supplementary guidance
Status	Czech technical standards; connection with Regulation 268/2009 on technical requirements on construction works
Year of implementation	intended to be issued in 12/2014 (presently is valid CSN ISO 13822:2005)

1 Executive summary

ISO 13822 was implemented and the set of National Annexes was developed for the assessment of existing structures in the Czech Republic in 2005 (as CSN ISO 13822). Presently a revised version of ISO 13822 is going to be implemented and a set of National Annexes in CSN 73 0038 is developed.

2 General

Apart from introductory chapters, the standard CSN 73 0038 includes:
Chapter 4 Complementary guidance for the basis of assessment of existing structures
Chapter 5 Testing of existing structures and materials
Chapter 6 Assessment of existing concrete structures
Chapter 7 Assessment of existing steel, cast iron and composite steel concrete structures
Chapter 8 Assessment of existing timber and timber concrete structures
Chapter 9 Assessment of existing masonry structures
Chapter 10 Assessment of existing bridges
Chapter 11 Assessment of existing heritage structures.

3 Basic requirements

Basic requirements on existing structures given in ISO 13822 should be fulfilled. Reliability level recommended in ISO 13822 for existing structures is accepted.

4 Framework of assessment and retrofitting

The general framework for the assessment and retrofitting of existing structures is given in CSN ISO 13822 and CSN 73 0038.

5 Updating information

The general framework for the updating based on Bayesian theorem is given in CSN ISO 13822 and CSN 73 0038.

6 Structural analysis and verifications

The structural verification is based on presently valid standards (presently on nationally implemented Eurocodes).

7 Interventions

Principle of minimum interventions should be taken into account. Basic guidance on intervention of existing structures is given in ISO 13822. Design and verification of interventions should be according to CSN Eurocodes.

MEMBER STATE	**DENMARK (DK)**
Title	Overview of DK position on national regulations and guidance for the assessment of existing Structures
Status	While there are no specific DK national ‘building’ regulations concerned solely with the assessment and retrofitting of existing structures, certain requirements relating to existing buildings are set down in a new SBi Guideline with the working title “Assessment of safety of existing structures”. There is established national guidance concerned with the assessment and retrofitting of some specific classes of existing structures, such as railway and road bridges. The following provides a simplified overview of the regulatory requirements for Denmark and the associated professional technical guidance which has been developed for the assessment of existing buildings and structures.
Year of implementation	Varies - depends upon the source document. The regulatory requirements for existing buildings and the professional guidance for the assessment of existing structures have existed for a number of decades.

1 Executive summary

Buildings - Regulatory requirements:

Current Danish Building Regulation (BR10) has no explicit rules for safety of existing structures, except that the safety is regarded as acceptable, if the structure is in accordance with regulations and standards at the time of construction. Guideline 230 from Danish Building Research Institute (SBi) on BR10 explains and interprets the provisions of the Regulations. The Guideline refers to relevant standards, other guidelines and relevant background material that provide more detailed information.

Buildings – Technical guidance on structural appraisal procedures to meet the regulatory requirements:

Until now no technical guidance on structural appraisal procedures has been developed for existing buildings. However, a new SBi Guideline 248 entitled “Assessment of safety of existing structures” is to be issued January 2015. The guideline describes how information can be provided and provides guidance for how this knowledge can be utilized in the safety assessment. Further, a new SBi Guideline 249 describes assessment of material properties of old masonry structures.

Road and railway bridges:

Normally, assessment and retrofitting of existing bridges are carried out based on supplementary rules and guidelines that are integrated parts of the following documents:

1. Guidance to Load and design specifications for bridges (road and pedestrian), Danish Road Directorate
2. Load and design specifications for railway bridges and earthworks, BN1-59, Net Rail Denmark

The supplementary rules and guidelines are carried out in a similar way in both documents. Basically, no distinctions are made between new and existing bridges regarding safety level. And basically, the same capacity models for members and sections are used. The differences are explained below.
Both documents allow for the application of probabilistic methods as explained below.
Besides, the following document applies as a Guideline Document for road bridges: "Reliability-Based Classification of Load Carrying Capacity of Existing Bridges", Report 291, Danish Road Directorate 2004.

This guideline has been prepared because it is often possible to obtain a satisfactory load-carrying class for an existing bridge by using probabilistic methods. Existing bridges are first classified using traditional deterministic methods, where after a reliability-based classification may be desirable in order to obtain a more realistic capacity and the possibility to avoid costly strengthening works or replacement. The purpose of this guide is to create a uniform basis for the reliability-based classification of the Road Directorate's bridges.

The guide has been prepared by a working group with participants from Ramboll as well as COWI and the Road Directorate having the steering role. Even though the document is not to be found on home page of Danish Road Directorate it is referred to in the Specifications for calculation of bridges, and yet it is still somehow considered the governing document for reliability based assessment of road bridges.
In the last 10 years the probabilistic methods has been used less frequently when assessing road bridges in DK. However, partial factors are still from time to time calibrated for a given safety level for some of the large international projects.

Other existing structures:
There are various types and classes of existing structure which are subject to special control requirements under legislation, typically for health and safety reasons, such as offshore platforms and some forms of industrial plants. There may be special requirements and procedures for the structural assessment of these structures. These special requirements are not considered here.

2 General
Buildings:
The above cited documents present varying degrees of technical guidance upon the procedures to be followed in structural assessment, the assumptions which may be made and various other items, such as material strengths and other properties that might be used in calculations, and other factors such as the types of deterioration which might occur.
While the philosophy employed is typically based upon the use of the partial safety factor approach for structural calculations, and what modifications which might be made to the magnitude of the partial safety factors used for design, it is also recognized that not all forms of existing buildings and structures are amenable to this approach. The use of appropriate engineering judgement is encouraged under such circumstances. Disparities occur between aspects of the detailing and forms of construction of existing buildings and structures and the assumptions (implicit and explicit) associated with some design equations presented by more modern design codes.
For older types of existing buildings and structures, there are no applicable modern design codes which might be adopted, although the Danish Agency for Palaces and Cultural Properties as well as local building authorities might give some directions on certain types of structures; e.g. structures of natural stones and old masonry structures, typically based on traditional construction practices and original legislation.

Road and railway bridges:
As mentioned above, the supplementary rules and guidelines for assessment of bridges are integrated parts of the following documents:

1. Guidance to Load and design specifications for bridges (road and pedestrian), Danish Road Directorate
2. Load and design specifications for railway bridges and earthworks, BN1-59, Net Rail Denmark.

Basically, no distinctions are made between new and existing bridges regarding safety level. And basically, the same capacity models for members and sections are used. The differences are explained below.
The supplementary rules and guidelines are carried out in a similar way in both documents:

a) Loads models for classification of road bridges (load capacity evaluation) that reflect the actual max allowed heavy transports on the Danish roads are used. A special model for the dynamic factor is applied. These load models substitutes the loads models in EN 1991-2. The load combinations are slightly modified compared to the load combinations for new bridges in EN1990/A1 DK NA. Design of rehabilitation and strengthening works is usually based on the same load models as for the classification/load capacity evaluation of bridges.
b) Load models for existing railway bridges are based on UIC Code 700 O with slightly modified load models for braking loads and nosing forces. Special fatigue models are established for railway bridges in order to take into account the previous load history of the bridge.
c) The capacity evaluation of members and cross-sections are basically based on the same codes as for new bridges, i.e. the same capacity models are used. However, special rules have been set-up of how to determine the properties of the existing structures, for example strength properties for an old reinforced concrete bridge (concrete, reinforcement). In addition to that, rules are set-up of how to adjust the partial safety factors taking into account that strength properties were determined in another way in previous times and the production conditions were different. Further, rules are setup of how to determine for instance the characteristic concrete strength from tests on site.
d) Possible deterioration shall be taken into account, e.g. loss of area of reinforcement and prestressed steel as well as a possible impact on the ductility of the steel.
e) For road bridges mainly, more advanced capacity models may be used in few cases, for instance regarding shear capacity evaluation of concrete structures (crack slide theory, the effect of bent-up bars, the effect of arching close to the support) provided that this is approved by the Owner. Also plastic methods for concrete members may be used (lower and upper bound solutions for concrete slabs and beams) proven that the ductility is satisfactory.
f) Both documents allow for the use of probabilistic methods as explained below.

As an example with regards to the application of probabilistic methods, Net Rail Denmark may dispense with the use of partial safety factor method if the following requirements are met:

1. The consultant shall, prior to solving the task to prove that he has experience in solving similar responsibilities.
2. Acceptance of the application of probabilistic methods is given only for the Verification of existing designs and only for specifically defined tasks where it would be an obvious advantage to use these methods.
3. The resistance demonstrated by means of probabilistic methods can never number more than a maximum of 20 years into the future, and it must always appear in the calculation, the traffic volumes and the projections used for the calculation. In addition, the sensitivity of the calculation result of variations in the assumed traffic volume is calculated.
4. The result of the demonstrated the capacity must include an overview of the associated control and inspection activities by the life expectancy. Using probabilistic tools for confirmation of the resistance, the result is always as a result of the above, be limited in time.
5. The target reliability index must comply with Nordic Committee for Building Structures. Recommendation for loading and safety regulations for structural design, NKB Report, No. 55. One must consider 1 year reference period of the target reliability. However, the JCSS target reliabilities that depend on consequences of failures and cost of safety measures respectively (monetary optimization), see also the new version of ISO 2394, have been used recently as the basis for strengthening of bridges with regards to the risk of ship impact. This approach is assumed to be common practice in Denmark in the future for both bridges and buildings in cases, where larger investments are needed for retrofitting and strengthening of existing structures.

No specific observations are offered in the following sections because of the diversity of the technical guidance that exists in the absence of a specific DK national ‘building’ regulation and associated technical guidance regarding assessment and retrofitting of existing structures.

3 Basic requirements See above.
4 Framework of assessment and retrofitting See above.
5 Updating information See above.
6 Structural analysis and verifications See above.
7 Interventions See above.

MEMBER STATE	FRANCE (FR)
Title	State of the art for the assessment and the retrofitting of existing bridges of the national road network, Cerema
Status	Guide
Year of implementation	Soon published

1 Executive summary

It does not exist official French texts related with the assessment and the retrofitting of existing structures. The methods used may vary according to the types of structure, the design offices and the owners. This paper presents the general trends for four cases:

- National road network bridges
- Buildings
- Railway bridges
- Subway tunnels and bridges in Paris

2 General

<u>- National road network bridges</u>

Practices relating to national road network bridges are very homogeneous and are consistent with ISO 13822 standard. A guide describing these practices «State of the art for the assessment and the retrofitting of existing bridges of the national road network» is about to be published.

Eurocodes for new structures are used, but they are adapted to take into account the knowledge of the bridges.

<u>- Buildings</u>

In France, there is no specific regulation for retrofitting of buildings, except for seismic actions since the introduction of Eurocode 8, part 3. However, in 1982, it has been created an organization called STRRES (Syndicat national des entrepreneurs spécialistes de travaux de réparation et de renforcement des structures : http://www.strres.org/). This organization has published a few technical guidelines for retrofitting of buildings. These guidelines have been applied in a various types of buildings but they are still simple technical documents, without any prescription in national regulation. Up to now, the retrofitting of buildings is done by experimented engineers, with their own knowledge and under their own responsibility.

In a similar way, the retrofitting and renovation works, and more particularly the works implemented for transformations of buildings, are made by specialized contractors, with overskilled workers, under the control of qualified independent engineers.

<u>- Railway bridges</u>

If we do not consider the high-speed lines built from 1975, most French railways were built between 1850 and 1920. Therefore, very few bridges still in use have been designed with the Eurocodes. For this reason, the compatibility between old bridges and loads they support nowadays is a topic that the French railway company (SNCF) has taken into account for a long time.

<u>- Subway tunnels and bridges in Paris (RATP)</u>

All the structural assets of the railway infrastructure belonging to RATP are subjected to periodic inspection.

Principal inspections are carried out every five years. Superficial inspections are carried out every 18 months, in average.

Assessment of an existing structure is done in case of structural damage or in case of change in the loads.

3 Basic requirements

<u>- National road network bridges</u>

For ULS, the level of reliability required for an existing structure is comparable to that of new bridges.

For SLS, the level may be lower. For example, if no crack is found and if theoretically the requirements of SLS are not met, no action will be performed because of the SLS.

<u>- Railway bridges</u>

There is no SLS or ULS verification like for new bridges, according to the Eurocodes or other Limit States rules.

Each sensitive old railway bridge (metal, reinforced concrete or mixed steel-concrete) has been checked by determining its resistance according to directives established in 1930 (*) which classified the structures by category (C4, D4 ...) corresponding to a coach diagram (C4, D4 ...). This regulation has been integrated in the EN15528 standard (**).

(*) - 7 august 1930 Rules about surveying of metallic bridges

(**) - EN 15528:2008 Railway applications — Line categories for managing the interface between loads limits of vehicle and infrastructure

Their load-bearing capacity is, indeed, for many old bridges, lower than new bridges designed and built with the Eurocodes (UIC71, SW ...). And their safety level is less important than that of a modern structure. However, the safety of these bridges remains acceptable nonetheless.

Surveying these structures may also detect certain pathologies that must be taken into account in maintenance policy of the French railways. Safety is indeed based on a global policy that may not be reduced to sole design rules.

Safety of old railway bridges, or simply their compatibility with railway trains, is based on:

- checking that the structure may theoretically carry the trains; this verification takes the speed of the trains into account;
- a detailed survey, appropriated to each type of structures;
- an adapted maintenance policy (repair, reinforce, replace) taking into account the two previous items

<u>- Subway tunnels and bridges in Paris (RATP)</u>

Practices relating to Subway tunnels and bridges in Paris (belonging to RATP) are homogeneous and consistent with ISO 13822 standard. Loads for the metro and RER (regional transit express network) are specified in a RATP document.

4 Framework of assessment and retrofitting

<u>- National road network bridges</u>

Structural assessment is carried out in several stages, more and more complicated, as shown in the table below from the BRIME report.

Assessment level	Resistance Load Model	Calculation Model for efforts	Type of analysis
0	No formal assessment (no worry about the structural condition)		
1	Models used for design	Simple	Semi-probabilist analysis
2	Material Properties coming from the bridges file or from standards	Refined	Partial Safety Coefficients at ULS (and SLS if necessary)
3	Models based on tests, investigations, observations on site, etc.	Refined	
4	Material Properties based on tests		Adaptation of Partial Coef.ULS
5	Probabilistic Distribution of all variables	Refined	Full reliability Analysis

<u>- Railway bridges</u>
The resistance calculations (see above) are updated in case of significant changes in the structural condition observed during survey.

<u>- Subway tunnels and bridges in Paris (RATP)</u>
The assessment of existing structures depends of the kind of structure and of the material used:
<u>Masonry tunnels and bridges</u>: no code available, when necessary the strength assessment is carried out by different kind of methods. This goes from very simple analytical methods to nonlinear finite element calculations in order to take into account the soil-structure interaction (for tunnels) and the cracks in the masonry lining.

Metallic bridges and cover:
For the structures built before 1930, the assessment is carried out in accordance to a text of 1930 (Circulaire du 7 août 1930 relative à la surveillance des ouvrages métalliques). This text describes how to use the code of 1927 for assessing metallic bridges designed with the code of 1891 or 1915. Calculation according to more recent codes (fascicule 61 titre V or Eurocodes) may also be done for comparison.
For the structures built between 1930 and 1960, the assessment is done in accordance the code of 1927 for metallic bridges and “Circulaire du 7 août 1930”. Calculation according to more recent codes (fascicule 61 titre V or Eurocodes) may also be done for comparison.
For the structures built after 1960 calculation according to the code used for the design (fascicule 61 titre V – editions: 1960 – 1970 – 1978) are performed. Calculation according to more recent codes (fascicule 61 titre V 1978 or eurocodes) may also be done for comparison.
Notes:
The greater part of RATP steel bridges and covers are more than 100 years old, and have been calculated with the design code for steel structure of 1891.
Some part of the bridges (column) are made of wrought iron : Eurocode is not relevant.
Fatigue for riveted bridge component is not described in Eurocodes.
Reinforced concrete structures: mainly ultimate limit state verification.
Prestressed concrete structures: very few cases of reassessment.
Geotechnical structures: it is very difficult to do the assessment of such structures when they are more than 70 years old. For example, in the case of retaining walls, geotechnical parameters were very different from those used now, friction angle $\varphi = 45°$ was very common. Moreover, most of retaining walls were built in masonry.

5 Updating information
- National road network bridges
For bridges built since 1960, materials characteristic values are derived values from the construction documents according to conversion factors. For bridges built before 1960, investigations are generally carried out for the update.
A lot of information on materials for existing bridges relevant for assessment and retrofitting (characteristics of steels, of prestressing, former regulations since 1852, papers, etc.) are freely downloadable from the website Cerema.
Eurocode traffic loads are generally used, but other values derived from traffic measurements (weight and axle spacing) may also be considered for a particular bridge.
- Railway bridges
For bridges built since 1930, materials characteristic values are derived values from the construction documents according to conversion factors. For bridges built before 1930, investigations are generally carried out for the update.
The resistance calculations are updated in case of significant changes in the structural condition observed during survey.

6 Structural analysis and verifications
- National road network bridges
Partial factor method is used.
Based on measurement results and knowledge of the bridge, adaptations of Eurocodes for new bridges are carried out. For example, studies are underway to provide adequate safety factors depending on the outcome measures (mean and coefficient of variation) for different families of bridges without reducing the level of reliability.

<u>- Railway bridges</u>
When the structure performance is suitable (C4, D4 ...) according to the criteria of this specific regulation, only trains using coaches compatible with the category (C4, D4 ...) may drive upon the bridge. The speed, in some cases, may be adapted to reduce stresses.
This regulation is adapted to the different materials used, depending on the time of construction, and defines:
- the different safety factors (currently under the form of acceptable strains);
- calculating methods aimed to determine the bridge resistance margins with regards to coaches (C4, D4 ...); those methods facilitate studies including the eligibility of certain exceptional trains.
The calculation rules of old structures (and in particular the safety factors adopted) must furthermore be closely related to the maintenance policy adopted on the network.
No partial factor method is used (see above).

<u>- Subway tunnels and bridges in Paris (RATP)</u>
The kind of structural analysis performed has to be consistent with the code used for the verification. It means simple methods are used with old codes. For example, old metallic truss bridges were calculated using isostatic models, even if truss members were clamped. In this case, if the old code is used for the assessment, the isostatic model will also be used.

7 Interventions
<u>- National road network bridges</u>
According to the result of assessment and the desired lifetime and service level, operational interventions may comprise intensified surveying, restrictions in the use or repair of the structure.

<u>- Railway bridges</u>
Each bridge (the 100,000 structures of the French rail network are concerned) benefits from a systematic and targeted survey which is adapted to the level of risk. The parameters for this adaptation are:
- cycles and types of visits;
- the competence level of professional staff according to the types of structures.
The achievement of these survey activities by internal staff to the railway network and therefore specially trained to the specificities of railway bridges is a national will to ensure an optimum level of diagnostics performed during these survey actions.
Corrective or preventive maintenance operations are deduced from survey activities mentioned above. Decisions to repair, reinforce or replace are, for each structure, based on a risk analysis that takes into account the load-bearing capacity, the observations made on the structural condition, diagnostics made by the various experts and costs associated with different choices.
Safety of railway bridges is based on all these actions and analyzes.

<u>- Subway tunnels and bridges in Paris (RATP)</u>
Idem to national road network bridges.

MEMBER STATE	GERMANY (DE)
Title	German Society for Concrete and Construction Technology – Guideline: Modified Partial Factors for Reinforced Concrete Members
Status	Guideline
Year of implementation	2013

1 Executive summary

Reconstruction of existing buildings is an increasing task for designers and companies. As opposed to new buildings, additional information can be gained and used beneficially in design. This Guide to Good Practice shows a possibility to modify partial factors for materials in ULS-design of reinforced concrete members considering the existing mechanical properties including their statistical evaluation. Reserves of resistance up to approximately 10 % to 20 % may be activated under defined special conditions.

The theoretical background of the guideline is summarized in “DBV-Heft 24”. Furthermore, this report comprehends lots of additional information about the safety concept and design philosophy of existing structures on the basis of DIN EN 1990. The verification of the modified partial factors for building constructions is performed by a probabilistic parameter verification.

2 General

The guideline gives a procedure for modifying partial factors on the basis of material test results on concrete structures under defined conditions. Furthermore, a description, of how to execute a qualified assessment of existing structures is included.

3 Basic requirements

For materials modified partial factors can be used in ULS-design, if:

- the existing structure is concepted for the standard reference period of 50 years;
- the structure has been operated for other use than designed for more than 5 years after bringing into service;
- the structure is free of damage (no signs of crack formation, plastic deformation, overloading, etc.);
- there are only dead loads, predominantly static loads ($Q_k \leq 5{,}0$ kN/m²) and single loads ($G_k + Q_k$) $\leq 7{,}0$ kN as well as usual wind and snow actions (standard civil construction engineering) on the structure;
- the load ratio is within $1{,}0 \geq G_k / (G_k + Q_k) \geq 0{,}5$;
- the structure is made out of concrete or reinforced concrete with strength classes C12/15 to C50/60;
- the geometric tolerances are within EN 13670 or they have to be detected on the structure.

4 Framework of assessment and retrofitting

The safety assessment of an existing building differs from that of a new one in essential ways. In contrary to new structures, the characteristic material parameters including the coefficient of variation can be detected on the structure. In this case, the partial safety factor for materials can be calibrated on the determined coefficient of variation. The partial safety factor for concrete γ_C can secondary be reduced by the conversion factor η = 1,15.

5 Updating information
In general, updated characteristic values of materials are defined according to EN 1990, Appendix D, on the basis of structural investigation. If partial factors should be modified, it is necessary to determine the coefficient of variation, too.

6 Structural analysis and verifications
The structural safety and serviceability verifications are performed using updated characteristic material values and modified partial factors on the basis of the primary design equations of EN 1992.

7 Interventions
Interventions should preferably be designed according to regulations for new structures.

Title	Structural Assessment Provisions for Existing Road Bridges
Status	Principle
Year of implementation	2011

1 Executive summary
The Federal Ministry of Transport and Digital Infrastructure (BMVI) is responsible for care, development and maintenance of the infrastructure in the country. The "Guidelines for re-analysis of existing road bridges" under the authority of BMVI were developed for the post-evaluation of structural load-bearing capacity and serviceability of existing road bridges that were designed and built not in accordance to its current state of codification. It is used in order to realistically assess the structural adequacy and the fitness for the intended use of existing road bridges under consideration of the increased yield of traffic and the development of new building technology. The review of existing road bridges cannot be done adequately using only the current standards for new bridges.

2 General
The principle gives guideline how to re-analyse and re-evaluate existing road bridges with regard to their building conditions and under consideration of subsequently grown loading conditions. For this purpose reference values for material characteristics, action effects and reduced partial safety factors are given as well as design procedures for different types of construction materials, such as concrete, masonry, structural steel and composite steel-concrete.. Furthermore the principle gives advice for the assessment of existing buildings in detail.

3 Basic requirements
Existing road bridges, which are not constructed on the basis of the actual design codes (Eurocodes), can be evaluated by this principle.

4 Framework of assessment and retrofitting

The current standards for new bridges are not appropriate for the economic assessment of existing road bridges. Lots of other information like historic standards, historic construction strategies and operating experience are necessary. The assessment has to take the actual construction condition into account. The principle gives introduction on how to recalculate existing structures with respect to the actual action forces and material parameters in fact. If historic documents are available and the structure was built after 1953, a qualified assessment of the structure is not forcing necessary. Inside the principle there are tables with actual material data derived on the basis of their historic definition.

5 Updating information

In general, updated characteristic values of materials are defined according to EN 1990, Appendix D, on the basis of structural investigation. On the basis of historic definitions, actual material properties can be taken out of tables inside the principle for different materials.

6 Structural analysis and verifications

The structural safety and serviceability verifications are performed using updated characteristic material values and modified partial factors, on the basis of the primarily design equations of EN 1992 within the partial factor concept. The principle provides four verification classes, which are different with reference to the knowledge of the structure and the recalculation concept.

7 Interventions

Interventions should preferably be designed according to regulations for new structures.

MEMBER STATE	**GREECE (GR)**
Title	CODE OF STRUCTURAL INTERVENTIONS 2012 (FINAL HARMONIZED TEXT). In Greek known as KANEPE (*Code for Retrofitting (of Existing Building)*)
Status	Code of Practice, NCCI to ELOT EN 1998-3
Year of implementation	2009 (initial version), 2013 (first revision of final version)

1 Executive summary

As it is probably known, most of the seismic energy in Europe is manifested in Greece, leading every few years to strong earthquake events, with considerable material, financial and social impact. For the design and construction of buildings, as well as bridges and other technical works, this is reflected by the fact that aseismic design and the relevant combinations of action are often critical, compared to the other actions. Consequently, KANEPE, the first Greek Code for the assessment and retrofitting of existing structures is mainly focusing on the aseismic design.

2 General

The Code considered here is the result of more than a decade's work of competent experts. It is a voluminous document of approximately 350 pages (including numerous appendices) and containing a commentary part on the left side of each page. In its current form it has the following contents :

Chapter 1 : Scope – Field of application – Obligations and responsibilities
Chapter 2 : Basic principles, criteria and procedures
Chapter 3 : Investigation and documentation of an existing structure
Chapter 4 : Basic data for assessment and redesign
Chapter 5 : Analysis prior and after the intervention
Chapter 6 : Basic behaviour models
Chapter 7 : Assessment of behaviour of structural elements
Chapter 8 : Design of interventions
Chapter 9 : Safety verifications
Chapter 10: Required contents of the design
Chapter 11: Construction – Quality assurance - Maintenance

For its drafting except EN 1998, some latest developments of FEMA, together with the Greek long experience on the topic, have been taken into account.

3 Basic requirements

According to the Code, the assessment of existing structures follows the principles listed below:

- When the existing load-bearing system is expected to participate in the configuration of the redesigned structural system by resisting solely vertical loads, its assessment may be performed based on simple, yet conservative, methods.

- When, however, the existing load-bearing system is expected to participate in the configuration of the redesigned structural system by resisting both vertical and seismic loads, it should be assessed based on the following principles:

i) The assessment is made by analytical methods as specified in Chapter 5 of this Regulation. Especially in structures for which the available approved study (which has been applied) and which do not harm, the assessment could be based on the contents of the approved design.

ii) The numerical models to be used for the assessment may represent the entire structure or individual members. Different numerical models may be used, depending on the type of the imposed actions. In general, the types of numerical models should be determined by the calculation methods to be applied

iii) It is recommended that the accuracy of the methods used, be compatible with the accuracy of the data.

iv) The use of empirical-analytical or purely empirical methods is allowed only in cases covered by relevant special provisions issued by the Public

v) In cases of structures that already present damage or deterioration, the applied assessment method must be able to interpret, as a rough approximation, both the mode and the location of these significant damage. In structures of great importance, where damage has been identified, parametric analyses may be required in order to achieve the interpretation of damage based on their mode and location.

vi) For analysis, limit states control, verification of the adopted behavior factor, control of the imposed displacements and local ductility indices, the provisions of Paragraphs 2.4.3 to 2.4.5 of this Standard are of proportional applicability. Especially for masonry walls, the next Paragraph 2.1.4.2 is applied.

vii) In many cases, a quick assessment of the loss of bearing capacity of a damaged or degraded structure may be useful and/or necessary. This estimate can be made based on the intensity and extent of damage, as derived according to valid (sophisticated or approximate) methods (see Paragraph 5.3 and Annex 7D).

4 Framework of assessment and retrofitting

Assessment and redesign objectives are specified as follows :

a. For serving broader socio-economic needs, various “performance levels” (target behaviors) are stipulated under relevant prescribed design earthquakes

b. The objectives of the assessment or redesign (Table 2.1) consist in combinations of both, a performance level and a seismic action, given an "acceptable probability of exceedance within the technical life cycle of the building" (design earthquake).

c. In the present Standard, reassessment objectives are prescribed, that refer solely to the load-bearing structural system. In contrast, no objectives are set for the non-load-bearing system. The relevant provision of EC 8 (R 3, § 2.1 (2)) is fulfilled through Table 2.1. In case of two (2) reassessment objectives, the possible pairs are B1 and A2 or C1 and B2.

Table. 2.1 Assessment or redesign objectives of the structure

Probability of exceedance of seismic action within a conventional life cycle of 50 years	Performance level		
	Immediate Occupancy	Life Safety	Collapse Prevention
10%	A1	B1	C1
50%	A2	B2	C2

The performance levels of the structure are defined as follows, particularly for the purposes of this Standard:

"Immediate Occupancy after the earthquake" (A) is a condition in which it is expected that no building operation is interrupted during and after the design earthquake, with the possible exception of minor importance functions. A few hairline cracks may occur in the structure.

"Life Safety" (B) is a condition in which repairable damage to the structure is expected to occur during the design earthquake, without causing loss or serious injury of people and without substantial damage to personal property or materials that are stored in the building.

"Collapse Prevention" (C) is a condition in which extensive and serious or severe (non-repairable, in general) damage to the structure is expected during the design earthquake; however, the structure retains its ability to bear the prescribed vertical loads (during and for a period after the earthquake), in any case without other substantial safety factor against total or partial collapse.

The objectives of the assessment or redesign are not necessarily identical. The objectives of redesign may be higher than those of the assessment.

The minimum acceptable assessment or redesign objectives for the load-bearing system of existing buildings are defined ad-hoc by the Public Authority. In special cases, the Public Authority may designate additional objectives of assessment, or redesign of the non-bearing system as well. In this case, the same Authority also defines the criteria for meeting the respective objectives.

In any case, the reassessment objective (assessment or redesign) is chosen by the project owner provided that it is equal to or higher than the above minimum acceptable objectives. In defining these objectives, the following criteria (among others) shall be taken into account:

• Social impact of the building (e.g., temporary construction, ordinary residential houses, area of public gathering, areas of crisis management, high-risk facilities).
• Available financial resources into the community during the given period.

The owner of the project or the Public Authority shall define the time frame within which the relevant interventions will be conducted, where required. A nominal technical life cycle equal to the conventional lifetime of 50 years is generally accepted, regardless of the estimated "actual" remaining life of the building. An exception to this rule is permitted only under very special circumstances where the remaining lifetime is fully guaranteed, based on the judgment and approval of the Public Authority; in such a case, the seismic actions prescribed in Chapter 4 are modified accordingly. It is indicatively noted that according to Table 2.1, the design objective B1 is set for new structures.

The adoption of an assessment or redesign objective with a probability of exceedance of the seismic action of 50% will generally lead to more frequent, more extensive and more severe damage compared to a corresponding objective with a probability of exceedance of seismic action equal to 10%.

The probability of exceedance of 50% (maximum tolerable) in 50 years corresponds to an average return period of about 70 years, while a probability of exceedance of 10% in 50 years corresponds to an average return period of approximately 475 years.

5 Updating information

The notion of “Data reliability level” (DRL) is defined and applied as follows :

The reliability level of data (DRL) related to actions or resistances, signifies the adequacy of the information regarding the existing building and is taken into account in the assessment and redesign. DRL is not necessarily the same for the entire building. Individual DRLs for the various sub-categories of information can be determined. For the selection of the methods of analysis described in Chapter 5 the most unfavourable among the individual DRL shall be used (see § 5.7.2 and § 5.8.1).

DRL is not defined by the dispersion of the results of the investigation works. The dispersion is already taken into account during the evaluation phase, and affects the “representative value” of every factor. The concept of DRL is also applied for the completeness of the survey of the structure and infill walls, especially in case of hidden elements. The effects of uncertainties can be taken into account in actions or resistances depending on the case (e.g. uncertainty in the thickness of the flooring of the slab will be taken into account in actions; uncertainty in the thickness of the slab itself will be considered mainly in the resistances).

Three Levels of Data Reliability are distinguished:

i. “High”

ii. “Sufficient”

iii. “Tolerable”.

6 Structural analysis and verifications

The established structural analysis methods are applied depending on essentially on the performance level and other criteria, namely:

- elastic static analysis (for performance level A, without additional conditions, and performance level B and C following the conditions set out in EN 1998-3 plus some additional criteria),
- elastic dynamic analysis (again similar conditions, as described in EN 1998-3 plus some additional criteria),
- inelastic static analysis (recommended when at least a “satisfactory” data reliability level (DRL) is ensured) and
- inelastic dynamic analysis (provided that adequate experience and expertise of the Civil Engineer is ensured).

Similarly, established numerical models for the mechanical behaviour, verification and design/detailing of structural elements are provided

7 Interventions

In Chapter 8 of the could the design of intervention is described addressing :

- General requirements
- Interventions in critical regions of linear structural members
- Interventions to frame joints, interventions on shear walls
- Frame encasement
- Construction of new lateral shear walls
- Interventions on foundation elements

In addition to this, provisions for the quality assurance and the maintenance are foreseen.

MEMBER STATE	**IRELAND (IE)**
Title	Overview of Irish position on national regulations and guidelines for the assessment of existing structures
Status	There are no specific Irish National Building Regulations concerned solely with the assessment and retrofitting of existing structures but certain requirements relating to existing buildings are set down in the Building Regulations. There are also established national guidelines concerning the assessment and retrofitting of some specific classes of existing structures such as highway bridges.
Year of implementation	Varies

1 Executive summary

Buildings – Regulatory requirements

1) The current legislative requirements for building structures are established in Part A of the Second schedule of the Building Regulations 1997-2012.
2) Guidelines on meeting the statutory requirements is given in Technical Guidelines Document, (TGD) A (currently 2012 version).

“Sub-section 2 Design and construction of all building types - codes, standards and references

Introduction

1.2.1 The following codes, standards and references are appropriate for all buildings and may be used to meet **Requirements A1 and A2** provided that:

(a) the design and construction of a structure is in accordance with the relevant recommendations of the codes, standards and references, and
(b) where alternative codes and standards have been listed, the whole of the design for the same material should normally be based on one of the codes only.

………………………

Appraisal of existing buildings

Appraisal of existing structures 3rd edition
Institution of Structural Engineers 2010.

Building Research Establishment Digest 366:
Structural appraisal of existing buildings for change of use 1991.

Structural renovation of traditional buildings,
Report 111. Construction Industry Research and Information Association (1994 reprint with amendments).”

Note, Part A3 (Disproportionate collapse) may not apply where a building undergoes a material change of use. See extract from S.I. 497 of 1997 below.

Material changes of use.

13. (1) Subject to articles 3 and 8, where a material change of use as regards a building takes place—

(*a*) the requirements of the following Parts of the Second Schedule:

Part A1 and A2

Part B

Part C4

Part F

Part G

Part H

Part J

Part L

shall apply to the building.

3) As a result of a gas exploration in a block of apartments, multi-storey buildings designed, post 1950 and prior to 1991, require a multi buildings act certificate. Buildings designed under the Building Regulations from 1991 do not require such.
4) Other than this, there are no statutory requirements for the structural assessment of existing buildings.

Bridges

Section 4: Assessment
3.4.1 NRA BD 21* The Assessment of Road Bridges and Structures
3.4.2 NRA BA 16* The Assessment of Road Bridges and Structures
3.4.3 NRA BA 38* Assessment of the Fatigue Life of Corroded or Damaged Reinforcing Bars
3.4.4 NRA BA 39* Assessment of Reinforced Concrete Half-joints
3.4.5 NRA BD 48* The Assessment and Strengthening of Road Bridge Supports
3.4.6 NRA BA 54* Load Testing for Bridge Assessment
3.4.7 NRA BA 55* The Assessment of Bridge Substructures and Foundations, Retaining Walls and Buried Structures
3.4.8 NRA BA 52* The Assessment of Concrete Road Structures Affected by Alkali Silica Reaction
3.4.9 NRA BD 56* The Assessment of Steel Road Bridges and Structures
3.4.10 NRA BA 51* The Assessment of Concrete Structures Affected by Steel Corrosion

3.4.11 NRA BD 44* The Assessment of Concrete Road Bridges and Structures
3.4.12 NRA BA 44* The Assessment of Concrete Road Bridges and Structures
3.4.13 NRA BD 61* The Assessment of Composite Road Bridges and Structures
3.4.14 NRA BD 79* The Management of Sub-standard Road Structures
3.4.16 NRA BD 81* Use of Compressive Membrane Action in Bridge Decks
3.4.18 NRA BD 101* Structural Review and Assessment of Road Structures

These documents rely on BS 5400. However, as there are no established Assessment codes within the Eurocode suite of documents, these are the documents which continue to be used in the meantime.

2 General

<u>Buildings and bridges</u>

The introduction to TGD A structures indicates that "in the case of material alterations or changes of use of existing buildings, the adoption without modification of the guidance in this document may not, in all circumstances be appropriate. In particular, the adherence to guidance, intended for application to new work may be unduly restrictive or impracticable. Buildings of architectural or historical interest are especially likely to give rise to such circumstances. In these situations, alternative approaches based on the principles contained in the document may be more relevant and should be considered".

The current design rules rests are in accordance with the Eurocodes and the appropriate other European Harmonised standards.
A list of documents is given in TGD A.

There are some specific design rules given for new houses. Assessment of existing buildings may take account of previous versions of the Building Regulations. In relation to all other building types, sub-section 2 includes amongst its references, three documents dealing with appraisal of existing buildings. These are:-

1. "Appraisal of existing structures", 3rd edition Institution of Structural Engineers, 2010,
2. "Building Research Establishment Digest 366, Structural appraisal of existing building for change of use", 1991. (This document has been altered in 2012 and this reference will need to be corrected in the next edition of TGD A.)
3. "Structural renovation of traditional building report 111, Construction industry research information association, (1994 re print with amendments).

Sub Section 3 of TGD A deals with recovering of existing roof structures and structural safety of external wall cladding. This specifies that for new roof coverings, strengthening measures may be required and requires structural investigation and strengthening as appropriate.

In general to buildings generally, the responsibility is left to the Design Engineer for the building to determine the most appropriate actions.

3 Basic requirements

The above cited documents present varying degrees of technical guidance upon the procedures to be followed in structural assessment, the assumptions which may be made and various other items, such as material strengths and other properties that might be employed in calculations, and other factors such as the types of deterioration which might occur. While the philosophy employed is typically based upon the use of the partial safety factor approach for structural calculations, and what modifications which might be made to the magnitude of the partial safety factors used for design, it is also recognized that not all forms of existing buildings and structures are amenable to this approach. The use of appropriate engineering judgement is encouraged in such and other circumstances. Disparities occur between aspects of the detailing and forms of construction of existing buildings and structures and the assumptions (implicit and explicit) associated with some design equations presented in more modern design codes. For some older types of existing buildings and structures, there are no applicable modern design codes which might be adopted.

Generally there is little explicit reference to structural reliability theory or encouragement to employ such techniques in assessment, although this is mentioned in some of the more recent technical guidance documents. Also more recent versions of the technical guidance documents on structural assessment of existing buildings and structures do make reference to the structural Eurocodes.

The greatest degree of development of standards for structural assessment has probably occurred in the area of highway and rail bridges. No observations are offered in the following sections because of the diversity of the technical guidance which exists in the absence of a specific Irish national ‘building’ regulation, and associated technical guidance, concerned solely with the assessment and retrofitting of existing structures.

The above text is based on the UK response. Irish design and assessment practice has tended to follow UK practice though there are differences in the National Annexes to the Eurocodes.

4 Framework of assessment and retrofitting

No observations made

5 Updating information

No observations made

6 Structural analysis and verifications

No observations made

7 Interventions

No observations made

MEMBER STATE	ITALY (IT)
Title	There are two fundamental documents: 1. Decreto Ministeriale 14 Gennaio 2008 “Norme Tecniche per le Costruzioni” Capitolo 8 “Costruzioni Esistenti” - ***Decree of Ministry of infrastructures 14th January 2008 Technical Regulation for Constructions – Chapter 8 Existing Constructions*** 2. Circolare Ministeriale del Ministero delle Infrastrutture 2 Febbraio 2009 n° 617: Istruzioni per l’applicazione delle “Norme tecniche per le costruzioni”di cui al D.M. 14 gennaio 2008. – ***Circular of the Ministry of Infrastructure 2 February 2009 – Instructions for the application of Technical Regulation for Construction of the Decree of Ministry of infrastructures 14th January 2008.*** Other documents exist, both as guidelines or they deal with different type of constructions not covered by the fore cited documents. In 2009 the new Regulation for Large Dams, including the existing ones, has been approved by the National Council for Public Works, but they have not been published as a regulation yet.
Status	Under revision. The new release is expected by the end of 2014, mid 2015
Year of implementation	2008

1 Executive summary

In the following the present Code for existing Construction is presented. After a short history, the code issued in 2008 is presented with reference to Chapter 8 on existing Constructions. The Code in fact, deals in a single document with new and existing constructions: safety level to be guaranteed and methods to achieve such requirements. Some indications about the new revision of the Code are given as well as short information with other documents: codes and Guidelines, dealing with other type of constructions not covered by the Code, or specific methods and provisions for assessment and interventions not covered by the Code.

2 General

In Italy there is a tradition of regulation on existing structures which comes from post-earthquake interventions since 1980. In 2003 Italian Civil Protection issued a Regulation for existing constructions, and it was required by the government that all public administrations executed the seismic assessment of all public existing constructions, and based on the cited regulation to establish peak ground accelerations which could cause the crisis of damage and ultimate limit state. In 2008 the new Decree of the Ministry of infrastructures was issued and became mandatory in June 2009. Therefore since 2009 existing constructions are subjected to the Code which set reliability levels for new as well as for existing structures. Chapter 8 of the Code deals with existing constructions and establishes the safety levels under all type of actions, not only for seismic action and relative combination of actions. The main points of the chapter are: how and when safety assessment is needed, how and when one has to intervene, and to which safety level one has to retrofit the structure, which are the procedure to make safety assessment, and what is a design for intervention on an existing structure, finally which materials can be utilized for interventions on existing structures, these in fact may differ with respect to what is admitted for new constructions, and finally there is an entire specific sub-chapter for seismic design.

The code, in the present version which is under revision, sets three important aspects:

1. existing structures must satisfy ultimate limit states only, neither the serviceability, nor the damage limit state,
2. existing structures need to satisfy the same verification for vertical loads prescribed for new constructions, though material strength characteristics are those obtained from tests with “adequate” reductions, the satisfaction of ultimate limit states for wind and seismic load is not mandatory, unless specific statements hold like changes in use or important changes in the existing structure.
3. Materials utilized in for interventions can differ from what is prescribed for new constructions and regulated by the Code. They shall however be dealt with in other technical document of proved value. In particular for masonry buildings materials similar to those of the structure at hand can be adopted (sub paragraph 8.6) if durability requirements can be provided.

Code chapter 8 is really very general without any detailed prescription about methods both, for what concerns assessment and for what concerns interventions. These aspects are treated with larger details into the explicative Circular, a document which is not mandatory except for public works. However, even in the Circular the operative procedures are given into appendixes dealing with method of assessment of material characteristic values for design. Specific sub-chapters are given for Concrete and steel structures. Many aspects on which it is assumed that the state of the art is still under development are given in specific and large appendixes of chapter 8. These latter deal with how to evaluate knowledge levels and relative confidence factors for concrete and steel, indications for masonry structures and specific typologies like aggregate masonry buildings, method of analysis for masonry buildings, methods to evaluate capacity of reinforced concrete and steel structures and finally techniques to retrofit reinforced concrete elements, indications, masonry-steel structures. In the appendix existing bridges including foundations and abutments, installations and non-structural elements are dealt with as well.
To have an idea of the different details included in the Mandatory Code (Decret), the mandatory instructions for public work (Circular) and the informative important reference of the Appendix of the Circular one can make reference to the number of pages of the different documents:

- Decret Chapter 8: 8 pages
- Circular Chapter 8: 24 pages
- Circular Appendix to Chapter 8 Total: 60 pages
- Circular Appendix to Chapter 8 Building only: 47 pages
- Circular Appendix to Chapter 8 Bridge specific: 5 pages
- Circular Appendix to Chapter 8 Installation specific: 11 pages

The present revision of the code, which is supposed to be ready by the end of 2014, is now in the phase of discussing whether the action for existing structures should be the same for the new ones. It has been assumed that they should be in general the same while for seismic action there are now two positions under discussion: the first one assumes that the same seismic action should be considered, while the other one assumes that a reduction should be accepted. In fact due to economic reason the reduction of seismic action permits to redistribute economic resources to retrofit other existing structures, this way the overall seismic risk can be strongly reduced.
A further important aspect of the revision concerns the procedure included in the appendix which deals with knowledge levels and confidence indexes. After about ten years of application it is clear that the cases that can be found in practice are so different that specific correlations between the number of site tests and the knowledge level cannot be established and in fact it has been applied in practice for very few cases.

3 Basic requirements

Unless specified in chapter 8 the same requirements for new realizations apply to existing constructions. In case of non-structural interventions the interaction with structural limit state (serviceability and ultimate) shall be considered.
In the assessment and design of interventions the designer shall take into account:

- The age of the constructions and state of the practice of the period

- Possible defects in conceptual design and realization
- Possible hidden damages due to exceptional events
- Possible changes or deteriorations

The designer shall take into account into the design model:

- Geometry and details based on existing documents and surveys on the construction
- Material properties can be obtained through inspection and tests, while uncertainties of new realizations do not apply with the exception of the new intervention of retrofitting.
- Dead loads are known, uncertainty depends on the amount of inspections and measurements.

Methods of analysis shall take into account the level of knowledge while adequate safety margin shall be considered on the base of the completeness of data as well (an explicit reference is done to “confidence factor”).

4 Framework of assessment and retrofitting

The Code require a check with respect to Ultimate Limit state only. However the designer in agreement with the owner can evaluate the safety margin for Serviceability limit states as well.

The scope of assessment is to establish whether the use of the construction can establish whether one can use the construction without interventions, or one has to reconsider and reduce acceptable variable loads or intervene to retrofit or upgrade the structure.

Assessment is mandatory when:

- There is an evident reduction of the capacity due to external environmental events or deterioration of mechanical characteristics of materials, or after exceptional events like fire impact explosions, or evident damages due for example to foundation settlements;
- There is a proven design error
- Load changes larger than a certain percentage
- Non-structural interventions modify construction stiffness or mass distribution are done
- Structural intervention which modify the original behaviour are done

Assessment shall establish the safety margin before and after the intervention. The check will be based on deterministic analysis. A detailed report will illustrate the situation before and after interventions as well as possible limitation in use.

5 Updating information

The Code does not give criteria for updating information. However it requires a general methodology for the assessment. The procedure starts from Documents collection. A detailed reconstruction of the history of the building since its construction, a detailed survey to check the correspondence between design charts and drawings, and as built state at the date of the check; in situ destructive and non-destructive tests in adequate number, based on the evaluation of the designer. The minima established by the Code for new realization do not represent a limitation for existing structures. Into the Circular of 2009 larger explanation are given, however quantitative numbers about tests to be done and level of knowledge and consequent reduction in design values are given into the appendix to the circular. It should be noted that for concrete, the Circular establishes that the design strength is obtained from the mean value obtained from the tests divided by a confidence factor equal to 1, 1.2, or 1.35 depending whether the knowledge level is good, medium, or low. For ductile failure one could use these values as design strengths, for fragile failures (mechanisms) one shall reduce the value dividing by the partial factor as well. Notice that for seismic action the design strength is the deformation capacity of the elements, such as beam chord rotation.

6 Structural analysis and verifications

Structural analysis can be carried out with any type of method. The code reminds the designer the adoption of complicate models requires a larger knowledge of the structural parameters. Furthermore, old masonry buildings allow kinematic analysis in case of seismic actions too.

In the Circular it is explained that problems that involve a limited part of the structure only can be solved locally. Therefore the analysis will be specific for that part of the structure.

Actions and action combinations are the same adopted for new structures. However dead load can be deduced from the real situation and the value of the partial factor can be reduced from 1.3 to smaller values.

		Linear analysis		Non-linear analysis	
		Demand	Capacity	Demand	capacity
Type of element or mechanism	Ductile/fragile	Acceptance of Linear Model		Use mean values of resistances	For deformations Use vales of deformation divided by confidence factor
		Mean deformability Modulus values	Resistance: Mean Values		
	Ductile	Verifications in case of Linear Model accepted			For Resistances Use vales of deformation divided by confidence factor and partial factors
		ρ=D/C>1, from analysis	Resistance. use mean values divided by CF		
		ρ=D/C<1; use capacity criteria, actions= sum of D of ductile elements time CF			

Circular, table. A8.4 – Material properties and criteria of analysis for assessment and design

The table is reproduced in the Annex to Chapter 8 of the Circular to be adapted to different materials.
For example for masonry structures the following table is given:
Many of the rules included into the Circular will be the subject of revision for next issue of the Code.

Table C8A.1.1 – Knowledge levels as a function of available information and Confidence Factors for Masonry

Knowledge Level	Geometry	Details	Material Properties	Method of Analysis	Confidence Factor
LC1 = Low	Survey of walls, vaults, slabs, stairs. Survey of loads. Survey of foundations Survey of crack pattern and of deformation/displacements	Limited in situ check	Limited in situ tests Resistances at minima of Table C.8.A.2.1 E Modulus: mean value of Table C8.A.2.1		1.0

LC2 = Medium			Extended in situ tests Resistances at mean of Table C.8.A.2.1 E Modulus: mean value of tests or mean of Table C8.A.2.1		1.2
LC3 = High		Extended and exhaustive in situ checks	Exhaustive in situ tests Case a) resistances, at least 3 results of tests, mean of the test results E Modulus: mean value of tests or mean of Table C8.A.2.1 Case b) resistances, at least 2 results of tests, mean of the test results if included in the range of Table C8A.2.1, however not larger than maximum table value E Modulus: mean value of tests or mean of Table C8.A.2.1 Case c) resistances, at least 1 result of tests, mean of the test results if included in the range of Table C8A.2.1, however not larger than maximum table value E Modulus: mean value of tests or mean of Table C8.A.2.1	All methods	1.35

The same for Concrete structures:

Tabella C8A.1.2 – Livelli di conoscenza in funzione dell'informazione disponibile e conseguenti metodi di analisi ammessi e valori dei fattori di confidenza per edifici in calcestruzzo armato o in acciaio

Livello di Conoscenza	Geometria (carpenterie)	Dettagli strutturali	Proprietà dei materiali	Metodi di analisi	FC
LC1	Da disegni di carpenteria originali con rilievo visivo a campione oppure rilievo ex-novo completo	Progetto simulato in accordo alle norme dell'epoca e *limitate* verifiche in-situ	Valori usuali per la pratica costruttiva dell'epoca e *limitate* prove in-situ	Analisi lineare statica o dinamica	1.35
LC2		Disegni costruttivi incompleti con limitate verifiche in situ oppure estese verifiche in-situ	Dalle specifiche originali di progetto o dai certificati di prova originali con limitate prove in-situ oppure estese prove in-situ	Tutti	1.20
LC3		Disegni costruttivi completi con limitate verifiche in situ oppure esaustive verifiche in-situ	Dai certificati di prova originali o dalle specifiche originali di progetto con estese prove in situ oppure esaustive prove in-situ	Tutti	1.00

7 Interventions

Three types of interventions can be adopted:

1. Retrofitting to sustain the full resistance (in term of action) as for new realizations

2. Retrofitting to increase the resistance of the existing structure
3. Local repairing, which however increases the safety margin of the existing structure

The first two type shall undergo to final independent check

One must Retrofit to full resistance in case of:

1. Increase of the total height of the building
2. Increase of the dimension of the structure
3. Increase loads of more than 10%
4. Modifying structural behaviour with structural interventions

Large detailed information is given in the Circular and its annex concerning methods of retrofitting. However, on this subject many guidelines have been issued by the National Council of Public Works and they are available on the website.

MEMBER STATE	NETHERLANDS (NL)
Title	NEN 8700 Assessment of existing structures in case of reconstruction and disapproval – Basic Rules
Status	Standard
Year of implementation	2009 (1e version), 2011 (2e version current in use)

1 Executive summary

Since 1992 there have been a number of proposals to develop calculation methods to assess the structural safety of existing buildings. From 1992 till 2009 it is regulated by amending the national design standards by Ministerial Order. Related to the European appointments about the Eurocodes, the Dutch Building Decree switched in April 2012 from the national design rules to the Eurocodes. Parallel of this movement the Content of the ministerial Order is translated to a Dutch national standard by two steps (first one in 2009 and the second one in 2011). On the first step it resulted in NEN 8700 in line with the national standards and safety philosophy. In the second step the relation had been made to NEN-EN 1990 and the NEN-EN 1991 series. The Building Decree 2012 refers to this standard for the assessment of existing structures and the retrofitting of it. The safety assessment of an existing building differs from that of a new one:

- cost in relation to safety;
- safety in relation to the reference period;
- availability of actual status data versus design data.

Like the regulations that apply to new buildings the new standard includes:

- probability theory;
- assessment of a structure during a lifetime of 1 year for the judgment in case of disapproval (reference period in case of life safety 15 years)
- assessment of retrofitting with rules for the minimum design working life and reference period.
- determination method that respects the actual properties of the structure.

The standard also contains the lowest limits of safety levels in the renovation, alteration or enlargement of an existing building.

In the near future material related standards are expected that will provide further details regarding the determination of the resistance, per construction material or type of structure.

2 General

This standard establishes the principles, rules of application and methods of determination that relate to the verification, if an existing structure possesses a sufficient degree of safety and serviceability, in general. More specifically this standard is meant for the verification if a reconstruction possesses a sufficient degree of durable safety and serviceability. Furthermore, this standard provides the principles and determination methods for testing structures in relation to possible disapproval. The methods to establish the resistance of the structure are established in a general sense. The specific material dependent aspects are not elaborated upon further. This standard can be used in addition to the Eurocodes for design.

3 Basic requirements

(1a)P A reconstruction shall be designed and executed in such a way that the structure, in the course of its intended remaining working life, according to required degrees of reliability and in an economical manner, will
– sustain all actions and influences that may to occur during execution and use, and
– remain fit for its intended use.

NOTE A reconstruction distinguishes itself from a new structure design in as far as, on the basis of a proportionality consideration, it may (for the competent authorities: must) be verified if the added gains of a higher safety or serviceability outweigh the efforts required, when seen in the light of the remaining working life of the structure that is no part of the reconstruction.

(1b)P An existing structure shall have a minimum remaining strength sufficient to, in the course of the remaining working life as established in this standard, and according to the required degrees of reliability:
– sustain all actions and influences that may to occur during execution, and
– remain fit for its intended use.

For all structures the minimum is a remaining live of 1 year and the disapproval level as described below.

4 Framework of assessment and retrofitting

The safety assessment of an existing building differs from that of a new one in a number of essential ways:
- Firstly, increased safety levels usually involve more costs for an existing building than for buildings that are still in the design phase. The safety provisions embodied in safety standards have to be set off against the cost of providing them, and on this basis these costs are more difficult to justify for the existing buildings. For this reason in certain circumstances a lower safety level is acceptable.
- Secondly, the remaining lifetime of an existing building is often different from the standard reference period of 50 years or 15 years that applies to new buildings. This aspect plays an important role in determining if the building construction is still adequately safe.

Therefore in NEN 8700 two safety levels are given:
- disapproval level: legal minimal level of structural safety upon the undershoot of which (preliminary) notice and enforcement by the competent authorities is mandatory
- reconstruction level: construction activities that result in a physical modification of the structure, or part of a structure; included are repairs, complete or partial renovations, modifications, as well as extensions.

5 Updating information

Actions:
For actions the standard NEN 8701 *Assessment of existing structures in case of reconstruction and disapproval – Actions* gives guidance on how to update the actions. Mainly the actions are the same as for design of new structures. For traffic loads on bridges some guidance is given on how to reduce the design load due to shorter reference period and/or lower traffic intensity on the structure.

Material and product properties:
Premise is that material properties should be determined through research / measurement on the actual structure. For the statistical evaluation of the results reference is made to EN 1990 Annex D. The consequence of present damage on the strength in time should be taken into account.

6 Structural analysis and verifications
For this reference is made to the corresponding chapter in NEN-EN 1990, with the proviso that:
- in the reconstruction of a structure those accidental actions shall be considered that have, or should have been considered in the design or earlier reconstructions; and
- for the verification if the disapproval level is undershot, 'design' shall be read as 'verification', and for accidental actions, in the case of buildings, only the action type 'fire' shall be selected.

(2A) In doing so, at the end of 5.2 of NEN-EN 1990 the following text shall be read as well:
START OF TEXT
(4A) The design value of the strength may be determined on the basis of test loads by way of a sample, while taking the teachings of statistics into account. The temporal effects shall be factored into the test load.

For the verification by the partial factor method adjusted (lower) partial factors for verification of the disapproval level and the design of reconstructions are given.

7 Interventions
Interventions should preferably be designed according to regulations for new structures. However, there is the possibility to design interventions according to the reconstruction level (the requirements for the application of this lower safety level are given in NEN 8700). In the regulations area for public buildings only the renovation level is applicable.

MEMBER STATE	**SPAIN (ES)**
Title	CTE DB SE Annex D: Spanish Technical Building Code – Basic Document: Structural Reliability; Annex D: Assessment of existing building structures. (*CTE DB SE Anejo D: Código Técnico de la Edificación – Documento Básico: Seguridad Estructural; Anejo D: Evaluación estructural de edificios existentes*).
Status	In force: Version 2009.
Year of implementation	2006

1 Executive summary

The rules set out in the Spanish Technical Building Code (CTE, Spanish initials for *Código Técnico de la Edificación*) for the evaluation of existing building structures establish a framework for general assessment. Like the assessment method proposed in ISO 13822:2010, they envisage a phased procedure in which the accuracy of resistance models and models for actions and their effects from phase to phase, is enhanced by improving examination assumptions through updates of the initial general data.

In a first phase, a preliminary assessment is carried out using the same partial factor format as defined in the current Spanish design code. For this, the calculation models are based on the available information about the structure, validated by visual inspection.

The most accurate way to find actual load and resistance would be to conduct a probabilistic analysis using site data. This is a time-consuming process, however, calling for a working knowledge of probabilistic methods that may not be suited to everyday use by practising engineers. Such methods are therefore limited to the third phase of the assessment, and may be applied if structural safety cannot be verified by means of more traditional methods (phases 1 and 2).

For the second phase of the assessment, the Spanish document therefore recommends the application of a simplified method, based on a similar partial factor formulation as adopted in structural design codes, in which the characteristic values for the variables and the partial factors can be modified on the basis of updated information.

While the CTE procedure formally includes such an assessment method, the lack of any specific information in the code on the aforementioned modifications limits its practical applicability. Tools are currently being developed for the safety assessment of existing sound and deteriorated structures using updated characteristic values and partial factors.

Finally, qualitative assessment based on satisfactory past performance is also allowed under given circumstances, e.g.:

– structures designed and built in accordance with good construction practice;
– satisfactory performance for a sufficiently long period of time;
– no changes for a sufficiently long period of time;

- adequate force transfer can be confirmed;
- no evidence of significant damage or deterioration.

2 General

CTE DB SE Annex D is applicable to the assessment of existing building structures (constituted by any type of material) that was originally designed and built based on accepted engineering principles or rules, as well as structures built on the basis of good workmanship, historic experience and accepted professional practice.

CTE DB SE Annex D governs the activities in relation with existing structures, supplementing the rules from structural design codes.

3 Basic requirements

Requirements are to be fulfilled for structural safety and serviceability:

- structural safety is considered adequate if the necessary level of numerically determined structural reliability is reached;
- alternatively, safety is considered acceptable if the risks associated with the structural system are kept under control by means of adequate measures;
- serviceability is verified on the basis of the condition survey if the use of the building will not be changed;
- on the other hand, if the use of the structure has changed or will change in the future, serviceability should be verified numerically, taking into account updated parameters for actions and structural behaviour.

As well structural safety as serviceability may be verified by means of deterministic or probabilistic methods, depending on the evaluation phase according to the established procedure (section 4 of this document). The required performance levels are to be established on the basis of adequate values for the reliability index, taking into account the appropriate reference period. Normally, these values are equivalent to those implicitly required by current design codes.

4 Framework of assessment and retrofitting

According to CTE DB SE Annex D, the assessment of existing building structures is broken down into a recommended maximum of three phases. No further evaluation is necessary if in one of the phases an unequivocal conclusion can be drawn on structural safety.

The purpose of the first phase is to carry out a preliminary assessment including:

- review of existing documents;
- visual inspection;
- evaluation of possible changes during the past service period;
- simplified assessment based on a partial factor formulation as used in structural design, but taking into account the actual condition of the structure.

If in the first phase no unequivocal decision can be adopted concerning structural reliability, a more detailed assessment is performed in the second phase:

- site investigation including quantification of damage and deterioration mechanisms;
- updating of information by means of measurements and tests (geometry, material properties, permanent and variable actions, etc.);
- assessment based on a partial factor formulation by using updated characteristic values of the variables and updated values for the corresponding partial factors.

If necessary, in a third stage it is recommended to verify structural performance by using reliability methods:
– acquisition of more data on different load and resistance variables;
– establishment of probabilistic models for the different variables;
– for the relevant examination situations, verification of structural reliability by means of probabilistic methods;
– plausibility check and review.

An intervention (operational: monitoring, change in use, etc.; constructional: repair, upgrading, demolition, etc.; combination of different measures) must be planned for the members for which safety is not verified by any of the aforementioned assessment methods.

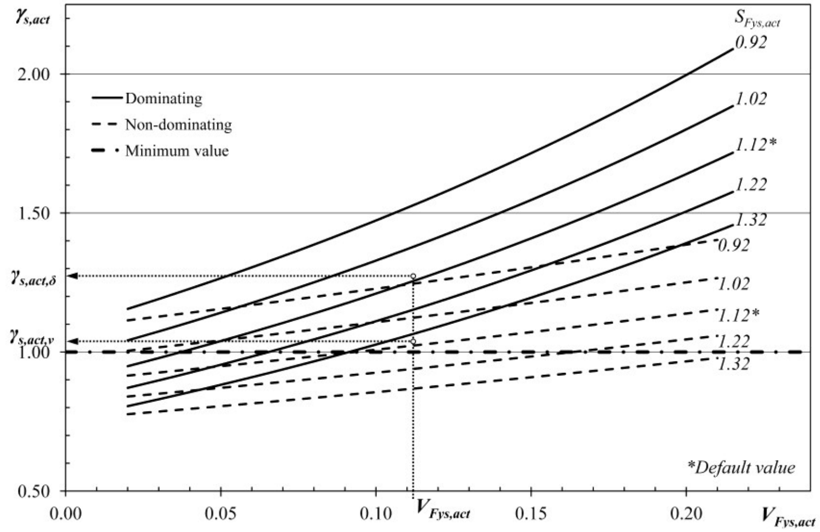
5 Updating information

Default probabilistic models for structural action-, action effects- and resistance variables have been developed, although they are not included in CTE DB SE Annex D. However, going out from such prior information, model updating on the basis of site data for a particular variable is carried out according to the following procedure:
– statistical evaluation of the site data gathered concerning variable X;
– combination of the sample results and prior information;
– determination of the relevant parameters for the updated probability density function, e.g. the updated mean value, $\mu_{X,act}$, standard deviation, $\sigma_{X,act}$, and characteristic value, $X_{k,act}$.

If the structural performance is verified by means of probabilistic methods, the updated mean value ($\mu_{X,act}$) and standard deviation ($\sigma_{X,act}$) may directly be used.

In the case of a verification based on the partial factor method with updated information, further to the updating of the characteristic value, updating is also required for the corresponding partial factor, $\gamma_{X,act}$. Tools have been developed or are under development for the updating of partial factors for the assessment of building structures from different materials (reinforced concrete, steel, composite steel and concrete, and timber). To this end, partial factors are represented in terms of the coefficients of variation as well as the bias coefficients, e.g. the ratio between mean and representative values, of the associated variables to estimate how they are impacted by the change in information on these variables. Furthermore, it is considered whether the corresponding variable is dominating or non-dominating. The partial factor $\gamma_{X,act}$ may therefore be updated as a function of the updated coefficient of variation for the considered variable (or combination of variables, depending on the adopted partial factor format), $V_{X,act}$, and the updated bias coefficient, $S_{X,act}$, taking into account whether the variable X is dominating or non-dominating.

The following figure shows, by way of example, the updated partial factor for reinforcing steel resistance, $\gamma_{s,act}$, versus the updated coefficient of variation for reinforcement tensile strength, $V_{Fys,act}$, depending on the updated bias coefficient, $S_{Fys,act}$.



As in the case of the default probabilistic models, these tools are not included in CTE DB SE Annex D.

6 Structural analysis and verifications

Structural analysis is to be performed using models that adequately describe the actual condition of an existing structure (including relevant deterioration processes), its behaviour, the resistance of its components and the actions on the structure. On the other hand, the verifications to be carried out depend on the phase of the assessment, as explained below.

Preliminary assessment:
Assessment is carried out based on the partial factor method, using the verification criteria defined in the current Spanish design code. For this purpose, the calculation models are based on the available information about the structure, validated by visual inspection.

Detailed assessment:
As mentioned earlier, CTE DB SE Annex D does not include any specific information on the aforementioned modifications (on the basis of updated information) of the characteristic values for the variables and the partial factors. However, the tools described in section 5 of this document have been developed or are under development based on the partial factor format for assessment described in the following.

When considering a limit state of rupture or excessive deformation of a section, member or connection, including foundations and the ground, structural safety is considered verified for the remaining service period under consideration, if for all relevant hazard scenarios the following criterion is fulfilled:

$$E_{d,act} \leq R_{d,act}$$

For persistent and transient situations, the examination values for the action effects, $E_{d,act}$, can be determined as follows:

$$E_{d,act} = \gamma_{Sd,act} \cdot E\left\{\sum_{j\geq 1}\gamma_{g,j,act} \cdot G_{k,j,act}; \gamma_{p,act} \cdot P_{k,act}; \gamma_{q,1,act} \cdot Q_{k,1,act}; \sum_{i>1}\gamma_{q,i,act} \cdot \psi_{0,i} \cdot Q_{k,i,act}\right\}$$

Since model uncertainties vary depending on the action effects considered, in lieu of taking into account one single partial factor for such uncertainties, $\gamma_{Sd,act}$, different factors are introduced depending on whether bending moments, shear forces or axial forces are to be calculated: $\gamma_{Sd,M,act}$, $\gamma_{Sd,V,act}$, $\gamma_{Sd,N,act}$, respectively.

The examination value of the ultimate resistance, $R_{d,act}$, is determined by using updated characteristic values of material or product properties, $X_{k,i,act}$, and updated examination values of geometrical data, $a_{d,act}$, consistent with the definitions from Eurocodes:

$$R_{d,act} = \frac{1}{\gamma_{Rd,act}} \cdot R\left\{\eta_{i,act} \cdot \frac{X_{k,i,act}}{\gamma_{m,i,act}}; a_{d,act}\right\} \quad i \geq 1$$

The partial factor for resistance is split into the updated partial factors for material or product properties, $\gamma_{m,i,act}$, and an updated partial factor associated with the uncertainties of the resistance model, $\gamma_{Rd,act}$. Also resistance model uncertainties vary depending on the failure mechanism considered, reason why different $\gamma_{Rd,act}$ factors are introduced.

Probabilistic assessment:
Going out from the axiom that a correct application of the current design codes results in a safe structure, the verification of structural safety of an existing structure consists of the following steps

- strict design of the existing structure according to a consistent set of codes;
- calculation of the reliability index, β_0, related to the dimensions obtained in the first step, considering the parameters (mean value, standard deviation, distribution function) of the variables assumed to lie behind the rules of codes;
- calculation of the reliability index, β_{act}, related to the actual structure using updated probabilistic models for actions and resistances;
- the structure may be considered safe if $\beta_{act} > \beta_{code}$.

7 Interventions
The final report on structural assessment should include clear conclusions with regard to the objectives of the assessment, the work done and the results obtained. If sufficient reliability can be demonstrated in one of the assessment phases, no action is required. If the reliability is found to be insufficient, appropriate interventions should be proposed. Temporary intervention should be proposed by the engineer if required immediately. In any case, the engineer

should recommend preferred solutions as a logical follow-up to the whole assessment. However, the final decision on possible interventions should be adopted by the client, in collaboration with the relevant authority and based on engineering assessment and recommendations.

CTE DB SE Annex D considers the following generic categories of measures:
- urgent safety measures;
- administrative and technical measures;
- constructional measures.

MEMBER STATE	**SWITZERLAND (CH)**
Title	– Guideline SIA 462 Assessment of the structural safety of existing structures
Status	Guideline
Year of implementation	1994 – 2011, 2011 replaced by Code SIA 269
Title	– Code SIA 469 Preservation of constructions
Status	Code of practice
Year of implementation	1997
Title	– Code SIA 269 Existing Structures – Basis for examination and interventions – 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 – Geotechnical Aspects
Status	Code of practice
Year of implementation	2011

1 Executive summary

Swiss Society of Engineers and Architects (SIA) launched a pioneering project in 2005 to develop a series of codes for existing structures. The objective of the project consists of compiling a series of user-friendly codes dealing with all aspects of existing structures. The series of codes 269 was implemented in 2011.

The professional approach to existing structures is based on an inherent methodology that essentially includes collecting detailed actual information since the structure already exists. The controlling parameters are determined more precisely, and for example, the structural safety of an existing structure is proven using so-called updated values for actions and resistance. The issues of updating, risk-based safety and proportionality of interventions are treated in more detail.

Note: For more detailed information see "Swiss Standards for Existing Structures" technical report 275, SEI 2/2012.

2 General

The Code SIA 269 "Existing structures – Basis for examination and interventions" is the basic document which is complemented by a series of codes which treat specific items:

- 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 – Steel-concrete composite structures”
- Code SIA 269/5 “Existing structures – Timber structures”
- Code SIA 269/6 “Existing structures – Masonry structures”
- Code SIA 269/7 “Existing structures – Geotechnical aspects”
- Code SIA 269/8 “Existing structures – Earthquake”.

The Code SIA 269/1 contains updated models for actions and action effects, and SIA 269/2 to 6 give specific indications for updating material and structural parameters and models valid for the various types of construction, in particular when materials and structural systems from the past (which are no longer used) are involved. The Code SIA 269/7 covers geotechnical aspects specific to existing structures, and SIA 269/8 refers to aspects of earthquake engineering of existing structures.

3 Basic requirements

The first principle of the code states that activities related to existing structures are carried out while duly respecting individual and society’s safety needs as well as economic, environmental, cultural and societal compatibility, thus following the principles of sustainable development of the built environment.

Maintenance of an existing structure over its remaining service life has to fulfil the following objectives:
- satisfying the requirements regarding the utilisation and legal conditions
- guaranteeing the structural safety and serviceability
- preserving the material and cultural values of a structure while accounting for economy and aesthetics.

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.

For semi-probabilistic and probabilistic verifications the requirement in terms of structural safety is defined through the target value of the reliability index or through the individual risk. 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 :

$\rho = C_F / C_W$

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. The target value of the reliability index β_0 with a reference period of 1 year is defined in the table below :

Efficiency of the interventions EF_M	Consequences of structural failure		
	minor $\rho < 2$	moderate $2 < \rho < 5$	serious $5 < \rho < 10$
Low: $EF_M < 0.5$	3.1	3.3	3.7
Medium: $0.5 \leq EF_M \leq 2.0$	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. The acceptable risk is 10^{-5} per year.

The proportionality of interventions, in particular those related to safety, has to be verified by expressing the efficiency of intervention, i.e., confrontation of effort and benefit, considering safety requirements, availability of the structure, magnitude of damage and the preservation of material and cultural values.

The *efficiency of intervention* EF_M is evaluated by a comparison of risk reduction ΔR_M with respect to safety costs SC_M, as expressed by the following ratio:

$$EF_M = \frac{\Delta R_M}{SC_M}$$

A safety related intervention is proportional when $EF_M \geq 1.0$.

4 Framework of assessment and retrofitting

The general framework of preservation of existing structures and procedures of examinations is defined in Code SIA 469. The examination is conducted following a *stepwise procedure* with increasing focus on details. The *general examination* comprises the whole structure with the objective to identify aspects that need to be examined in more detail. One or more *detailed examinations* follow with the objective to focus on the identified aspects.

The *condition survey*, provisions are given regarding collecting information from an existing structure with respect to hazard scenarios, actions and the conditions. The objectives of the study of the structure are to identify potential conceptual and constructive deteriorations and deficiencies and to collect the information for the necessary update of structural analysis models. The material characteristics should ideally be determined by means of non-destructive testing methods. Provisions are also given for in-situ load testing of existing structures.

The *condition evaluation* is usually based on the quantitative information about the structural safety as expressed for example by the degree of compliance, and it includes a condition forecast. In case the quantitative verifications of the structural safety are not conclusive, a so-called *empirical analysis* may be performed, i.e., sufficient structural safety can be presumed if the structure is in a satisfactory condition, it shows no abnormal behaviour, the live load is not increased and an assessment rates the risk as being acceptable.

The *intervention recommendation* comprises a wide range of potential interventions from accepting the existing condition to implementing a heavy construction intervention. The intervention recommendation concludes the examination.it is a recommendation to the owner (and *not* a design of an intervention).

5 Updating information

In general, updated characteristic values of actions are defined according to Code SIA 269/1. If statistical distributions for the 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.

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

6 Structural analysis and verifications

The structural safety and serviceability verifications are performed using updated values, so-called examination values. In general, deterministic verification will be conducted; probabilistic verifications are in particular appropriate in cases where either very little or a lot of information on the structure is available as well as in cases of large consequences of structural failure.

The notion of *degree of compliance n* is introduced in the *deterministic verification of the structural safety*:

$$n = \frac{R_{d,updated}}{E_{d,updated}}$$

where $R_{d,updated}$ and $E_{d,updated}$ are the examination values of resistance and action effect, respectively. This formulation not only gives the information whether the structural safety is fulfilled, i.e. $n \geq 1.0$, it also indicates by how much the verification is fulfilled (or not). The latter is necessary for the evaluation of results and in view of the planning of interventions. The code also defines (smaller) load factors for permanent actions (compared to those used for the design of new structures) as uncertainties in the determination of permanent actions are reduced through the updating process.

If updated probability distributions of basic variables (action effects and ultimate resistances) are available, the examination values may be determined according to the *semi-probabilistic approach*. 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.

7 Interventions

Maintenance interventions are based on the *concept of intervention* which includes long-term considerations and which is obtained by optimisation of intervention variants (as derived from the results of the examination).

The *design of an intervention* is the implementation of the concept of intervention including operational and/or constructional interventions to be performed. Operational interventions may comprise intensified surveying (e.g. monitoring) or restrictions in the use of the structure; constructional interventions include rehabilitation or modification of the structure (i.e., adaptation or transformation to respond to the new requirements of its utilization).

The resulting *intervention project* needs to be justified by checking it against technical, economical and operational criteria. In particular, the code prescribes that the efficiency of measures to restore and guarantee the durability has to be demonstrated. In addition, the influence of the intervention on the aesthetics of a structure and on its cultural value needs to be assessed. The objective of this procedure is to obtain optimised maintenance interventions.

MEMBER STATE	UNITED KINGDOM (UK)
Title	Overview of UK position on national regulations and guidance for the assessment of existing structures
Status	While there are no specific UK national 'building' regulations concerned solely with the assessment and retrofitting of existing structures, certain requirements relating to existing buildings are set down in 'The Building Regulations'. There is no single set of Building Regulations for the UK and there are separate (but similar) legislative requirements for England and Wales, Scotland, and Northern Ireland. The following provides a simplified overview of the regulatory requirements for England and Wales and the associated professional technical guidance which has been developed for the assessment of existing buildings and structures. There is also established national guidance concerned with the assessment and retrofitting of some specific classes of existing structures, such as highway bridges.
Year of implementation	Varies - depends upon the source document. The regulatory requirements for existing buildings and the professional guidance for the assessment of existing structures have existed for a number of decades.

1 Executive summary

Buildings – Regulatory requirements:

1. The current legislative requirements for the structural performance of buildings are established in Part A (Structure) of Schedule 1 of The Building Regulations 2010 for England and Wales. There are separate (but generally similar) legislative requirements for Scotland and Northern Ireland.
2. Guidance on meeting the statutory requirements established in Part A of 'The Building Regulations ' is given in Approved Document A (currently the 2004 edition; incorporating the 2004, 2010 and 2013 amendments), which establishes the need for certain uses of existing buildings to comply with the requirements of Part A (Structure) of Schedule 1 of The Building Regulations.
3. Large panel system-built (LPS) dwelling (housing) blocks have been treated as a special class of building in the UK since the partial collapse of Ronan Point in May 1968. The requirements for undertaking their structural assessment are set down in the then Ministry of Housing and Local Government Circulars (MHLG) 62/68 and 71/ 68 (1968).
4. Other than these there are no explicit requirements defined for the structural assessment of existing buildings apart from those that arise in relation to health & safety related legislation (primarily The Health and Safety at Work Act (1974) and subsequent Acts).

Buildings – Technical guidance on structural appraisal procedures to meet the regulatory requirements:

1. Section 1 of Approved Document A indicates that in these circumstances appropriate technical guidance on structural appraisal is given in:
    a. *BRE Digest 366: Parts 1 to 4: "Structural Appraisal of Existing Buildings"* (2012), and

b. The Institution of Structural Engineers' publication "*Appraisal of Existing Structures*" (2010).

These documents define procedures that may be used to undertake an assessment of an existing structure and some aspects of the calculation procedures that might be employed.

2. BRE Report 511 "*Handbook for the Structural Assessment of Large Panel System (LPS) Dwelling Blocks for Accidental Loading*" defines revised performance requirements (updating those given in MHLG Circulars 62/68 and 71/ 68) and provides technical guidance on structural appraisal procedures that may be employed.

Other existing structures - Highway and rail bridges:

Some of the UK standards used for the design and assessment of highway (DMRB standards) and rail bridges are listed below.

The DMRB standards are used by the Highways Agency, Transport Scotland, Welsh Government and The Department for Regional Development Northern Ireland. Although not obliged to do so, the DMRB standards are also used by Transport for London (TfL) and local authorities.

The cited documents are part of the technical guidance published by the Highways Agency in its "Design Manual for Roads and Bridges" (DMRB), being contained in Volume 0 (Introduction and General Requirements), Volume 1 (Highway Structures: Approval Procedures and General Design), Volume 2 (Highway Structures: Design (Substructures and Special Structures), Materials) and Volume 3 (Highway Structures: Inspection and Maintenance).

These are listed below in the following:

List 1: DRMB Standards specifically for Assessment and Retrofitting of Existing Structures

List 2: DRMB Standards used in conjunction with those listed above (in List 1)

Other UK standards for the design and assessment of rail bridges are prepared by Network Rail and London Underground, but their relevant standards are not listed here.

The DMRB standards can be found from the following web link to the introductory text to the general DMRB index page, as follows:

http://www.standardsforhighways.co.uk/ha/standards/dmrb/index.htm

List 1: DRMB Standards specifically for Assessment and Retrofitting of Existing Structures

DMRB 1.3.16	BD 84/02 Strengthening of Concrete Bridge Supports for Vehicle Impact Using Fibre Reinforced Polymers
DMRB 1.3.18	BD 85/08 Strengthening Highway Structures Using Externally Bonded Fibre Reinforced Polymer
DMRB 3.1.2	BD 54/93 Post-tensioned Concrete Bridges. Prioritisation of Special Inspections
DMRB 3.1.3	BA 50/93 Post-tensioned Concrete Bridges: Planning, Organisation and Methods for Carrying Out Special Inspections
DMRB 3.1.4	BD 63/07 Inspection of Highway Structures
DMRB 3.1.5	BA 93/09 Structural Assessment of Bridges with Deck Hinges

DMRB 3.1.6	BD 53/95 Inspection and Records for Road Tunnels
DMRB 3.1.7	BA 86/06 Advice Notes on the Non-destructive Testing of Highway Structures
DMRB 3.3.1	BA 30/94 Strengthening of Concrete Highway Structures Using Externally Bonded Plates
DMRB 3.3.2	BA 43/94 Strengthening, Repair and Monitoring of Post-tensioned Concrete Bridge Decks
DMRB 3.3.2	BD 27/86 Materials for the Repair of Concrete Highway Structures (Not applicable for use in Scotland)
DMRB 3.3.2	BA 35/90 Inspection and Repair of Concrete Highway Structures (Not applicable for use in Scotland, Northern Ireland Addendum applicable for use in Northern Ireland)
DMRB 3.3.3	BA 83/02 Cathodic Protection for Use in Reinforced Concrete Highway Structures
DMRB 3.3.4	BA 87/04 Management of Corrugated Steel Buried Structures
DMRB 3.3.5	BA 88/04 Management of Buried Concrete Box Structures
DMRB 3.4.3	BD 21/01The Assessment of Highway Bridges and Structures
DMRB 3.4.4	BA 16/97 The Assessment of Highway Bridges and Structures
DMRB 3.4.5	BA 38/93 Assessment of the Fatigue Life of Corroded or Damaged Reinforcing Bars
DMRB 3.4.6	BA 39/93 Assessment of Reinforced Concrete Half-joints
DMRB 3.4.7	BD 48/93 The Assessment and Strengthening of Highway Bridge Supports
DMRB 3.4.8	BA 54/94 Load Testing for Bridge Assessment
DMRB 3.4.9	BA 55/06 The Assessment of Bridge Substructures and Foundations, Retaining Walls and Buried Structures
DMRB 3.4.10	BA 52/94 The Assessment of Concrete Structures Affected by Alkali Silica Reaction
DMRB 3.4.11	BD 56/10 The Assessment of Steel Highway Bridges and Structures
DMRB 3.4.13	BA 51/95 The Assessment of Concrete Structures Affected by Steel Corrosion
DMRB 3.4.14	BD 44/95 The Assessment of Concrete Highway Bridges and Structures
DMRB 3.4.15	BA 44/96 The Assessment of Concrete Highway Bridges and Structures
DMRB 3.4.16	BD 61/10 The Assessment of Composite Highway Bridges and Structures
DMRB 3.4.17	BE 13/68 Fatigue Risk in Bailey Bridges
DMRB 3.4.18	BD 79/13 The Management of Sub-standard Highway Structures
DMRB 3.4.19	BD 86/11The Assessment of Highway Bridges and Structures For The Effects of Special Types General Order (STGO) and Special Order (SO) Vehicles
DMRB 3.4.21	BD 97/12 The Assessment of Scour and Other Hydraulic Actions at Highway Structures
DMRB 3.4.22	BD 101/11Structural Review and Assessment of Highway Structures

List 2:	**DRMB Standards used in conjunction with those listed above (in List 1)**
DMRB 0.2.3	GD 04/12 Standard for Safety Risk Assessment on the Strategic Road Network
DMRB 1.1	BD 2/12 Technical Approval of Highway Structures
DMRB 1.2.3	BD 95/07 Treatment of Existing Structures on Highway Widening Schemes
DMRB 1.3.1	BD 24/92 The Design of Concrete Highway Bridges and Structures. Use of BS 5400: Part 4: 1990
DMRB 1.3.2	BD 15/92 General Principles for the Design and Construction of Bridges. Use of BS 5400:Part 1: 1988
DMRB 1.3.3	BD 49/01Design Rules for Aerodynamic Effects on Bridges
DMRB 1.3.4	BD 40/93 Tack Welding of Reinforcing Bars
DMRB 1.3.5	BD 60/04 Design of Highway Bridges for Vehicle Collision Loads
DMRB 1.3.6	BD 59/94 Design of Highway Bridges for Hydraulic Action
DMRB 1.3.9	BD 58/94 Design of Bridges and Concrete Structures with External and Unbonded Prestressing
DMRB 1.3.10	BA 58/94 Design of Bridges and Concrete Structures with External and Unbonded Prestressing
DMRB 1.3.12	BA 42/96 The Design of Integral Bridges
DMRB 1.3.13	BA 53/94 Bracing Systems and the Use of U-Frames in Steel Highway Bridges
DMRB 1.3.14	BD 9/81 Implementation of BS 5400: Part 10: 1980 - Code of Practice for Fatigue
DMRB 1.3.14	BD 13/06 Design of Steel Bridges. Use of BS 5400-3:2000
DMRB 1.3.14	BD 16/82 Design of Composite Bridges. Use of BS 5400: Part 5: 1979
DMRB 1.3.14	BD 37/01 Loads for Highway Bridges
DMRB 1.3.14	BA 9/81 The Use of BS 5400 Part 10: 1980 - Code of Practice for Fatigue
DMRB 1.3.14	BA 19/85 The Use of BS 5400: Part 3: 1982
DMRB 1.3.17	BD 90/05 Design of FRP Bridges and Highway Structures
DMRB 1.3	BE 23/71 Shear Key Decks
DMRB 1.3	BE 5/75 Rules for the Design and Use of Freyssinet Concrete Hinges in Highway Structures (Scottish Addendum applicable for use in Scotland)
DMRB 2.1.1	BD 41/97 Reinforced Clay Brickwork Retaining Walls of Pocket-Type and Grouted-Cavity Type Construction Use of BS 5628: Part 2: 1995
DMRB 2.1.2	BD 42/00 Design of Embedded Retaining Walls and Bridge Abutments
DMRB 2.1.3	BD 68/97 Crib Retaining Walls
DMRB 2.1.4	BA 68/97 Crib Retaining Walls
DMRB 2.1.5	BD 70/03 Strengthened/Reinforced Soils and other Fills for Retaining Walls and Bridge Abutments Use of BS 8006: 1995
DMRB 2.1.5	BD 30/87 Backfilled Retaining Walls and Bridge Abutments

DMRB 2.1.7	BA 80/99 Use of Rock Bolts
DMRB 2.1.8	BD 74/00 Foundations
DMRB 2.2.1	BD 94/07 Design of Minor Structures
DMRB 2.2.4	BD 51/14 Portal and Cantilever Signs/Signal Gantries
DMRB 2.2.5	BD 65/97 Design Criteria for Collision Protection Beams
DMRB 2.2.6	BD 12/01Design of Corrugated Steel Buried Structures with Spans Greater than 0.9 Metres and up to 8.0 Metres
DMRB 2.2.8	BD 29/04 Design Criteria for Footbridges
DMRB 2.2.8	TD 19/06 Requirement for Road Restraint Systems
DMRB 2.2.9	BD 78/99 Design of Road Tunnels
DMRB 2.2.10	BD 82/00 Design of Buried Rigid Pipes
DMRB 2.2.12	BD 31/01The Design of Buried Concrete Box and Portal Frame Structures
DMRB 2.2.14	BD 91/04 Unreinforced Masonry Arch Bridges
DMRB 2.3.1	BD 20/92 Bridge Bearings. Use of BS 5400: Part 9: 1983
DMRB 2.3.2	BD 37/92 Priority Ranking of Existing Parapets
DMRB 2.3.4	BD 47/99 Waterproofing and Surfacing of Concrete Bridge Decks
DMRB 2.3.5	BA 47/99 Waterproofing and Surfacing Concrete Bridge Decks
DMRB 2.3.6	BD 33/94 Expansion Joints for Use in Highway Bridge Decks
DMRB 2.3.7	BA 26/94 Expansion Joints for Use in Highway Bridge Decks
DMRB 2.3.7	BA 82/00 Formation of Continuity Joints in Bridge Decks
DMRB 2.3.8	BD 7/01 Weathering Steel for Highway Structures
DMRB 3.4.20	BD 81/02 Use of Compressive Membrane Action in Bridge Decks

Other existing structures

There are various types and classes of existing structures which are subject to special control requirements under legislation, typically for health and safety reasons, such as nuclear and some forms of industrial plants. There may be special requirements and procedures for the structural assessment of these structures. These special requirements are not considered here.

2 General

The above cited documents present varying degrees of technical guidance upon the procedures to be followed in structural assessment, the assumptions which may be made and various other items, such as material strengths and other properties that might be employed in calculations, and other factors such as the types of deterioration which might occur. While the philosophy employed is typically based upon the use of the partial safety factor approach for structural calculations, and what modifications which might be made to the magnitude of the partial safety factors used for design, it is also recognized that not all forms of existing buildings and structures are amenable to this approach. The use of appropriate engineering judgement is encouraged in such and other circumstances. Disparities occur between aspects of the detailing and forms of construction of existing buildings and structures and the assumptions (implicit and explicit) associated with some design equations presented in more modern design codes. For some older types of existing buildings and structures, there are no applicable modern design codes which might be adopted.

Generally there is little explicit reference to structural reliability theory or encouragement to employ such techniques in assessment, although this is mentioned in some of the more recent technical guidance documents. Also more recent versions of the technical guidance documents on structural assessment of existing buildings and structures do make reference to the structural Eurocodes.

The greatest degree of development of standards for structural assessment has probably occurred in the area of highway and rail bridges.

No observations are offered in the following sections because of the diversity of the technical guidance which exists in the absence of a specific UK national ‘building’ regulation, and associated technical guidance, concerned solely with the assessment and retrofitting of existing structures.

3 Basic requirements

No observations due to the diversity of the technical guidance which exists in the UK in the absence of a specific UK national ‘building’ regulation

4 Framework of assessment and retrofitting

No observations due to the diversity of the technical guidance which exists in the UK in the absence of a specific UK national ‘building’ regulation

5 Updating information

No observations due to the diversity of the technical guidance which exists in the UK in the absence of a specific UK national ‘building’ regulation

6 Structural analysis and verifications

No observations due to the diversity of the technical guidance which exists in the UK in the absence of a specific UK national ‘building’ regulation

7 Interventions

No observations due to the diversity of the technical guidance which exists in the UK in the absence of a specific UK national ‘building’ regulation

NEW EUROPEAN TECHNICAL RULES FOR THE ASSESSMENT AND RETROFITTING OF EXISTING STRUCTURES

PART III: PROSPECT FOR CEN GUIDANCE

Contents Part III

Preamble

This Part III presents scientific and technical proposals intended to serve as a starting point for further work to achieve a harmonized European view on the assessment and retrofitting existing structures. Its fundamental purpose is to stimulate debate. To enable this objective to be fulfilled, it contains preliminary proposals for technical provisions and identifies key issues requiring resolution. It is emphasised, however, that it is not intended for use in practice at this stage.

The application of design-orientated methods to the assessment of existing structures often leads to a high degree of conservatism. This conservatism has severe economic, environment and socio-political consequences when it results in satisfactory structures being condemned as unsafe, thereby leading to an unnecessary investment of resources in replacement or retrofitting, with its associated dismantling.

The approach to the assessment of an existing structure is in many respects different from that in designing new structures. The effects of the construction process and subsequent life of the structure, during which it may have undergone alteration, deterioration, misuse and other changes to its as-built (as-designed) state, need to be taken into account.

It is thus possible to obtain and gain more or less detailed information on a specific structure. This is one of the fundamental differences with respect to the methodology used for the design of new structures where uncertainties are dealt with by relying on information gained from experience.

This is why the assessment of existing structures often requires the application of refined methods that are beyond the scope of design codes for new structures. That is the reason that over the last 20 years, methodologies inherent to existing structures have evolved in many countries and have been applied on a national level. However they have not yet been generally adopted in broad practice.

The CEN/TC250 initiative is motivated by the lack of an applicable set of European-wide technical rules to deal with the enormously expanding construction activities in assessing and retrofitting buildings and engineering works. There is an urgent need for bringing together, where it is realistic and constructive to do so, the different national approaches to a broadly accepted, coherent and harmonised set of rules for existing structures.

It is proposed that new European technical rules for existing structures are related to the principles and fundamental requirements of the EN Eurocodes. Thus, technical rules for existing structures would not be self-standing rules but rather they will complement rules of the relevant EN Eurocodes by identifying and distinguishing the differences between the design of new structures and the assessment and retrofitting of existing structures.

New European technical rules for the assessment and retrofitting of existing structures are planned for all types of buildings, bridges, and construction works including geotechnical aspects, exposed to all kind of actions. However as an initial work item, the present draft deals with the material independent general rules and actions equivalent to Eurocode EN1990.

CEN/TC250 policy as set out in resolutions 254 and 255, is that the work for all new Parts of the Eurocodes, including the new European technical rules for the assessment of existing structures follows a step-by-step approach, as follows:

1. Step: Preparation and publication of a “Science and Policy Report”(S&P report), subject to agreement of CEN/TC250.

2. Step: After agreement of CEN/TC250, preparation and publication of CEN Technical Specifications (previously known as ENV).

3. Step: After a period for trial use and commenting, CEN/TC250 will decide whether the CEN Technical Specifications should be converted into Eurocode Parts.

The stepwise procedure allows for a progressive development in order to consider observations from national experts and users and to take into account comments received by CEN members.

It should be noted that the initial purpose of the "Science and Policy Report" was widened complying with CEN/TC250 decision 340 by adding an overview of the state of the art and a collation of existing national regulations and standards for the assessment and retrofitting of existing structures. In consideration of the status of the report the content of Part III is broader, covers more aspects, and includes more information than prospects for technical specifications.

The structure of Part III represents the actual result of the preliminary discussions in Working Group WG2. It reflects the wide range of different and sometimes divergent positions on guidance for the assessment of existing structures in the Member States. Particularly, the annexes contain some aspects, which were brought in for discussion. They should be considered as guidance for the evaluation of a harmonized approach in the frame of the decision making process in step 2.

In that respect the present draft provides the bases for the further development of new European technical rules for the assessment of existing structures and for the conversion into the format of CEN Technical Specifications. Therefore, as explained above, the actual draft of Part III is not yet intended for direct application and use in practice. It should rather stimulate the debate within CEN/TC250 and serve as a starting point for step 2.

Key issues

In particular it should be noted, that the Working Group WG2 has recorded key issues that require resolution in the next steps rather than seeking to resolve all difficult technical issues during the preparation of the "Science and Policy Report".

In this context the following key issues have been identified:

1. The technical rules for existing structures are not intended to be independent (self-standing) rules but to complement the existing rules of the relevant EN Eurocodes for the design of new structures. The key issue is whether the additional technical rules for existing structures should be provided in the form of additional annexes or as additional parts (books) to the respective EN Eurocode.

2. Will it be appropriate to have different target reliability levels for the assessment of existing structures compared to the design of new structures? If so, should the target reliability levels take into account the remaining working life, human safety, the consequences of failure and the proportionality of the costs of any required interventions?

3. Is it possible to update partial-safety factors, based on knowledge of the structure and its condition (materials, actions etc.), recognising the uncertainties associated with the updating process?

4. How are model uncertainties to be taken into account in the partial-safety factor format when undertaking non-linear structural analyses?

5. Should the remaining working life be taken into account when determining live loads, variable actions etc.?

6. Under what circumstances would it be necessary to undertake a structural assessment when there is a change in the design requirements arising from a revision of a design code for new structures?

7. Under what circumstances would it be appropriate for a structural assessment to be based solely upon satisfactory past performance of an existing structure?

8. Should the approach of structural assessment based on knowledge levels, as defined in seismic design, also be applied to persistent or transient design situations and what should the respective criteria be?

The key issues will be discussed and resolved in step 2 while preparing the CEN Technical Specifications. For this reason one of the main purposes of the commenting phase is to seek views with regard to these key issues. In this context it should be emphasized that some of the key issues include aspects, which finally are to be determined on national level.

1 General

1.1 Scope

This report provides proposals for general requirements and procedures for the assessment and retrofitting (repair and upgrade) of existing structures (buildings, bridges, construction works, etc.) based on the principles of structural reliability and consequences of failure in agreement with the principles of EN 1990.

This report is applicable to the assessment and retrofitting 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 various circumstances such as:

- an anticipated change in use or extension of design working life;
- changes in the structural system (e.g. retrofitting, modifications, extensions to the structure);
- an increase of total loads;
- a reliability check as required by authorities, insurance companies, owners, etc.;
- change in design requirements due to revision of design codes;
- structural deterioration due to time-dependent actions (e.g. corrosion, fatigue);
- structural damage caused by accidental events, overloads, or induced by other change of conditions (e.g. settlements);
- defects resulting from previously undetected errors during design or construction.

NOTE 1 Changes in design codes are often based on new insights into actions or mechanisms. It can be necessary to verify how this will affect existing structures, for example, when traffic actions increase.

NOTE 2 This report is applicable to historical structures, provided additional considerations are taken into account concerning the conservation of the construction identity and authenticity, through the preservation of its appearance and materials.

This report provides the basic requirements and principles regarding assessment and interventions. The report is applicable to all different types of construction works and of any construction material. Specific rules can be required depending on the type of construction material, such as concrete, steel, timber, masonry, etc. These specific rules will be given in separate reports complementing the respective EN 1992 to EN 1997 or EN 1999.

This report provides principles regarding actions and environmental influences. Supplementary principles and specific rules for the different types of actions will be given in a separate report complementing the different parts of EN 1991.

Performance requirements concerning serviceability for existing structures are generally based on life cycle cost and/or special functional requirements.

This report does not cover assessment related to special performance requirements of the client related to property protection (economic loss, aesthetics, etc.).

1.2 Normative reference

The 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.

1.3 Assumptions

In general it is assumed for the assessment and retrofitting of existing structures that the structure was:

- originally designed, analysed and specified based on accepted engineering principles and/or design rules;

- constructed on the basis of good workmanship, historic experience and accepted professional practice.

If these circumstances do not apply, or if damage or deterioration has occurred to an existing structure, special care will be needed to obtain adequate results.

For the design of a reconstruction the assumptions of EN 1990 clause 1.3 apply:

1.4 Terms and definitions

NOTE In addition to the definitions given in EN 1990 clause 1.5 the following definitions apply.

1.4.1
assessment
set of activities performed in order to verify the reliability of an existing structure for future use

1.4.2
assessment situation (equivalent to design situation)
a set of physical, chemical and other conditions associated with the structure, taking into account the current condition and it's development in the remaining working life, for which the assessment shall demonstrate that relevant limit states are not exceeded

1.4.3
assessment value (equivalent to design value)
actual value of a variable applied in the analysis and verification of the structural performance of an existing structure determined from a characteristic or another representative value combined with partial or conversion factors, or also directly defined values

1.4.4
damage
unfavourable change in the condition of a structure that can adversely affect structural performance

1.4.5
deficiency
missing characteristics that can adversely affect structural performance

1.4.6
deterioration
process that adversely affects the structural performance, including reliability, over time due to:

- naturally occurring chemical, physical or biological actions;

- repeated actions such as those causing fatigue;

- normal or severe environmental influences;

- wear due to use;

- improper operation and maintenance of the structure.

NOTE Several deterioration processes may act together in conjunction on a structure

1.4.7
deterioration model
mathematical model that describes structural performance as a function of time, taking deterioration into account

1.4.8
existing structure
load-bearing part of a completed and accepted structure

1.4.9
hazard scenario
critical situation characterized by a leading hazard and accompanying circumstances

1.4.10
inspection
on-site non-destructive examination of the structure and/or its components with the objective of updating information with regard to the geometry, current condition, service environment and general circumstances

1.4.11
investigation
collection and evaluation of information through document search, inspection, measurements, material testing, load and other testing

1.4.12
load testing
test of the structure or part thereof by loading to evaluate its behaviour or properties, to predict its load-bearing capacity

1.4.13
maintenance
routine intervention to preserve appropriate structural performance

1.4.14
material properties
mechanical, physical or chemical properties of construction materials

1.4.15
material testing
test of construction material to evaluate, or to predict its actual or future mechanical, physical or chemical properties

1.4.16
monitoring
frequent or continuous, normally long-term, observation or measurement of structural conditions or actions

1.4.17
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 may be taken as reference period (see Annex A).

1.4.18
remaining working life
period for which an existing structure is intended/expected to operate with planned maintenance

1.4.19
retrofitting
structural intervention (repair, upgrade) to reach compliance with required structural performance

*NOTE In ISO 13822 [1] the term **rehabilitation** is used. On the contrary CEN/TC250 decided to introduce the term **retrofitting***

1.4.20
repair
measures that are intended to improve the condition of a structure which is defective, deteriorated, degraded or damaged in some way; to bring its functional performance to the level anticipated by the designer.

NOTE This may involve restoring or replacing existing structural members that have been damaged or are deteriorated, but could involve the addition of new structural members in order to reach its required structural performance

1.4.21
safety plan
plan specifying the performance objectives, the hazard scenarios to be considered for the structure, and all present and future measures (design, construction, or operation, such as monitoring) to ensure the required structural safety

1.4.22
structural performance
qualitative or quantitative structural behaviour under expected circumstances in terms of its structural safety and serviceability

1.4.23
target reliability level
level of reliability required to ensure acceptable safety or serviceability

1.4.24
upgrading
intervention made to an existing structure to improve some aspects of its structural performance.

1.4.25
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

2 Basic requirements

2.1 Objectives

The objective of the assessment and retrofitting of an existing structure in terms of its required future structural performance shall be specified in consultation with the client and the relevant authority based on the following performance levels:

- safety performance level, which provides appropriate safety for the users of the construction and third parties, in accordance with the principles of the Eurocodes;

- 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;

- serviceability performance levels if required by the client, based on criteria that can affect the appearance of the structure, the comfort of users, or the functioning of the structure.

Performance requirements for existing structures are to be based on an acceptable level of risks to persons (individual and societal) and, simultaneously, on economic criteria including environmental aspects. In some cases, cultural and social aspects should also be taken into account.

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

The assessment should be carried out taking into account the actual and/or future condition for the remaining life time. Management of the structure by techniques such as monitoring may be taken into account to warrant the performance requirements over the lifetime.

The performance requirements should be set down in the utilization plan for the structural assessment.

2.2 Target reliability

The requirements in terms of structural safety are defined through the target value of reliability index, acceptable probability of failure or the acceptable level of risk.

The reliability requirements can be expressed in terms of the reliability index β which is related to the probability of failure P_f, corresponding to a specified reference period, as follows:

$$\beta = -\Phi^{-1}\left(P_f\right) \tag{2.1}$$

- Target values of reliability index shall be defined for a given period, e.g. period of 1 year

In an existing structure, target reliability levels may be modified with respect to the current code values assumed for new structures.

The following considerations motivate a differentiation of target reliability levels between new and existing structures:

- economic considerations: the incremental cost between acceptance of the current condition (with a certain minimum target reliability level) and retrofitting the existing structure (to a higher target reliability level) can be very large, whereas the incremental cost of increasing the safety of a structural design of new structures is generally small; consequently conservative criteria are used in design codes for new structures;

- social considerations: these include dismantling, or even displacement, of occupants and activities, and heritage values; such considerations that do not affect the design of new structures;

- sustainability considerations: repair or retrofitting of an existing structure leads to a reduction of waste and recycling, compared to the construction of a new structure.

The target reliability levels used for verification of existing structures may be determined based on explicit risk analysis taking into account both, human safety and economic criteria according to the principles established in [2]. Alternatively, they may be inferred by calibration with current practice (i.e. current design codes) and/or economic optimization criteria (concept of the minimum through-life expected cost). Such requirements should also reflect the type and importance of the structure, possible failure consequences (fatalities, injuries, environmental loss, economic loss) and socio-economical criteria.

Acceptance criteria for individual and societal risks to persons, as well as the corresponding target reliability levels are proposed in Annex A.

NOTE 1 Target reliability levels and the level of risks are determined by relevant National authorities.

NOTE 2 The target reliability index for existing structures may be lower than for new structures, when accepted by National authorities.

Assessment of existing structures, deteriorating or not, may be based on shorter reference periods than the design of new structures and the reliability assessment should be conducted by considering structural performance at the end of the anticipated working life, taking into account the evolution of deterioration and defects.

Former codes and standards are not to be used as a basis for decisions about the acceptability of an existing structure in terms of its reliability.

NOTE 1 Codes, standards and recommendations that were in force at the time when a particular existing structure has been built contain very valuable information about usual conceptual designs at that *time, applied loads in design, materials used, etc. However, according to actual state-of-the-art some assumptions, models, etc. used in these former standards may be antiquated or even wrong.*

NOTE 2 The national annex should list the former standards that provide information about existing structures.

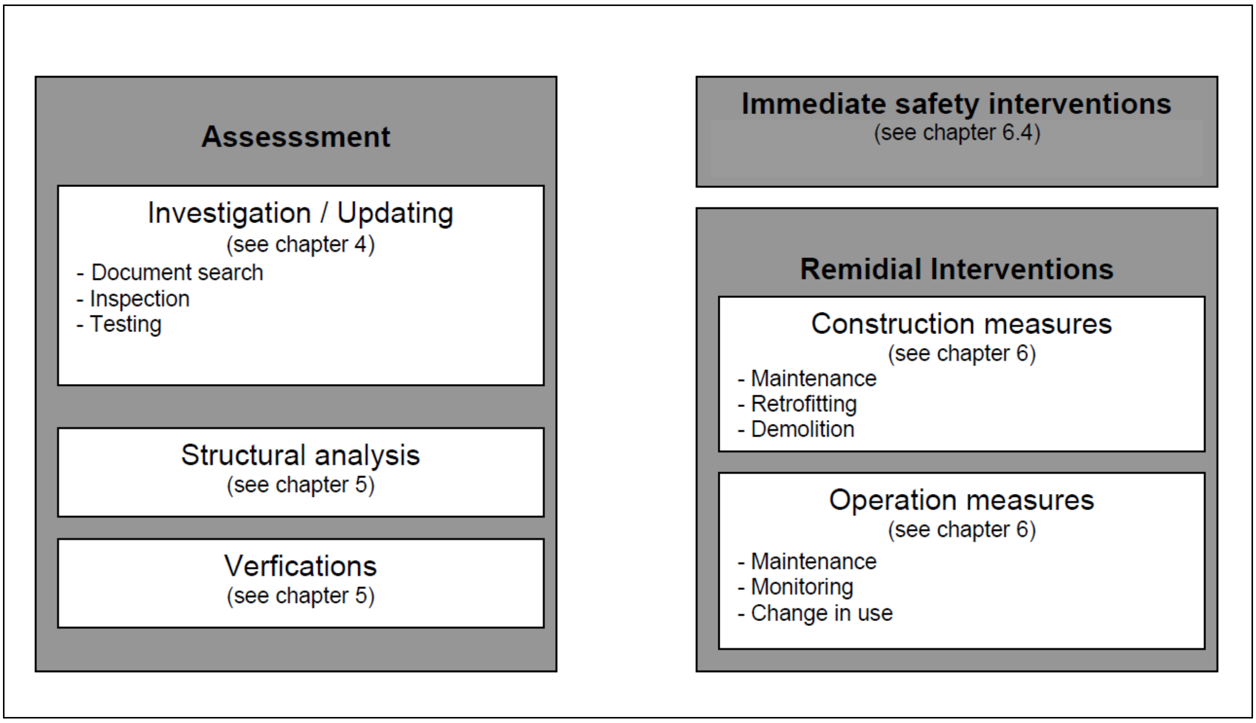
3 Framework for assessment, structure management and retrofitting upon existing structures

3.1 Introduction

The process of assessment and structure management is a decision process which aims to remove any doubts regarding its current condition and future structural performance and/or to identify the most effective interventions required to fulfil the basic requirements. It is important that this process is optimised considering the total service life costs of the structure.

The assessment of existing structures refers to the whole procedure including the different activities. The hierarchy of terms referring to the activities is illustrated in Table 3.1.

Table 3.1: Main components of assessment, structure management and interventions upon existing structures [1] and [8]



The investigation, including updating of information is one of the most important activities in the assessment process (see chapter 4). It must take into consideration all available information and, in particular, the influences of present damage and deterioration mechanisms.

The purpose of the structural analysis is to verify the structural safety and, if required, serviceability of a structure with respect to its specified remaining working life and, where necessary, to suggest interventions. The structural analysis and verifications should take place on the basis of the updating of actions, construction material and geotechnical properties, structural models and geometrical properties, damage and deterioration mechanisms, all of which in turn are used for the establishment of updated values for the actions effects, ultimate resistance and deformation capacity.

Based on the outcome of the structural analysis and verification it has to be decided whether immediate interventions or remedial interventions might be required. If so, then the necessary interventions have to be determined. If structural safety and serviceability are verified, the structure is fit for future use. The planned inspection and maintenance activities are to be carried out during the future service period.

3.2 Generic procedure

3.2.1 Overview

In general, the assessment of an existing structure is carried out in progressive stages, in increasing depth, depending on the quality and the importance of information available.

The assessment procedure is composed in general of subsequent steps to ensure that the actual conditions of the structures are taken into account (see the detailed presentation in Table 3.2). The procedure depends on the assessment objectives, and on specific circumstances (e.g. the availability of the design documents, the observation of damage, the use of the structure) and consists of:

(1) Specification of the assessment objectives;

(2) Identification of scenarios, with respect to changes in structural system and actions;

(3) Preliminary assessment, level of detail to be agreed;

(4) Detailed assessment, level adequate to conclude on structural performance (normally);

(5) Evaluation of results.

Each step of the assessment should include an evaluation of the plausibility of the results prior to the decision being made to implement the required works.

3.2.2 Specification of the assessment objectives

The objectives of the assessment and retrofitting of an existing structure shall be clearly specified respecting its required future structural performance in consultation with the client and the authorities when relevant.

The required future structural performance in terms of serviceability shall be specified in the utilization plan and in terms of structural safety in the safety plan. Durability aspects concern both structural safety and serviceability of the existing structure.

3.2.3 Identification of scenarios

Scenarios related to the change in structural conditions, structural system, actions and influences shall be specified in order to identify possible critical situations and hazards for the structure.

The identification of relevant scenarios should include further the anticipated development of the structural conditions during the foreseen remaining working life.

3.3 Preliminary assessment

3.3.1 Overview

The scope and the content as well as the level of detailing of the preliminary assessment should be agreed with the client and authorities when relevant.

The scope of the evaluation needed for the assessment of the structure has to be defined specifically for concerned structural members. The extent strongly depends on the plausibility and on the quantity of the documentation available (design documents, recordings, testing reports, etc.).

The preliminary assessment includes:

- study of documents and other evidence;
- preliminary inspection;
- preliminary checks;

- decisions on immediate safety interventions;
- recommendation for detailed assessment.

The work carried out and the findings shall be documented in a report.

3.3.2 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.

3.3.3 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.

3.3.4 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.

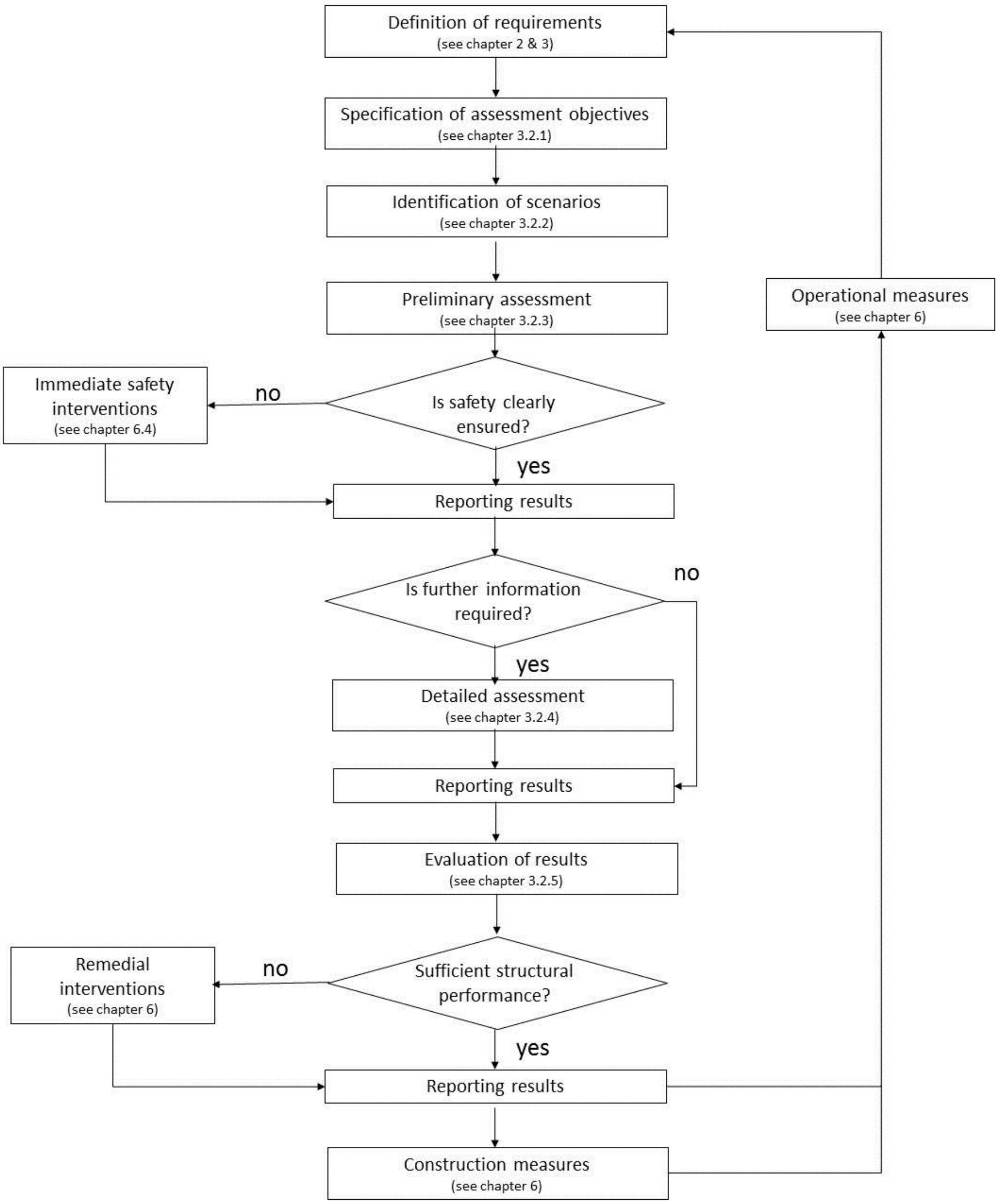
3.3.5 Decisions on immediate safety interventions

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.

3.3.6 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 3.4.

Table 3.2: Generic procedure of assessment and retrofitting of existing structures.



3.4 Detailed assessment

3.4.1 Overview

The scope and the content as well as the level of detailing of the assessment at this stage should be adequate in order to conclude on the structural performance.

The detailed assessment includes:

- detailed document search and review;
- detailed inspection and material testing;
- updating of actions and influences;
- updating of properties of the structure;
- structural analysis;
- verifications;
- evaluation of results;
- recommendation of measures.

The results of the detailed assessment shall be documented in a report.

3.4.2 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;
- topography, subsoil conditions, groundwater level at the site.

When using original design information attention has to be paid to differences in the methods of verification in old and new codes. Further guidance for this is given in 4.

3.4.3 Detailed inspection and material testing

The details and dimensions of the structure as well as characteristic values of material properties may be obtained from design documents, provided that the documents exist and that there is no reason for doubt (see 4). 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.

3.4.4 Updating of actions and influences

Actions and in particular environmental actions on structures shall be determined by analysis in accordance with EN 1991 and [2], taking into account provisions laid down in the safety plan and utilisation plan. Based on updated information the action may be adjusted, guidance for this is given in 4.2.

3.4.5 Updating 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 ISO 13822 Annex D).

3.4.6 Structural analysis

Structural analysis 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. Further guidance on the assessment of time-dependent reliability is given in [1].

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.

3.4.7 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 5).

Former codes that were valid at the time of construction of an existing structure should be used as informative documents.

3.4.8 Evaluation of results

If the structural safety or serviceability is shown to be inadequate, remedial interventions should be planned and implemented. The results of the assessment should be the bases for recommendation of construction measures (see chapter 6) for retrofitting or upgrading the structure to perform according to the objectives for its remaining working life.

In some circumstances the control or modification of the risk may be an alternative approach to construction interventions. Risk control measures include:

- imposing load restrictions;
- change aspects of the use of the structure;
- monitoring and control;
- risk acceptance.

If risk control measures are adopted, an appropriate risk management procedure is to be defined and implemented.

3.5 Assessment based on knowledge levels

Depending on the amount and quality of the information available for the assessment of existing structures different types of analysis and the appropriate value of confidence factors shall be adopted.

Methods based on different knowledge levels are only applicable for the assessment of existing buildings (see Annex B).

Confidence factors can be adopted based on the available knowledge, for instance according to Bayesian updating methods.

4 Investigation and updating information

4.1 General

Data for assessment and retrofitting are related to the material properties, structural properties, dimensions, soil conditions, deformation capacity and other conditions as actually established for the existing structure, and to previous, actual and/or future actions to the structure.

In general, updating of information consists of:

- Document search (design information and information on interventions, alterations during use etc.);
- Inspection of the structure;
- Establishment of prior information based on the results from document search and inspection, taking into account information from literature;
- Testing;
- Evaluation of site data from measurements, tests, etc.;
- Combination of site data and prior information in order to obtain updated information.

The document search and check of original design, if available, should focus on assumptions, static systems (joints, support conditions, etc.) and detailing.

Inspections may help to detect deterioration, which in turn may be the consequence of particular exposure conditions and hazard scenarios.In general, updated information on an existing structure should take into account:

- occurrences during construction and use affecting structural performance;
- the findings from observations, inspections, and measurements;
- previous interventions;
- experience gained from the behaviour of comparable structures under comparable use;
- the results of investigations;
- the specified scenarios and assessment situations for the remaining working life.

The assessment approach on the basis of the partial factor format in accordance to the current generation of standards requires the knowledge of actual characteristic values of action-, action effects- and resistance variables. If the uncertainties associated with the relevant parameters are small, or if updating is impossible for some reason, characteristic values may be deduced from the previously available information (e.g. construction documents, etc.). Otherwise, characteristic values of the variables should be obtained by updating. In case of probabilistic verifications, the parameters of the updated basic variables must be established (see Annex C).

For the purposes of assessment, an existing structure can be inspected/tested so that load, resistance and environmental parameters can be measured. However, this does not mean that the uncertainties can be completely resolved because of uncertainties associated with inspection or testing, natural variability, etc. It is essential to remember that data acquisition methods have a limited resolution. Furthermore in many cases the number of tests should be limited not only from an economical point of view but also to avoid excessive damage to the structure which might negatively affect the load bearing capacity. Thus, in most cases results from inspections and tests cannot be directly used for the subsequent verification of structural reliability. To this end, such results should be combined with relevant prior information in order to obtain posterior information, e.g. updated models.

In the case of verification based on the partial factor method with updated information, further to the updating of the characteristic values of relevant variables, the corresponding partial factors may also be updated.

If the structural performance is verified by means of probabilistic methods, the updated parameters of basic variables may directly be introduced in the analysis.

NOTE 1 Prior information on action and resistance variables is included in the S&P reports complementing EN 1991 to EN 1999. Additional information may be taken from [6] and [7].

NOTE 2 Detailed information on updating of measured quantities is given in [1].

NOTE 3 The national annex could recommend partial factor values according to the level of knowledge of the relevant basic variables.

4.2 Actions

4.2.1 Permanent actions

NOTE The subsequent clauses are additions and adjustments to EN 1990 clause 4.1.2 (5).

Permanent actions may be represented by means of characteristic values based on nominal dimensions and mean unit masses, taking into account the information from the future S&P report complementing EN 1991. In case of probabilistic verifications, the relevant statistical parameters are to be established for the variables describing permanent actions. This information may be considered as prior information which can be updated if the required site information from measurements is available.

NOTE Furthermore, detailed guidance on statistical technique how to determine the actual permanent load using measurements and updating permanent actions is given in [1] (see 4.1) and will be provided in the S&P report “Assessment and Retrofitting of existing structures – Actions” complementing EN 1991-1-1

4.2.2 Prestressing

NOTE The subsequent clauses are additions and adjustments to EN 1990 clause 4.1.2 (6).

Prestressing is classified as a permanent action caused by either controlled forces (e.g. prestress by tendons) and/or controlled deformations imposed at supports of the structure. The time-dependent effects that have already occurred should be taken into account in the determination of the actual prestressing force.

NOTE 1 Further detailed guidance for updating prestressing will be given in the respective reports for the different construction materials, e.g., the S&P report “Assessment and Retrofitting of existing structures – Concrete structures” complementing EN 1992 complementing EN 1992.

NOTE 2 Uncertainties of methods to determine the actual prestressing should be known and taken into account when deriving upper and lower limits for P_k.

4.2.3 Variable actions

NOTE The subsequent clauses are additions and adjustments to EN 1990 clause 4.1.2 (7)P.

For variable actions, the characteristic value Q_k shall correspond to either:

- an upper limit value with an intended probability of not being exceeded or a lower limit value with an intended probability of being achieved, during some specific reference period;
- a nominal value, which may be specified in cases where no statistical distribution is known.

Updated characteristic values, $Q_{k,act}$, are to be established in accordance with the corresponding definition of Q_k in EN 1990 or EN 1991. They may be based on different reference periods if the verifications for the remaining working life are based on a comparison with the corresponding target reliability. In the case of probabilistic assessment or risk based evaluation, parameters of the updated basic variables are to be established accordingly.

NOTE 1 Values are supplied in the various parts of EN 1991. In the case of known use these values do not have to be held unconditionally. After all, these values are standardized to the most unfavorable scenarios within a broad definition of intended use, while the values to be used may also be derived from actual use, taking the backgrounds of the standardized values into account.

NOTE 2 In EN 1991 the characteristic values of climate actions are based upon the probability of 0,02 of its time-varying part being exceeded for a reference period of one year. This is equivalent to a mean return period of 50 years for the time-varying part. However, in some cases the character of the action or the selected assessment situations render another fractile or return period more appropriate.

NOTE 3 If a reference period other than the reference period of 50 years is used, the extreme values of the uniformly distributed loads may be adjusted. In a number of cases rules for adjusting are included in the relevant parts of EN 1991, e.g.:

- *snow loads: EN 1991-1-3, Annex D;*
- *wind actions: EN 1991-1-4, clause 4.1, Note 4;*
- *thermal actions: EN 1991-1-5, Annex A.2.*

NOTE 4 The remaining working life for an existing structure is often different compared to the design working life of a new structure. In consequence the reference period to be considered may differ as well. The rules for the determination of adjusted reference periods applicable for new structures may also be used for the assessment of existing structures.

NOTE 5 Detailed information will be provided in the S&P report "Assessment and Retrofitting of existing structures – Actions" complementing EN 1991. They may be considered as prior information which can be updated if the required statistical information based on series of measurements is available. Updating can be carried out according to [1].

4.2.4 Accidental actions

For accidental actions EN 1990 clause 4.1.2 (8) applies. Hence, the accidental actions for the assessment of an existing structure should be specified for each individual project.

Retrofitting a structure those accidental actions shall be considered that should have been considered in the former design. In the case of extending a structure the relevant clauses of EN 1991-1-7 should be applied if required.

NOTE Detailed information will be provided in the S&P report "Assessment and Retrofitting of existing structures – Actions" complementing EN 1991. They may be considered as prior information which can be updated if additional data is available on accidental actions. Updating can be carried out according to [1].

4.2.5 Representation of fatigue actions

NOTE The subsequent clauses are additions and adjustments to EN 1990 clause 4.1.4.

The actions that have occurred and those that will occur in future should be taken into account.

NOTE Further information on actions that have occurred may be given in the National Annex or be based upon past records or past information.

4.2.6 Geotechnical actions

NOTE The subsequent clauses are additions and adjustments to EN 1990 clause 4.1.6.

Geotechnical actions should be assessed in accordance with EN 1997-1, while taking into account effects that have already occurred.

Specifically for the assessment and retrofitting of an existing structure the actual settlements and their future development should be considered.

In case of changes in the structural system (e.g. retrofitting, modifications, extensions to the structure) or increase of loads, going out from the actual values the future variation of settlements should be quantified and taken into account.

NOTE 1 The effects of altered geotechnical conditions (e.g. construction pits in the vicinity) on the existing structure should be considered in the assessment.

NOTE 2 Further detailed guidance on geotechnical aspects will be provided in the S&P report "Assessment and Retrofitting of existing structures – Geotechnics" complementing EN 1997. For the updating of geotechnical parameters on the basis of test results, statistical procedures are to be applied according to [1], [2].

4.3 Material properties

4.3.1 Actual material properties

The assessment and retrofitting of existing structures shall be based on (updated) actual material properties. Where relevant, these properties shall be updated by considering deterioration and possible influences of actions (e.g. fire) during the history of the structure.

For the assessment of existing structures on the basis of the partial factor format, the main representative value is the actual characteristic value of a material property similar as for the design for new structures for what concerns strength, while for deformations the mean value of the modulus of elasticity is the main parameter.

Unless otherwise stated:

- the characteristic value shall be defined as the 5% fractile value, when a low value of a material or product property is unfavorable;
- the characteristic value shall be defined as the 95% fractile value, when a high value of a material or product property is unfavorable.

Statistical uncertainties shall be taken into account in the evaluation of test results. Therefore, if the partial factor method is used, the updated characteristic value for a given variable is to be established on the basis of the updated distribution.

Probabilistic methods should be considered to combine prior information about a variable with results from tests or measurements, guidance for this is given in [1].

NOTE Prior information on material properties and default probabilistic models should be developed for relevant resistance variables and will be included in the respective reports for the different construction materials, such as "Assessment of existing structures – Concrete structures", "Assessment and Retrofitting of existing structures – Steel structures", etc. complementing EN 1992 to EN 1997 and EN 1999.

If insufficient statistical data are available to establish the actual characteristic value of a material or product property, a nominal value may be taken as the respective actual representative value for the assessment. When the upper or lower limit values of a material or product property are established directly (e.g. friction factors, damping ratios), they should be selected in such a manner that, whenever possible, only the more adverse values would affect the probability of occurrence of the structural performance under consideration to an extent similar to other updated values.

To determine the material properties it is also possible to use information from design and construction documents (e.g. drawings, specifications, test results), if they are available. However further tests on the existing structure may be necessary to verify the validity and representativeness of the original data.

NOTE The methods of verification and the safety levels at the time of construction (e.g. method of permissible stresses) often differ from the current methods. These differences have to be taken into account, when the prior information on material properties is converted into actual material properties used for the assessment.

In case of probabilistic verifications, updated distributions are directly taken into account in the assessment.

NOTE Detailed information on updating of measured quantities is given in [1].

4.3.2 Sampling and material testing

In cases of uncertainty, actual material properties should be determined by testing, including non-destructive or destructive material testing. Non-destructive material testing should be only performed in combination with destructive material testing. Non-destructive material testing methods have to be calibrated with destructive test methods.

The testing should be prepared in such a way to deliver data which are of direct concern to the required structural performance. The conditions of the structure and the environmental influences shall be taken into account.

For determination of actual characteristic material properties including the corresponding coefficients of variation, random samples from the existing construction elements are usually taken and examined with regard to their properties in the laboratory. Material property values should be determined by standardized tests that shall be applied to test pieces made up of materials taken from the structure to be assessed, and performed under specified conditions. If necessary to convert the test results into values that can be assumed to be representative for the behaviour of the material or product in the structure or the ground, a conversion factor should be applied.

NOTE Not for every material standardized tests may be available, for timber structures for instance tests may depend on the kind of timber.

If a conversion factor is required for materials or products, a conservative value should be used, unless suitable statistical information is available to establish the reliability of the value chosen. When appropriate, the unfamiliar nature of the application or materials/products used should be taken into account in a suitable manner.

Because statistical procedures are used for determining actual characteristic values of material properties the quality of results depends strongly on the number of samples. However, the number of samples is usually limited, to avoid damage to the structure which could jeopardize structural reliability, and to optimize costs and other feasibility reasons. Sampling locations should be repaired immediately after sampling.

4.3.3 Analysis of test results

When samples are tested, the material properties of the structure shall be determined, statistically if possible, from the test results. Generally, the log-normal distribution is accepted for terms of resistances. The 5% percentile value is calculated on the basis of a unilaterally limited confidence level of (1-α) = 0,75 as described in Annex D of EN 1990.

NOTE Further guidance on the combination of information is given in [1]

This report distinguishes between the cases of application "V_x known" if relevant information on the coefficient of variation is available, and "V_x unknown" if no relevant information is available. Generally any information about the coefficients of variation does not exist for existing structures because each structure comprises its specific characteristics in terms of built-in materials and conditions during construction.

The first step for the determination of updated characteristic material properties including its coefficients of variation is the sorting of the existing structure to be examined in single sections representing areas, of which reasonably can be assumed, that they consist of material of the same population. If a complete structure is to be assessed, materials may belong to different populations and the corresponding variability must be handled in the assessment.

NOTE Belonging to a common population anticipates that portions were produced and built-in under the same conditions.

Starting with the test results x_i, the characteristic values required for the calculation of existing structures are concluded by using statistical parameters (mean value m_y, standard deviation s_y and coefficient of variation v_y) obtained from the random samples of size n, adopted as log-normally distributed. It is essential to ensure that the determination of the parameters is done for one population only. Since materials may belong to different populations, appropriate combination of test results with prior information is important (see 4.1). In case of probabilistic verifications, updated parameters describing the considered material properties are to be used (see 4.1).

4.3.4 Geotechnical investigation

Geotechnical and subsoil influences on structural behaviour may be determined from construction documents when there is no uncertainty about their validity.

In cases of uncertainty, they should be investigated.

NOTE Further detailed guidance on geotechnical investigations will be given in the S&P report complementing EN 1997. For the updating of geotechnical parameters on the basis of test results, statistical procedures are to be applied according to [1], [2].

4.4 Geometrical properties

4.4.1 Actual dimensions

When determining dimensions of structural members of an existing structure, the actual dimensions should be used.

4.4.2 Determination of dimensions

Dimensions may be determined from drawings and design specifications when there is no uncertainty about their validity. In order to confirm the absence of uncertainty, it may be necessary to carry out some measurements. In cases of uncertainty, dimensions should be determined by inspection and measurement.

Deterioration and imperfections identified during the inspections should also be taken into account. Inconsistencies with the construction documents should be clarified.

If the measured geometric imperfections are smaller than tolerances given in the codes for new structures, the minimal value of the codes has to be considered.

4.5 Structural models

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 [1].

The structural model should reflect the actual condition of the existing structure. The factors influencing changes of the structural model are treated in the forgoing chapters of updating information. Deterioration due to environmental influences may result in an unfavourable reduction of the structural performance.

Additional factors to be considered are permanent deformations due to overloads and accidental actions as well as settlements or changes of geotechnical conditions induced by e.g. flooding.

Site inspections and surveying are the key elements in evaluating the actual behaviour of the structural model.

Partial or complete static load tests can be useful, as well as dynamic tests. The type of tests and the applied loads are to be carefully chosen in order to avoid damages to the structure. Still, load testing must be chosen only when there is no alternative.

Inconsistencies between the structural behaviour registered during testing and that predicted by the structural models must be clarified.

In addition it should be taken into account that the structural behaviour might be different at test load level and at ultimate limit state, respectively. This fact should be carefully taken into consideration when designing and evaluating load tests, and reliability updating based on such tests must carefully be carried out.

4.6 Resistance and deformations

The updating of the resistance and of the deformation capacity should be carried out according to the respective reports for the different construction materials which will be published, such as “Assessment of existing structures – Concrete structures”, “Assessment and Retrofitting of existing structures – Steel structures”, etc. complementing EN 1992 to EN 1997 and EN 1999.

It should be taken into consideration that the actions and the deformation capacity of the structure can influence one another.

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

5 Structural analysis and verifications

5.1 General

The evaluation and assessment of an existing structure should be based on the principles of limit states. The relevant assessment situations (equivalent to design situations for new structures) should be selected taking into account the updated information and the actual conditions and circumstances under which the structure is required to fulfill its function during the remaining working life.

Structural assessment aims to determine the reliability of a structure as a whole or in terms of individual members, with respect to prescribed limit states and for a given time period.

The assessment of an existing structure should focus on the verification of structural safety, serviceability, and durability. To this scope the existing structure should be adequately modeled and the limit state function clearly formulated.

The actual reliability of the structure should be compared to the corresponding target values by means of:

- the partial factor format or the global resistance format;
- the probabilistic format;
- risk analysis.

In the present document, information is given concerning analysis and verifications based on the partial factor format or global factor format, respectively (see 5.3).

The probabilistic format or a risk analysis may be appropriate:

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

Guidance for probabilistic verifications is given in 5.4, whereas risk analysis may be carried out according to the guidelines from [7]. Acceptable levels for risks to persons are given in Annex A, as well as target reliability levels.

The structural analysis and verifications should always be carried out with the actual (updated) values of the variables, parameters, and factors. The influences of deterioration and defects on the ultimate resistance, deformation capacity and action effects, where relevant, must be taken into account. This shall be done by means of updated geometrical properties, material as well as geotechnical characteristics (see 4).

5.2 Structural analysis (static analysis)

Structural analysis shall be carried out in accordance with the basic principles from EN 1990, taking into account the relevant parameters with their actual (assessment) values (see 4.1), and by using one of the following methods:

- linear elastic analysis;
- linear elastic analysis with limited redistribution;
- plastic analysis;
- non-linear analysis.

The type of analysis should be chosen on the basis of the type of structure and material. The models applied for the assessment (linear elastic analysis, linear analysis with limited redistribution, plastic analysis, etc.) should be such that they reflect the structural behavior as closely as possible or needed. Application limits of the models used must be compatible with the structural behavior. This is particularly important and must be taken into account if the minimum requirements for the validity of resisting models used for new structures are not fulfilled.

NOTE 1 When performing non-linear analysis the actual deformation capacity of the structure should be known.

NOTE 2 For a non-linear analysis upper and lower bound values should be used to study the effect on the plastic deformation capacity.

NOTE 3 The allowance of the method proposed is up to Member States since this affects the safety philosophy and the required reliability level (element-, system reliability).

In the case of linear elastic analysis, linear elastic analysis with limited redistribution, and plastic analysis, verification of structural reliability may be carried out by means of the partial factor format. Other generally accepted methods for taking into account uncertainties (see 4.1) may also be used together with the aforementioned methods for structural analysis.

If the structural behaviour is investigated by a non-linear analysis, structural reliability should be verified by means of probabilistic methods or by carrying out a risk analysis. The global resistance format may also be applied. The partial factor format may be used if the required level of redistribution of internal forces and moments is low and the partial factors are adjusted to take into account the influence of non-linear behaviour.

5.3 Verifications based on partial factors

5.3.1 Partial factor format

The partial factor format takes account of the uncertainties originating from various sources by means of assessment values. For each limit state condition, it is necessary to verify that the following inequality is fulfilled:

$$g\left(F_{act}, f_{act}, a_{act}, \theta_{act}, C\right) \geq 0 \tag{5.1}$$

where:

g is the limit state function;

F_{act} is the assessment value of actions;

f_{act} is the assessment value of material properties;

a_{act} is the assessment value of geometrical quantities;

θ_{act} is the assessment value of model uncertainties;

C is the serviceability constraints.

The actual assessment values of the mentioned properties shall be determined based on the target reliability index, the remaining working life and the outcomes of tests, if available.

NOTE Updating of model uncertainties is a time-consuming process. Default models taking into account uncertainties associated with action-, action effect- and resistance models are therefore included in the S&P reports complementing EN 1991 to EN 1999, depending on the adopted verification format.

5.3.2 Global resistance format

The safety verification can be performed in the domains of actions or actions effects.

In the first case, it should be verified that:

$$\gamma_{G,act} G_{k,act} + \gamma_{Q,act} Q_{k,act} + \gamma_{P,act} P_{k,act} \leq \frac{q_{u,act}}{\gamma_{R,act}} \tag{5.2}$$

or:

$$\gamma_{G,act} G_{k,act} + \gamma_{Q,act} Q_{k,act} + \gamma_{P,act} P_{k,act} \leq \frac{q_{u,act}}{\gamma_{R,act}{}' \gamma_{R,act}} \tag{5.3}$$

where:

$\gamma_{G,act}\, G_{k,act}$ is the assessment value of permanent actions;

$\gamma_{Q,act}\, Q_{k,act}$ is the assessment value of variable actions;

$\gamma_{P,act}\, P_{k,act}$ is the assessment value of pre-stressing;

$q_{u,act}$ is the failure load estimated by means of non-linear analysis with the actual mean values of the material resistances.

$\gamma_{R,act}$ is the actual global resistance factor which accounts for the uncertainties in the resistance model;

$\gamma_{R,act}{}'$ is the actual global resistance factor, which accounts for the uncertainties in the structural resistance and in the resistance model.

The global resistance factors γ_{Ract} and $\gamma_{R,act}{}'$ should be defined for each material or composition of them. For example for concrete structures, the value of the global resistance factors may be taken from the EN 1992-2. In this case, the mean values of yield strength and tensile strength are considered for the reinforcement, while the value $0.843f_{ck}$ is used for the concrete compressive strength.

In alternative, $\gamma_{R,act}$ and $\gamma_{R,act}{}'$ can be derived using a probabilistic approach. According to EN 1990, the actual assessment value R_{act} of a resistance R is correspondingly defined as:

$$\text{Prob}\left(R \leq R_{act}\right) = \Phi\left(-\alpha_R \beta\right) \tag{5.4}$$

where:

$\Phi(\cdot)$ is the cumulative distribution function of the standard normal distribution, α_R is the resistance sensitivity factor and β is the reliability index.

The structural resistance can be described by a two-parameter lognormal distribution. In general, the coefficient of variation is small ($V_{R,act} < 0.25$), then the actual assessment value R_{act} is approximated by:

$$R_{act} = \mu_{R,act} \exp\left(-\alpha_R \beta V_{R,act}\right) \tag{5.5}$$

being $V_{R,act}$ estimated by means of, for example, the Monte Carlo method. The global resistance factor γ_R is defined as the ratio between the mean value and the actual assessment value of the distribution of the resistance:

$$\gamma_{R,act} = \frac{\mu_{R,act}}{R_{act}} = \frac{\mu_{R,act}}{\mu_{R,act} \exp\left(-\alpha_R \beta V_{R,act}\right)} \approx \exp\left(\alpha_R \beta V_{R,act}\right) \tag{5.6}$$

The global resistance factor $\gamma_{R,act}'$ can be estimated by means of the following expression:

$$\gamma_{R,act}' = \exp(\alpha_R \beta V_{R,act}') \tag{5.7}$$

where $V_{R,act}'$ accounts for the actual uncertainty in the structural resistance and in the resisting model. As a simplification, the global resistance factor $\gamma_{R,act}'$ can be expressed as:

$$\gamma_{R,act}' = \gamma_{R,act}\gamma_{Rd,act} \tag{5.8}$$

The actual global resistance factor shall be determined based on the target reliability index, the remaining working life and the outcomes of tests.

In alternative, the safety verification can be performed in the domain of the actions effects:

$$\gamma_{Sact} E(\gamma_{g,act} G_{k,act} + \gamma_{q,act} Q_{k,act} + \gamma_{P,act} P_{k,act}) \le \frac{R\left(\dfrac{q_{u,act}}{\gamma_{R,act}}\right)}{\gamma_{Ract}} \tag{5.9}$$

or:

$$E(\gamma_{G,act} G_{k,act} + \gamma_{Q,act} Q_{k,act} + \gamma_{P,act} P_{k,act}) \le \frac{R\left(\dfrac{q_{u,act}}{\gamma_{R,act}}\right)}{\gamma_{Ract}} \tag{5.10}$$

or:

$$E(\gamma_{G,act} G_{k,act} + \gamma_{Q,act} Q_{k,act} + \gamma_{P,act} P_{k,act}) \le R\left(\frac{q_{um,act}}{\gamma_{R,act}'}\right) \tag{5.11}$$

where:

E is the effect of actions;

R is the resistance;

γ_{Ract} is the actual partial factor for model uncertainties on the resisting side;

γ_{Sact} is the actual partial factor for model uncertainties on the load effect side;

$\gamma_{R,act}$ is an actual global resistance factor taking into account the randomness of the structural response;

$\gamma_{R,act}' = \gamma_{R,act}\ \gamma_{Rd,act}$ is an actual global resistance factor taking into account also resisting model uncertainty.

NOTE See Note on model uncertainties in 5.3.1.

5.4 Verifications based on probabilistic format

The probabilistic safety format allows explicitly assessing the reliability of an existing structure by estimating the probability of failure (or the reliability index β).

This safety format shall be applied in accordance with the principles and recommendations laid down in JCSS Probabilistic Model Code [6] and in JCSS Probabilistic Assessment of Existing Structures [7].

The assessment of the probability of failure can be described as follows:

- formulation of a structural model;
- randomization of input variables (actions, material properties, dimensions, boundary conditions, model uncertainties, etc.). Random properties shall be described by random variables or random fields, when the property is characterized by spatial randomness;
- probabilistic analysis of the structural performance. This can be performed by analytical, numerical or simulation methods. Results of this analysis provide an estimate of the structural reliability.

The random variables modeling the following properties shall be updated using information about the actual condition of the structure:

- actions (incl. model uncertainties);
- material properties;
- geometrical properties;
- structural model (incl. model uncertainties);
- deterioration models.

The uncertainties related to the action and structural models shall be accurately modeled, since they have a strong influence on the reliability of the structure.

NOTE See Note on model uncertainties in 5.3.1.

5.5 Plausibility check

The conclusion form the assessment shall withstand a plausibility check. In particular, discrepancies between the results of structural analysis (e.g. insufficient safety) and the real structural condition (e.g. no sign of distress or failure, satisfactory structural performance) shall be explained.

NOTE Many engineering models are conservative and cannot always be used directly to explain an actual situation (see Foreword).

6 Interventions

6.1 Recommended measures

If the structural safety or serviceability is shown to be inadequate, remedial interventions should be planned and implemented. The recommended measures taking into account the results of the assessment form the basis for fundamental decision with respect to required interventions.

The concept of interventions may include the following different options for construction measures:

- immediate correction of the existing condition by means of urgent safety measures;
- retrofitting, repair and/or upgrading;
- replacement of the entire structure or of individual parts thereof;
- decommissioning;
- dismantling.

As an alternative to construction measures risk control may include the following operation measures:

- acceptance of the existing condition;
- restrictions in use;
- supplementary safety measures;
- performance of a further detailed assessment;
- initiate or change in monitoring and maintenance procedures.

In case of a transformation of a part of the structure, the concept of interventions remains pertinent.

6.2 Retrofitting

Responding to the requirements defined in the safety plan and/or utilisation plan, assessment of existing structures may result in several possible construction interventions. Retrofitting as a structural intervention to reach compliance with required structural performance includes:

- repair;
- upgrading.

The purpose of repair is to improve the condition of a structure either by repairing or replacing existing structural members that have been damaged, or by adding new structural members in order to reach its originally intended structural performance.

Upgrading modifications are applied to improve the structural performance of an existing structure compared to its originally intended structural performance.

These construction interventions should consider previous applied interventions and may be necessary in combination with operational interventions such as survey and monitoring maintenance.

NOTE Further detailed guidance for retrofitting will be given in the respective S&P reports complementing EN 1992 to EN 1999.

6.3 Survey and monitoring maintenance

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

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

The measured (monitored) values should be compared to threshold values which, in turn, should be established on the basis of the admissible probability of failure. Actions to be taken when exceeding the thresholds should be determined and registered in the monitoring and maintenance plan.

6.4 Immediate safety interventions

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

The identification of structures which constitute an immediate risk requires engineering judgement and will be dependent upon specific circumstances. In assessing immediate risk to public safety the following relevant factors should be taken into account:

- consequence of failure;
- nature of the structural weakness;
- any signs of damages or defects and the rate of deterioration or change occurring;
- possibility of hidden damages or defects;
- condition data;
- sensitivity of the structure to the applied loading;
- recent load history of the structure;
- level of assessment completed.

The past performance of the structure under unrestricted loading can often provide valuable evidence in assessing whether an immediate risk is posed.

In case of a risk to the public the following immediate safety interventions should be considered:

- evacuation of endangered persons, before material goods;
- causing alarm to persons who may be at risk;
- decommissioning and cordoning-off of the structure;
- urgent structural safety measures (i.e. shoring and underpinning of the structure);
- restrictions of use and access;
- intensified monitoring.

Immediate safety interventions shall neither prejudice nor hinder supplementary safety interventions.

6.5 Remedial interventions

Remedial interventions 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 behavior;
- possibility of controlling use;
- costs-risk considerations;
- various possibilities of damage limitation.

The nature of remedial interventions may be operational or constructional. Often, different measures may successfully be combined.

Additionally to the operational measures mentioned in 6.1, the following supplementary safety measures can be considered:

- limitation of the use and limitation of the remaining working life;
- limitation of live loads (possibly through structural design measures);
- monitoring of the structural behavior (control measurements, interim inspection);
- permanent or periodic monitoring of use;
- comparison of monitored values with threshold values;
- installation of automatic warning and safety equipment;
- preparation of emergency measures;
- drafting of alarm dispositions;
- introduction of evacuation plans.

Annex A – Reliability requirements (informative)

A1 General

Reliability requirements for existing structures may be defined in terms of, respectively, acceptable levels of risks, acceptable probabilities of failure or target values of the reliability index.

The requirements depend on the adopted reference period, the expected failure consequences and the relative costs of safety measures.

Requirements for the verification of serviceability and fatigue limit states associated with existing structures may be determined based on economic optimization criteria. Alternatively, target reliability indices for the intended remaining working life may be adopted from [1].

For structural safety, this Annex proposes reliability requirements in terms of, respectively, acceptable risks to persons (section A2) and the associated reliability indices (section A3). The indicated values may be interpreted as minimum requirements for human safety to be used in ultimate limit state verifications of existing structures.

A2 Acceptable risks to persons

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

Societal risk may be accepted if the following requirement is fulfilled:

$$F(n) = p(N \geq n) \leq F(1) \cdot n^{-\alpha} \tag{A.1}$$

where:

F(n) is the annual frequency of events with *n* or more fatalities;

F(1) is the annual frequency of events with 1 or more fatalities;

N is the number of fatalities in one event;

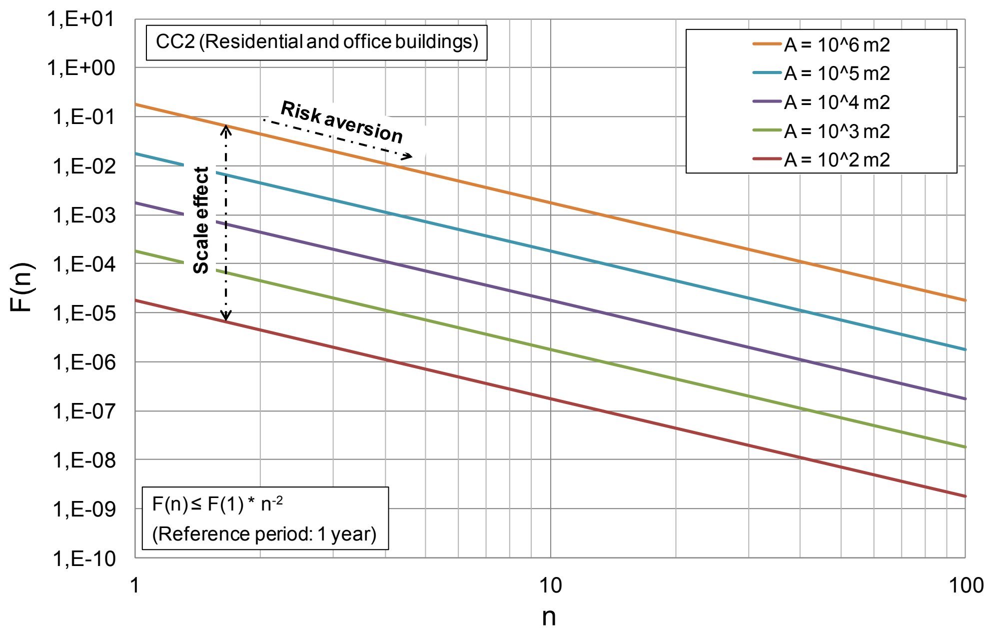
n represents the failure consequences in terms of the number of fatalities;

p(…) is the annual probability of *(…)*;

α is a constant taking into account social aversion to events with large consequences.

For risk aversion a value of α=2 may be adopted.

For a given system, *F(1)* may be considered constant. The numerical values of *F(1)* increase with the size of the reference system (e.g. the structure of one building; all structures designed to a set of code rules; all buildings in a country; etc.) and should be consistent with the socially acceptable risks on a national level. Figure A.1 represents the acceptable level of societal risks associated with building structures belonging to the consequence classes CC2 and CC3, respectively. The different reference systems are expressed in terms of the net room area, *A*.



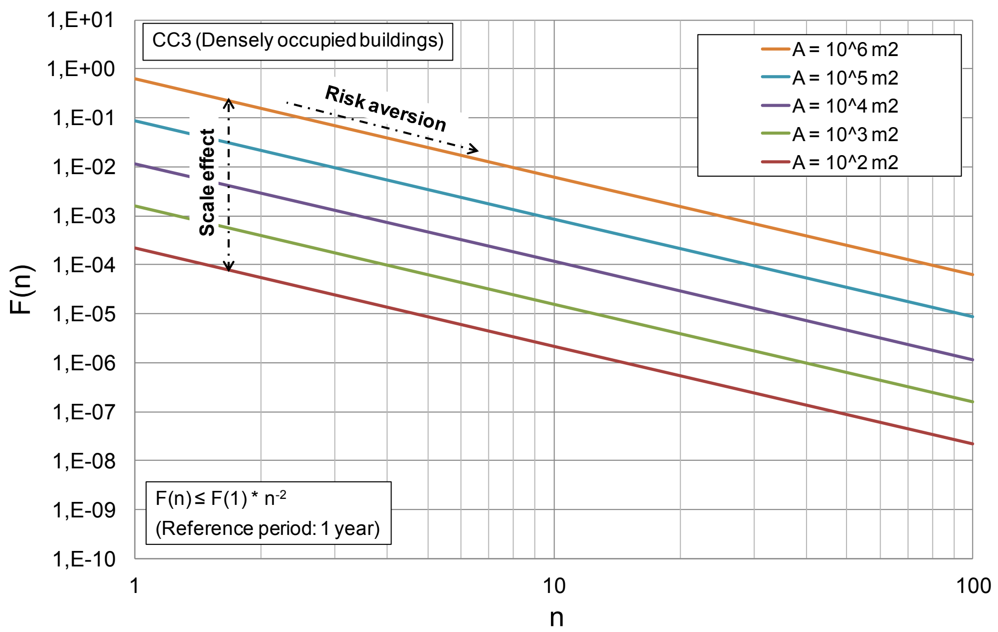


Figure A.1: Acceptable level of social risks expressed in terms of the net room area A in buildings

A3 Target reliability indices

Minimum reliability indices for a reference period of 1 year, associated with building structural members belonging to the consequence classes CC2 and CC3, respectively, are represented in Figure A.2, as a function of the area affected by the collapse, A_{col}, in case of structural failure. These requirements are consistent with the acceptable risks to persons according to section A2, taking into account individual as well as societal risks.

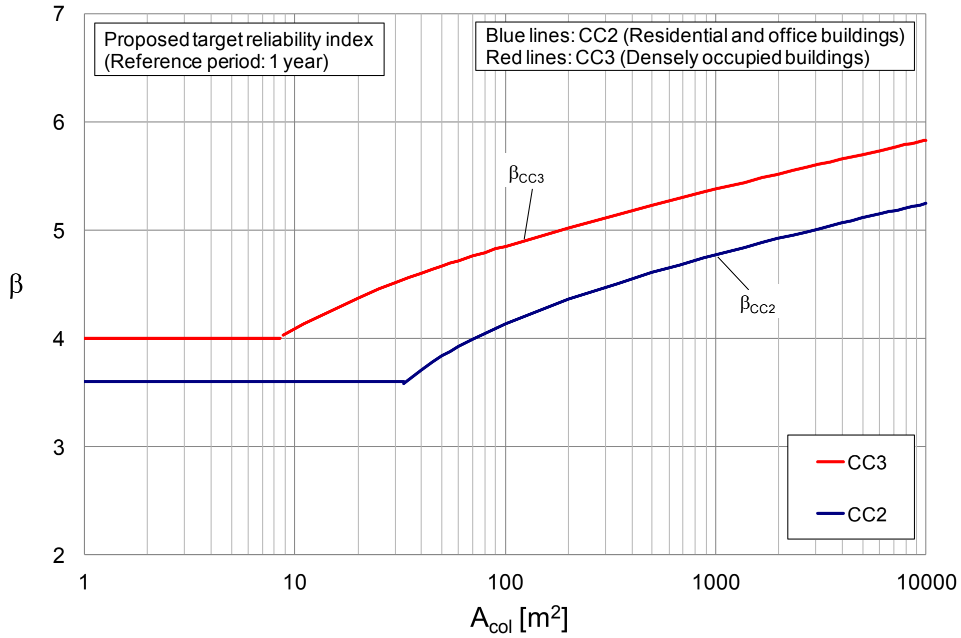


Figure A.2: Target reliability indices expressed in terms of affected area in case of collapse

Annex B - Knowledge levels of the existing structure (informative)

The level of knowledge mainly depends on the following elements:

- geometrical properties of the structural system;
- detailing of reinforcement for reinforced concrete, connections between steel components, connections between floors and wind bracing systems, characteristics of mortar in masonry joints, etc.;
- materials: actual material properties.

The following classification is provided:

- KL1: limited knowledge of the existing structure;
- KL2: normal knowledge of the existing structure;
- KL3: full knowledge of the existing structure.

KL1 corresponds to the following level of knowledge:

- geometry: geometry and dimensions of the structure are determined either from an in situ complete examination or from general drawings and a sufficient in situ examination,
- detailing: from a simulated design, with a careful inspection of the most critical elements,
- materials: if no testing report of the existing components is available, carefully estimated values in accordance with the code of design of the existing structure, together with in situ testing carried out on the most critical components.

KL2 corresponds to the following level of knowledge:

- geometry: the geometry of the whole structure and its dimensions are determined either from a complete visual in situ examination or from general drawings including further modifications, combined with a more complete in situ examination of geometry and dimensions; in case of differences between the actual structure and the drawings, a precise collect of the dimensions may be necessary,
- detailing: determined either from an increased in situ inspection either from detailed construction drawings; in that case, it may be necessary to carry out in situ examinations of detailing of the most critical elements in order to verify that the available documentation is suitable,
- materials: information on the properties of materials is available either from complete in situ testing or from specifications of the design of the existing structure; in that case, it may be necessary to carry out limited testing.

KL3 corresponds to the following level of knowledge:

- geometry: the geometry end dimensions of the structure are determined either from an exhaustive examination of the existing structure or from the exhaustive as built drawings, completed with a sufficient examination of the structure; in case of a contradiction between drawings and in situ examination, inspection of the most critical elements should be carried out in order to verify the correctness of the drawings.
- detailing: detailing is determined either from an exhaustive in situ examination or from an exhaustive as built drawings file; in that case, the most critical elements should be inspected.
- materials: information on materials is determined either from an exhaustive testing or from construction testing reports combined with limited in situ testing.

NOTE The ratio of elements to be inspected and the number of elements tested for each level KL1, KL2 or KL3 and the corresponding confidence level are to be determined in the National Annex. Recommended values are given in EN 1998-3 as:

- $CF_{KL1} = 1.35$
- $CF_{KL2} = 1.2$
- $CF_{KL3} = 1$

Since the difference between the existing structure and the retrofitted, upgraded or transformed one is set out, the proposal for reinforcing the structure or reinforcing and transforming by phase parts of it can be designed according to EN Eurocodes, provided the intact part of the existing structures is not necessarily reinforced in case of assessment based on satisfactory past experience.

Annex C - Reliability based derivation of partial factors (informative)

The application of the partial factor method requires the definition of the design values of the actions, material and product properties, geometrical data and model uncertainties.

In [1] and [3] it is recommended to calibrate the design values R_d and E_d using the values of the variables R and E at the FORM design point P. The FORM is a simple and effective reliability method, which aims to assess the failure probability of a structure with respect to a limit state condition. The failure probability P_f is defined as:

$$P_f = P\,(g \leq 0) \tag{C.1}$$

The failure probability P_f may be substituted by the reliability index β, which is defined as:

$$\beta = -\,\Phi^{-1}\,(P_f) \tag{C.2}$$

where:

Φ^{-1} is the inverse standardized normal distribution.

In this annex C the attention is focused on the ultimate limit state STR, which concerns the failure or excessive deformation of a structure or its constituent members. Nevertheless, the partial factors can be derived using the same approach also for other limit state conditions.

Let us assume that the limit state function g is a function of the resistance R and the load effect E:

$$g = R - E \tag{C.3}$$

The distributions of the variables R and E are denoted by F_R(r) and F_E(e) respectively. The two distributions are characterized by mean values μ_R and μ_E and standard deviations σ_R and σ_E.

The coordinates of the FORM design point P (R^*, E^*) are:

$$R^* = F_R^{-1}\,[\Phi\,(-\alpha_R\,\beta)] \tag{C.4}$$

$$E^* = F_E^{-1}\,[\Phi\,(-\alpha_E\,\beta)] \tag{C.5}$$

where:

α_R and α_E are the sensitivity factors of the resistance and load effect, respectively, and β is the reliability index.

If R and E are independent Gaussian random variables, the design point is defined as the point of the limit state surface closest to the average point in the space of normalized variables R/σ_R and E/σ_E. The design point and its relationship to the distributions of R and E are shown in Figure C.1.

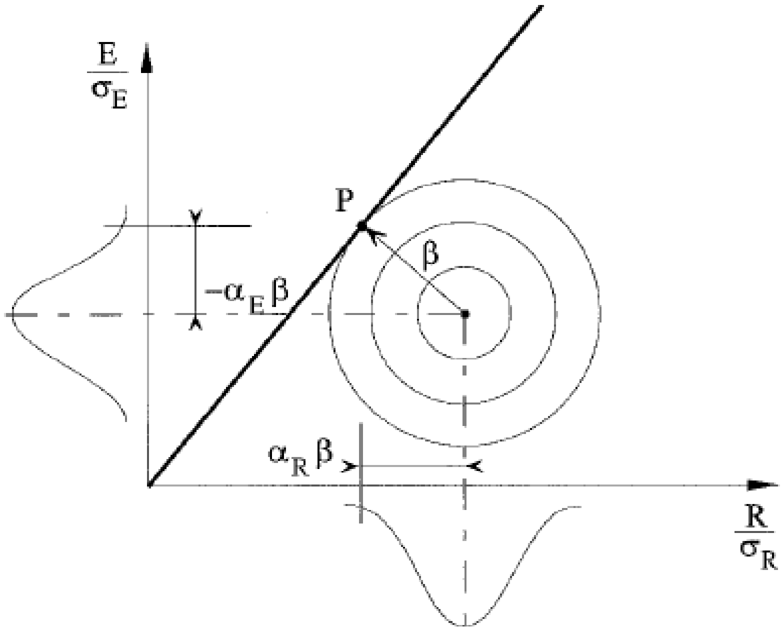


Figure C.1: FORM design point.

Assuming a Gaussian distribution for *R* and *E,* the expressions (C.4) and (C.5) can be rewritten as:

$$R^* = \mu_R - \alpha_R \beta \sigma_R \quad \text{(C.6)}$$

$$E^* = \mu_E - \alpha_E \beta \sigma_E \quad \text{(C.7)}$$

The reliability index, sensitivity factors, design values and the partial factors change according to the reliability problem (distributional assumptions, mechanical model, etc.).

In order to derive practical design rules for a wide-range of new structures the values of α_R and α_E have been fixed to the following values [5]:

$$\alpha_R = 0.8 \quad \text{(C.8)}$$

$$\alpha_E = -0.7 \quad \text{(C.9)}$$

These values have been defined by minimizing the deviation from the target reliability index for different values of the ratio between the standard deviations of the random variables *R* and *E*, provided:

$$0.16 < \frac{\sigma_E}{\sigma_R} < 7.6 \quad \text{(C.10)}$$

Let's consider the general case, where both the resistance and the load effect are functions of several random variables. In this case expressions (C.8) and (C.9) hold only for the leading variables (in terms of their contribution to the resistance or load effect). It can be shown that the sensitivity factors of the non-dominant variables are given by expressions (C.11) and (C.12) [5]:

$$\alpha_R = 0.4 \cdot 0.8 = 0.32 \quad \text{(C.11)}$$

$$\alpha_E = 0.4 \cdot (-0.7) = -0.28 \quad \text{(C.12)}$$

At this point it is possible to define analytical expressions for the partial factors γ_m and γ_f.

On the resisting side, the most important variable is the material strength, which is generally described by a Gaussian or a lognormal distribution. In this case, suitable expressions for the partial factor γ_m are the following:

$$\gamma_{\mathrm{m}} = \frac{X_{\mathrm{k}}}{X^*} = \frac{\mu_X(1-1.645\delta_X)}{\mu_X(1-\alpha_R\beta\delta_X)}$$ Gaussian distribution (C.13)

$$\gamma_{\mathrm{m}} = \frac{X_{\mathrm{k}}}{X^*} = \frac{\mu_X \exp(-1.645\delta_X)}{\mu_X \exp(-\alpha_R\beta\delta_X)}$$ Lognormal distribution (C.14)

where:

δ_X is the coefficient of variation of the material property.

Concerning the load effect side, the permanent and variable actions are treated separately.

For the permanent actions G, the partial factor can be defined from its statistical distribution. Assuming a Gaussian distribution (e.g. dead loads), the partial factor in the case of an unfavourable effect of the action is given by:

$$\gamma_{\mathrm{g}} = \frac{G^*}{G_{\mathrm{k}}} = \frac{\mu_G(1-\alpha_E\beta\delta_G)}{\mu_G(1+k\delta_G)} \quad \text{(C.15)}$$

where:

δ_G is the coefficient of variation of the action

The value $k = 0$ is assumed for the permanent actions (i.e. the mean value is chosen as the representative value). In the case of a favourable effect of a permanent action, the partial factor becomes:

$$\gamma_{\mathrm{g}} = \frac{G^*}{G_{\mathrm{k}}} = \frac{\mu_G(1-\alpha_{E,fav}\beta\delta_G)}{\mu_G(1+k\delta_G)} \quad \text{(C.16)}$$

where:

$\alpha_{\mathrm{E,fav}}$ is equal to 0.32.

For variable actions Q, the following expression of the partial factor γ_q is used:

$$\gamma_{\mathrm{q}} = \frac{Q^*}{Q_{\mathrm{k}}} = \frac{F_{Q,tref}^{-1}\left[\Phi\left(-\alpha_E\beta, t_{ref}\right)\right]}{Q_{\mathrm{k}}} \quad \text{(C.17)}$$

where:

$F_{Q,tref}^{-1}$ is inverse of the distribution of the maxima over the period $t_{\mathrm{ref.}}$

As an example, consider a climatic action. It is possible to assume:

- the maxima over the basic reference period t_0 are modelled by a Gumbel distribution;
- the characteristic value of an action is defined as the 98th fractile of the maxima over the basic reference period t_0;
- mutually independent maxima over the basic reference period t_0.

The expression of the partial factor γ_q is:

$$\gamma_q = \frac{\mu_{Q,tref}\left[1-\delta_{Q,tref}\left(0.45+0.78\ln\left(-\ln\left(\Phi^{-1}\left(-\alpha_E\beta\right)\right)\right)\right)\right]}{\mu_{Q,t0}\left[1-\delta_{Q,t0}\left(0.45+0.78\ln\left(-\ln\left(0.98\right)\right)\right)\right]} \tag{C.18}$$

It should be mentioned that other distributions (i.e. the Weibull distribution) could be used to model the variable actions.

With reference to the reliability index of Table A.2, the partial factors γ_m, γ_g and γ_q are listed in Table C.1 to C.3. The partial factor γ_m has been evaluated with expression (C.14), where the coefficient of variation δ_X is equal to 0.05. The partial factors $\gamma_{g,unfav}$ and $\gamma_{g,fav}$ are determined for permanent actions by means of expressions (C.15) and (C.16) assuming a coefficient of variation δ_G of 0.05. The partial factor γ_q is evaluated by means of expression (C.17), as an example, for the snow load. It has been assumed t_0 = 1 year, t_{ref} = 50 years, $\mu_{q,t0}/q_k$ = 0.4 and $\delta_{q,t0}$ = 0.5.

Table C.1: Partial factors for material resistances.

Consequence class	β		γ_m	
	wn	wd	wn	wd
0	1.8	0.8	0.99	0.95
1	1.8	1.1	0.99	0.96
2	2.5	2.5	1.02	1.02
3	3.3	3.3	1.05	1.05

Note: wn - wind not dominant; wd - wind dominant.

Table C.2: Partial factors for permanent actions.

Consequence class	β		$\gamma_{g,fav}$		$\gamma_{g,unfav}$	
	wn	wd	wn	wd	Wn	wd
0	1.8	0.8	0.97	0.99	1.06	1.03
1	1.8	1.1	0.97	0.98	1.06	1.04
2	2.5	2.5	0.96	0.96	1.09	1.09
3	3.3	3.3	0.95	0.95	1.12	1.12

Note: wn - wind not dominant; wd - wind dominant.

Table C.3: Partial factors for variable actions (t_{ref} = 50 years).

Consequence class	β		γ_q	
	wn	wd	wn	Wd
0	1.8	0.8	1.25	1.01
1	1.8	1.1	1.25	1.03
2	2.5	2.5	1.40	1.11
3	3.3	3.3	1.61	1.16

Note: wn - wind not dominant; wd - wind dominant.

Annex D - Assessment based on satisfactory past performance (informative)

Assessment of safety

Structures designed and constructed based on earlier codes, or in accordance with good workmanship when no code applied, may be considered safe for the future use, provided that simultaneously:

- careful inspection does not reveal any evidence of significant damage, distress or deterioration;
- the structural system is reviewed, including investigation of critical details checking them for stress transfer;
- the structure has demonstrated satisfactory performance during a sufficiently long time for extreme actions and for the occurrence of environmental effects;
- predicted deterioration taking into account the present condition and planned maintenance ensures sufficient durability;
- there have been no changes for a sufficiently long time which could significantly increase the actions on the structure or affect its durability; and no such changes are anticipated.

Assessment of serviceability

Structures designed and constructed based on earlier codes or designed and constructed in accordance with good workmanship when no code applied may be considered serviceable for future use, provided that simultaneously:

- careful inspection does not reveal any evidence of significant damage, distress, deterioration or displacement;
- the structure has demonstrated satisfactory performance for a sufficient time;
- there will be no changes to the structure and in its use that can significantly affect the actions;
- predicted deterioration taking into account the present condition and planned maintenance or modifications of detailing ensures sufficient durability.

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