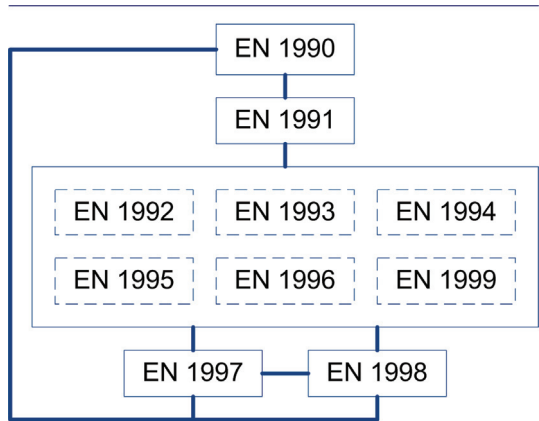


B2 THE ROLE OF EN 1990: THE KEY HEAD EUROCODE



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regarding support to the implementation, harmonization and further development
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Eurocodes – Building the future
DG ENTR, Construction Sector
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1. THE EUROCODES

The Eurocodes are a set of European Standards (EN) for the design of buildings and civil engineering works and construction products, produced by the Comité Européen de Normalisation (CEN).

They embody national experience and research output together with the expertise of CEN Technical Committee 250 (CEN/TC250) and of International Technical and Scientific Organisations and represent a world-class standard for structural design.

The Eurocodes suite is made up by 10 European Standards for structural design. Each Eurocode consists of a number of parts that cover particular technical aspects, e.g. fire, bridge design, etc.

EN 1990	Eurocode: Basis of structural design
EN 1991	Eurocode 1: Actions on structures
EN 1992	Eurocode 2: Design of concrete structures
EN 1993	Eurocode 3: Design of steel structures
EN 1994	Eurocode 4: Design of composite steel and concrete structures
EN 1995	Eurocode 5: Design of timber structures
EN 1996	Eurocode 6: Design of masonry structures
EN 1997	Eurocode 7: Geotechnical design
EN 1998	Eurocode 8: Design of structures for earthquake resistance
EN 1999	Eurocode 9: Design of aluminium structures

The EN Eurocodes

The Eurocodes cover in a comprehensive manner all principal construction materials (concrete, steel, timber, masonry and aluminium), all major fields of structural engineering (basis of structural design, loading, fire, geotechnics, earthquake, etc) and a wide range of types of structures and products (buildings, bridges, towers and masts, silos, etc).

Publication of the Eurocodes was completed in May 2007. Following CEN rules, the Eurocodes will be used in parallel with National Standards until mid 2010, when all conflicting National Standards will be withdrawn.

A European Standard (EN) is published by one of the European Standards Organisations, i.e. CEN, CENELEC and ETSI, and must be adopted as an identical National Standard by the National Standards Bodies.

2. EN 1990: EUROCODE – BASIS OF STRUCTURAL DESIGN

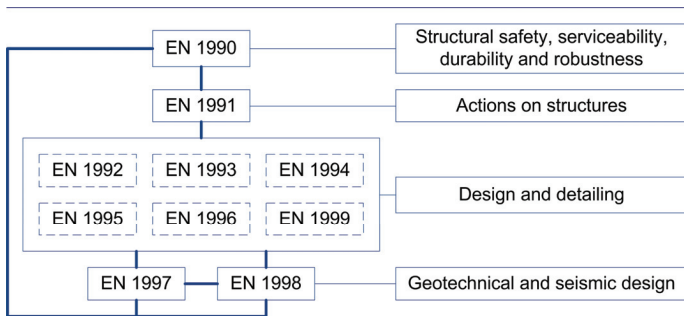
2.1. Objectives

EN 1990 establishes for all the structural Eurocodes the Principles and Requirements for safety, serviceability and durability of structures.

It also provides the basis for the structural design and verification of buildings and civil engineering works and gives guidelines for related aspects of structural reliability.

2.2. Links with the other Eurocodes

EN 1990 is intended to be used together with EN 1991: Eurocode 1 – Actions on Structures and the design Eurocodes, EN 1992 to EN 1999, for the structural design of buildings and civil engineering works, including geotechnical aspects, structural fire design, situations involving earthquakes, execution and temporary structures.



Links between the Eurocodes

EN 1990, alone within the Eurocodes suite, gives all the operative material-independent rules (e.g. partial factors for actions, load combination expressions for ultimate and serviceability limit states). Therefore EN 1991 and EN 1992 to EN 1999, which do not provide material-independent guidance, must be used with EN 1990.

Reliability is the ability of a structure or a structural member to fulfil the specified requirements for which it has been designed.

2.3. Use

EN 1990: Eurocode – Basis of Structural Design provide principles and rules for the design of whole structures, their components and construction products of both traditional and innovative nature.

EN 1990 is applicable to the structural design for the execution stage and for temporary or auxiliary structures.

EN 1990 is applicable for the structural assessment of existing construction, in developing the design of repairs and alterations or in assessing changes of use.

EN 1990 may be used, when relevant, as a guidance document for the design of structures outside the scope of EN 1991 to EN 1999 for:

- assessing other actions and their combinations;
- modelling material and structural behaviour;
- assessing numerical values of the reliability format.

For the design of special construction works (e.g. nuclear installations, dams, etc.) and for unusual design situations, additional provisions than those in EN 1990 to EN 1999 might be necessary.

2.4. Assumptions

A construction work or product designed according to the principles and rules of EN 1990 is deemed to meet the fundamental requirements (see 3.1), provided the assumptions of EN 1990 to EN 1999 are satisfied.

The general assumptions of EN 1990 are:

- the choice of the structural system and the design of the structure is made by appropriately qualified and experienced personnel;
- execution is carried out by personnel having the appropriate skill and experience;
- adequate supervision and quality control is provided during execution of the work, i.e. in design offices, factories, plants, and on site;
- the construction materials and products are used as specified in EN 1990 or in EN 1991 to EN 1999 or in the relevant execution standards, or reference material or product specifications;
- the structure will be adequately maintained;
- the structure will be used in accordance with the design assumptions.

Member States implementing the Eurocodes can alter the recommended values for partial factors and other reliability parameters in order to obtain different reliability levels.

Construction work is everything that is constructed or results from construction operations.

3. MAJOR CONCEPTS

3.1. Fundamental requirements

The structure and structural members should be designed, executed and maintained in such a way that they meet the following principal fundamental requirements:

- **Safety** requirement – the structure during its intended life with appropriate degrees of reliability and in an economic way, will sustain all actions and influences likely to occur during execution and use.
- **Serviceability** requirement – the structure during its intended life with appropriate degrees of reliability and in an economic way, will remain fit for the use for which it is required.
- **Robustness** requirement – the structure will not be damaged by events such as explosion, impact or consequences of human errors, to an extent disproportionate to the original cause.
- **Fire requirement** – the structural resistance shall be adequate for the required period of time. The general objective is to limit risks with respect to the individual and society, neighbouring property, the environment, or directly exposed property.

3.2. Reliability management

EN 1990 is the first operational code to recognise the possibility of reliability differentiation and provides guidance for obtaining different levels of reliability.

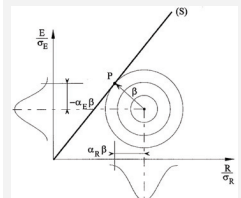
Reliability differentiation comprises the measures intended for the socio-economic optimisation of the resources to be used to build construction works, taking into account all the expected consequences of failures and the cost of the construction works.

The choice of the levels of reliability for a particular structure takes account of the relevant factors, including:

- the possible cause and/or mode of attaining a limit state;
- the possible consequences of failure in terms of risk to life, injury and potential economical losses;
- public perception of failure, and social and environmental conditions in a particular location;
- the expense and procedures necessary to reduce the risk of failure.

The main tools selected in EN 1990 for the management of structural reliability of construction works are:

- differentiation by Reliability Index β ;
- modification of partial factors γ ;
- design supervision differentiation;
- inspection during execution.



Design point P and reliability index β according to the first order reliability method for Normally distributed uncorrelated variables.

3.3. Design working life

The design working life is the period for which a structure or part of it is to be used for its intended purpose with anticipated maintenance but without major repair being necessary.

Design working life	Examples
10 years	Temporary structures
10 to 25 years	Replaceable structural parts
15 to 30 years	Agricultural and similar structures
50 years	Building structures and other common structures
100 years	Monumental buildings, bridges, other structures

Indicative design working life

The notion of design working life is useful for the:

- selection of design actions (e.g. wind, earthquake);
- consideration of material property deterioration (e.g. fatigue, creep);
- evaluation of the life-cycle cost;
- development of maintenance strategies.

3.4. Durability

The durability of a structure or part of it in its environment is such that it remains fit for use during the design working life given appropriate maintenance.

The structure is designed in such a way that deterioration should not impair the durability and performance of the structure.

3.5. Quality management

In order to provide a structure that corresponds to the requirements and to the assumptions made in the design, appropriate quality management measures should be in place. These measures comprise:

- definition of the reliability requirements;
- organisational measures;
- controls at the stages of design, execution, use and maintenance.

Maintenance is a set of activities performed during the working life of the structure in order to enable it to fulfil the requirements for reliability.

Repair comprises the activities to preserve or restore the function of a structure that fall outside the definition of maintenance.

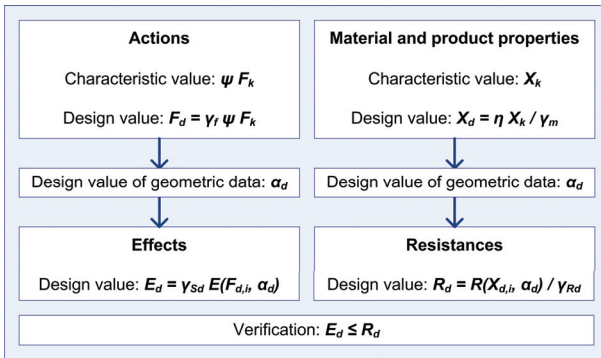
4. LIMIT STATE DESIGN

4.1. Principles of limit state design

Eurocode – Basis of Structural Design is based on the limit state concept used in conjunction with the partial safety factor method.

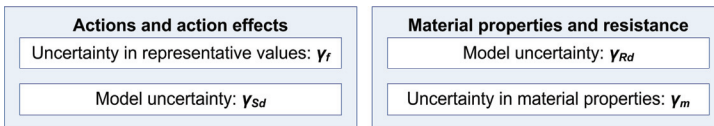
Limit states are the states beyond which the structure no longer fulfils the relevant design criteria. Two different types of limit states are considered, namely **Ultimate Limit State** and **Serviceability Limit State**.

Based on the use of structural and load models, it is verified that no limit state is exceeded when relevant design values for actions, material and product properties, and geometrical data are used. This is achieved by the partial factor method.



Verification by the partial factor method

In the partial factor method the basic variables (i.e. actions, resistances and geometrical properties) are given design values through the use of partial factors, γ , and reduction coefficients, ψ , for the characteristic values of variable actions and reduction coefficient, ξ , for the characteristic values for permanent action.



Individual partial safety factors

Design may also be based on a combination of tests and calculations, provided that the required level of reliability is achieved. Alternatively, EN 1990 allows for design directly based on probabilistic methods.

Design criteria are quantitative formulations that describe for each limit state the conditions to be fulfilled.

η is a conversion factor accounting for volume and scale effects, etc.

Effect of action, E , is the action effect on structural members (e.g. internal force, moment, stress, strain) or on the whole structure (e.g. deflection, rotation).

Resistance is the capacity of a structural member, component, or cross-section to withstand actions without mechanical failure.

4.2. Design situations

Design situations are sets of physical conditions representing the real conditions occurring during the execution and use of the structure, for which the design will demonstrate that relevant limit states are not exceeded.

EN 1990 covers the following design situations for Ultimate Limit State verification:

- persistent situations, which refer to the conditions of normal use;
- transient situations, which refer to temporary conditions applicable to the structure, e.g. during execution or repair;
- accidental situations, which refer to exceptional conditions applicable to the structure or to its exposure, e.g. to fire, explosion, impact or the consequences of localised failure;
- seismic situations, which refer to conditions applicable to the structure when subjected to seismic events.

4.3. Actions

Actions are sets of forces, imposed displacements, or accelerations. They are classified by their variation in time as follows:

- permanent actions, G , e.g. self-weight of structures, fixed equipment and road surfacing, and indirect actions caused by shrinkage and uneven settlements;
- variable actions, Q , e.g. imposed loads on building floors, beams and roofs, wind actions or snow loads;
- accidental actions, A , e.g. explosions, or impact from vehicles.

A variable action has four representative values. In decreasing order of magnitude, they are:

- characteristic value Q_k ;
- combination value $\psi_0 Q_k$;
- frequent value $\psi_1 Q_k$;
- quasi-permanent value $\psi_2 Q_k$.

4.4. Combinations of actions

Combination of actions is a set of design values used for the verification of the structural reliability for a limit state under the simultaneous influence of different actions.

For each critical load case, the design values of the effects of actions, E_d , are determined by combining the values of actions that are considered to occur simultaneously. Each combination of actions includes a leading variable action, or an accidental action.

Effects of actions that cannot exist simultaneously due to physical or functional reasons should not be considered together in combinations of actions.

5. VERIFICATION OF LIMIT STATES

5.1. Ultimate Limit States

Ultimate Limit States concern the safety of people and/or the safety of structures and, in special circumstances, the protection of the contents. They are associated with collapse or with other similar forms of structural failure.

The following Ultimate Limit States are verified, where relevant:

- **EQU.** Loss of static equilibrium of the structure or any part of it considered as a rigid body, where:
 - minor variations in the value or the spatial distribution of actions from a single source are significant;
 - the strengths of construction materials or ground are generally not governing.
- **STR.** Internal failure or excessive deformation of the structure or structural members, including footings, piles, basement walls, etc., where the strength of construction materials of the structure governs.
- **GEO.** Failure or excessive deformation of the ground where the strengths of soil or rock are significant in providing resistance.
- **FAT.** Fatigue failure of the structure or structural members.

The following combinations apply:

- persistent or transient design situation (fundamental combination);
- accidental design situation;
- seismic design situation.

For a limit state of static equilibrium (EQU), it is verified that:

$$E_{d,dst} \leq E_{d,stab}$$

where $E_{d,dst}$ is the design value of the effect of destabilising actions and $E_{d,stab}$ is the design value of the effect of stabilising actions.

When considering a limit state of rupture or excessive deformation of a section, member or connection (STR and/or GEO), it is verified that:

$$E_d \leq R_d$$

where E_d is the design value of the effect of actions and R_d is the design value of the corresponding resistance.

Specific rules for FAT limit states are given in EN 1991 for actions, as well as in the design Eurocodes, EN 1992 to EN 1999.

Strength is a mechanical property of a material indicating its ability to resist actions, usually given in units of stress.

5.2. Serviceability Limit States

Serviceability Limit States concern the functioning of the structure or structural members under normal use, the comfort of people and the appearance of the construction work.

Serviceability Limit States correspond to conditions beyond which specified service requirements for a structure or structural member are no longer met.

The verification of Serviceability Limit States is based on criteria pertaining to:

- deformations that affect the appearance, comfort of users or functioning of the structure (including machines and services);
- vibrations that cause discomfort to people or limit the functional effectiveness of the structure;
- damage that is likely to affect the appearance, durability, or functioning of the structure.

The following combinations of actions are taken into account:

- **characteristic** combination, for function and damage to structural and non-structural elements;
- **frequent** combination, for comfort to user, use of machinery, etc;
- **quasi-permanent** combination, for long-term effects and the appearance of the structure.

It is verified that:

$$E_d \leq C_d$$

where C_d is the limiting design value of the relevant serviceability criterion and E_d is the design value of the effects of actions specified in the serviceability criterion, determined on the basis of the relevant combination.

The deformations to be taken into account in relation to serviceability requirements are explained in EN 1990 and these generally are according to the type of construction works, or agreed with the client or the National Authority.

In the context of serviceability, the term “appearance” is concerned with such criteria as high deflection and extensive cracking, rather than aesthetics.

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