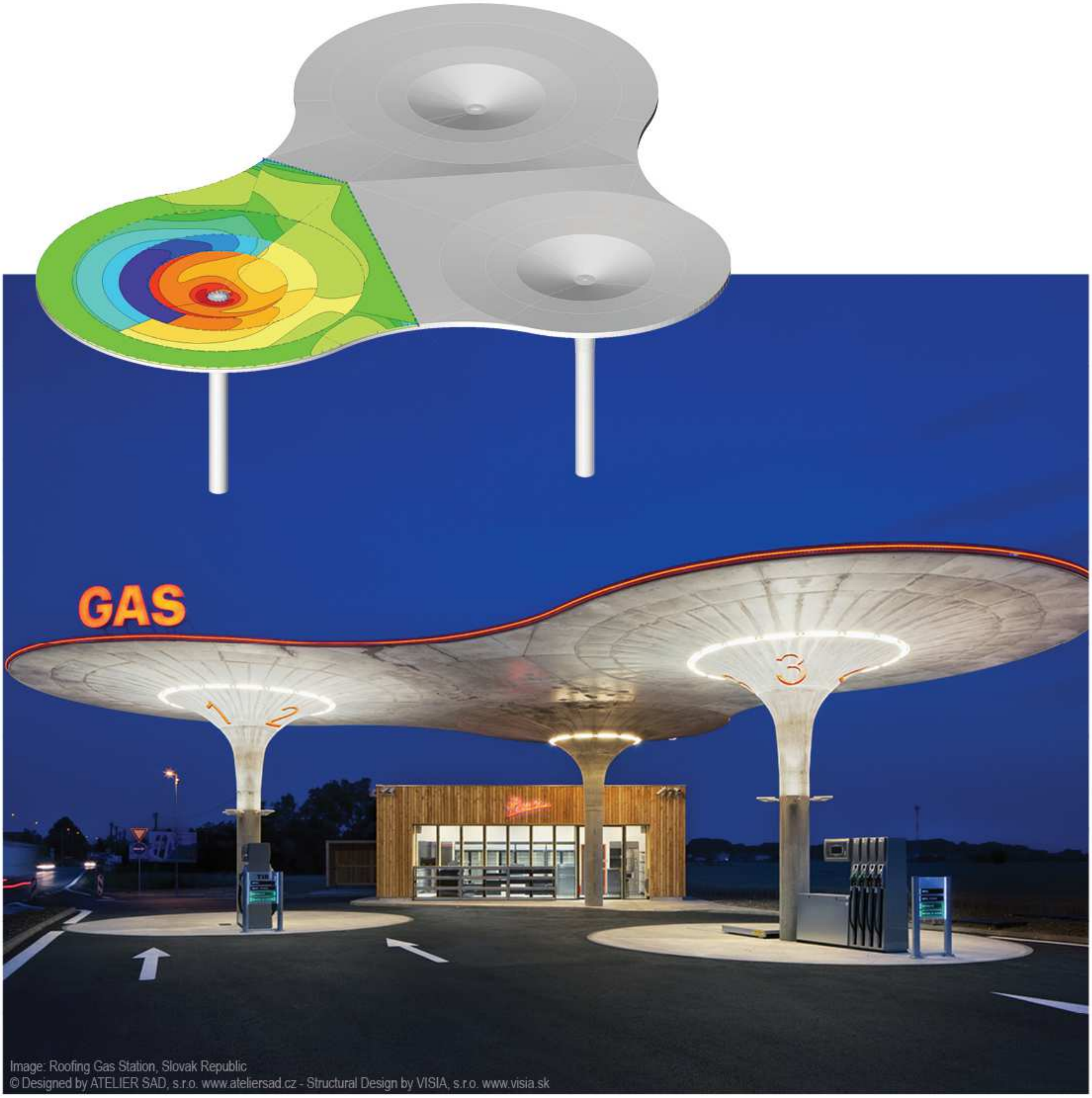


Eurocode Training

EN 1990:Basis of structural design

Table of contents

Overview

The Structural Eurocode programme comprises the following standards generally consisting of a number of Parts:

EN 1990	Eurocode:	Basis of structural design
EN 1991	Eurocode 1:	Action 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

EN 1990: Basis of structural design

The following subjects are dealt with in EN 1990:

Section 1:	General
Section 2:	Requirement
Section 3:	Principles of limit states design
Section 4:	Basis variables
Section 5:	Structural analysis and design assisted by testing
Section 6:	Verification by the partial factor method

National annex for EN 1990
This standard gives alternative procedures, values and recommendations for classes with notes indicating where national choices may have to be made. Therefore the National Standard implementing EN 1990 should have a National annex containing all Nationally Determined Parameters to be used for the design of buildings and civil engineering works to be constructed in the relevant country.

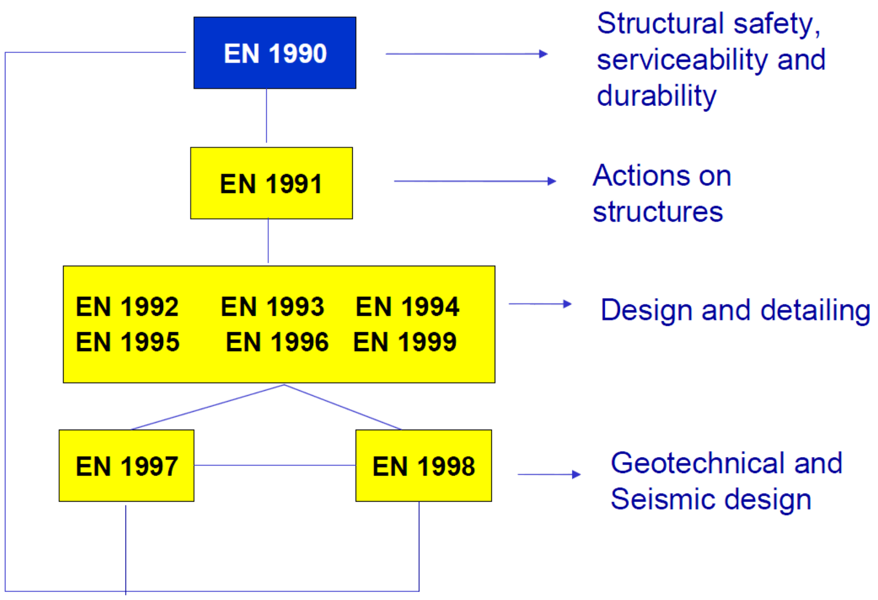
National choice is allowed in EN 1990 through :

- **A1.1(1)**
- **A1.2.1(1)**
- **A1.2.2 (Table A1.1)**
- **A1.3.1(1) (Tables A1.2(A) to (C))**
- **A1.3.1(5)**
- **A1.3.2 (Table A1.3)**
- **A1.4.2(2)**

Section 1: General

Scope:

EN 1990 is an material-independent operational code of practice that establishes the principles and requirements for safety and serviceability and describes the basis for their design and verification. It also provides guidelines for the aspects of structural reliability and durability.



Assumptions

The choice of the structural system and the design of the structure is made qualified and experienced personnel.

The execution is carried out by personnel with appropriate skill and experience.

During execution, adequate supervision and quality control is provided.

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.

Adequate maintenance will be provided on the structure.

The structure will be used in the way it is defined by the design assumptions.

Distinction between Principles and Application Rules

A principle is a general statement or definition for which there’s no alternative or for which there is no alternative allowed.

The Application Rules are generally recognized rules which comply with the Principles and satisfy their requirements.

Terms and definitions

For the structural Eurocode, attention is drawn to the following key definitions, which may be different from current national practices:

- "Action" means a load, or an imposed deformation (e.g. temperature effects or settlement)
- "Effects of Actions" or "Action effects" are internal forces, bending moments, shear forces and deformations caused by actions.
- "Strength" is a mechanical property of a material, in units of stress.
- "Resistance" is a mechanical property of a cross-section of a member, or a member or structure.
- "Execution" covers all activities carried out for the physical completion of the work including procurement, the inspection and documentation thereof. The term covers work on site; it may also signify the fabrication of components off site and their subsequent erection on site.

Symbols

Actions (*F*)

- Permanent Actions (*G*)
- Variable Actions (*Q*)
- Accidental Actions (*A*)
- Seismic Action (A_e)

Values of Actions: Representative Values of Actions

- Characteristic Value (Q_k)
- Combinations Value of a Variable Action ($\psi_0 Q_k$)
- Frequent Value of a Variable Action ($\psi_1 Q_k$)
- Quasi-permanent Value of a Variable Action ($\Psi_2 Q_k$)

Section 2: Requirements

Basic requirements:

The fundamental requirements stipulate that:

Structure shall be designed and executed in such a way that it will, during its intended life and with appropriate reliability and in economical way:

- Sustain all actions and influences which can occur during execution and use
- Remain fit for the use for which it is required

A structure must have adequate:

- Structural resistance (ULS)
- Serviceability (SLS)
- Durability: The structure needs to be designed in such a way that during its intended life, the use of structure shall be guaranteed taking into account its environment and the foreseen maintenance.

In the case of fire, the structural resistance shall be adequate for the required period of time.

The structure shall be designed and executed in such a way that it will not be damaged by events as:

- Explosion
- Impact
- Consequences of human errors

to an extend disproportionate to the original cause.

Figure: Damage caused by explosion

Potential damage shall be avoided by:

- avoiding, eliminating or reducing the hazards to which the structure can be subjected
- selecting a structural form which has low sensitivity to the hazards which are considered
- selecting a structural form and design that can survive adequately:
    - the accidental removal of an individual member or a limited part of the structure
    - the occurrence of acceptable localized damage

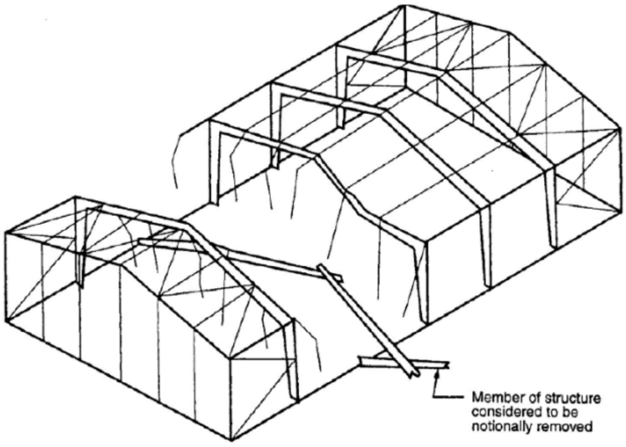


Figure: Part of the structure is removed.

- avoiding as far as possible structural systems that can collapse without warning
- tying the structural members together

The requirement above can be met by choosing suitable materials, an appropriate design and detailing and by specifying control procedures for design, production, execution and use.

Reliability management

An appropriate degree of reliability for the majority of structures is obtained by design and execution according to Eurocodes 1 to 9, with appropriate quality assurance measures.

EN 1990 provides guidance for obtaining different levels of reliability.

The choice of the levels of reliability for a particular structure should take into account:

- the possible cause and /or mode of attaining a limit state
- the possible consequences of failure in terms of risk to life, injury, potential economical losses

Consequences Class	Description	Examples of buildings and civil engineering works
CC3	**High** consequence for loss of human life, *or* economic, social or environmental consequences **very great**	Grandstands, public buildings where consequences of failure are high (e.g. a concert hall)
CC2	**Medium** consequence for loss of human life, economic, social or environmental consequences **considerable**	Residential and office buildings, public buildings where consequences of failure are medium (e.g. an office building)
CC1	**Low** consequence for loss of human life, *and* economic, social or environmental consequences **small or negligible**	Agricultural buildings where people do not normally enter (e.g. storage buildings), greenhouses

Table B1: Definition of consequences classes

- public perception to failure

  Public perception does not accept fatalities and injuries due to structural failure (at home, at the work place, during recreational and other activities etc), for the design working life of a structure. The accepted risk of death is compared to fatalities arising from other hazards and events.

- the expense and procedures necessary to reduce the risk of failure.

Table: Accepted risk of death due to exposure to various hazards

Hazard	Risk ($x10^{-6}$ p.a.)	Hazard	Risk ($x10^{-6}$ p.a.)
Building hazards:		Occupations (UK)	
Structural failure (UK)	**0.14**	Chemical and allied industries	85
Building fires (Australia)	4	Ship building - marine engineering	105
		Agriculture	110
		Construction industries	150
		Railways	180
		Coal mining	210
		Quarrying	295
		Mining (non-coal)	750
		Offshore oil and gas (1967-76)	1650
Natural hazards (USA):		Sports (USA)	
Hurricanes (1901-72)	0.4	Cave exploration (1970-78)	45
Tornadoes (1953-71)	0.4	Glider flying (1970-78)	400
Lightning (1969)	0.5	Scuba diving (1970-78)	420
Earthquakes (California)	2	Hang gliding (1977-1979)	1500
		Parachuting (1978)	1900
General accidents (USA 1969)		All causes (UK, 1977)	
Poisoning	20	Whole population	12000
Drowning	30	Woman aged 30 years	600
Fires and burns	40	Man aged 30 years	1000
Falls	90	Woman aged 60 years	10000
Road accidents	300	Man aged 60 years	12000

(Risk expresssed as a probability of death for typical exposed person per calendar year)

The theoretical basis of the partial factor method and procedures for determination of partial factors of material properties and actions is based on probabilistic methods.

The basic reliability elements considered in these procedures include probability of failure P_f (or equivalent reliability index β) corresponding to a certain reference period T used in verification of structural reliability. The reference period T may or may not coincide with the design working life T_d , which is the time period during which the a structure is required to perform adequately.

P_f	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}
β	1,28	2,32	3,09	3,72	4,27	4,75	5,20

Table C1: Relation between β and P_f

Reliability Class	**Minimum values for β**	
	1 year reference period	**50 years reference period**
RC3	5,2	4,3
RC2	4,7	3,8
RC1	4,2	3,3

Table B2: Recommended minimum values for reliability index (ultimate limit state)

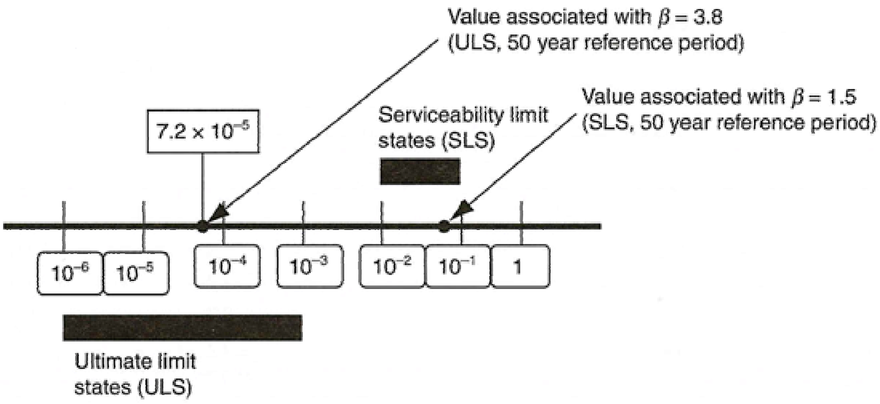


Figure: Probabilities associated with limit states

p_f	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}
β	1·28	2·32	3·09	3·72	4·27	4·75	5·20

Table 5. Relation between β and p_f

Table: Ref.[4]- Table 5

Following Annex B3.3 (EN1990e) one way of achieving reliability differentiation is by distinguishing classes of γ_F factors to be used in fundamental combinations for persistent design situations. For example, for the same design supervision and execution inspection levels, a multiplication factor K_{FI}, see Table B3, may be applied to the partial factors.

Table B3 - K_{FI} factor for actions

K_{FI} factor for actions	Reliability class		
	RC1	RC2	RC3
K_{FI}	0,9	1,0	1,1

Design working life

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

Design working life needs to be considered for material property deterioration, for life cycle costing and for evolving maintenance strategies.

Table 2.1: Indicative design working life

Design working life category	Indicative design working life (years)	Examples
1	10	Temporary structures (1)
2	10 to 25	Replaceable structural parts, e.g. gantry girders, bearings
3	15 to 30	Agricultural and similar structures
4	50	Building structures and other common structures
5	100	Monumental building structures, bridges, and other civil engineering structures
(1) Structures or parts of structures that can be dismantled with a view to being re-used should not be considered as temporary.		

Durability

The structure shall be designed that deterioration over its design working life does not impair the performance of the structure.

The environmental conditions shall be identified at the design stage so that their significance can be assessed in relation to durability and adequate provisions can be made for protection of the materials used in the structure.

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
- organizational measures
- controls at the stages of design, execution, use and maintenance.

Section 3: Principles of limit states design

General

EN 1990 is based on the limit state concept used in conjunction with the partial safety factor method.

Limit states are states beyond which the structure no longer fulfils the relevant design criteria. Two different types of limit state are considered:

- Ultimate limit state
- Serviceability limit state

It has to be verified that no limit state is exceeded when relevant design values for actions, material and product properties and geometrical data are used.

Limit states have to be related to design situations.

Design situations

Design situations are sets of physical conditions representing the real conditions occurring during the construction and use of the structure.

EN 1990 stipulates that relevant design situations need to be selected taking into account the circumstances in which the structure may be required to fulfill its function.

Design situations can be classified as follows:

- Persistent design situations: conditions of normal use
- Transient design situations: temporary conditions e.g. during execution or repair
- Accidental design situations: exceptional conditions e.g. fire, explosion, impact
- Seismic design situations: seismic events

Ultimate limit states

Ultimate limit states concern the safety of people and the safety of the structure. Also the protection of the contents should be classified as Ultimate Limit States

The following ultimate limit states need to be verified when relevant:

- loss of equilibrium of the structure or any part of it, considered as a rigid body
- failure by excessive deformation, transformation of the structure or any part of it into a mechanism, rupture, loss of stability of the structure or any part of it, including supports and foundations
- failure caused by fatigue or other time-dependent effects.

Serviceability limit states

Serviceability limit states concern the functioning of the structure under normal use, the comfort of people and the appearance (high deflection, extensive cracking)

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 concerning:

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

Limit state design

According to the partial factor method, a structure is deemed to be reliable if no limit state considered to be relevant is exceeded when calculation models applied using appropriate design values for:

- the geometrical data
- the actions in question
- the properties of structural materials and members

It therefore is necessary to identify the design situations and critical load cases.

A load case contains compatible load arrangements and sets of imposed deformations. Load cases must also take into account structural imperfections. These may be evaluated in two distinct ways:

- via an equivalent geometric imperfection (initial displacement of the structure)
- in terms of equivalent forces

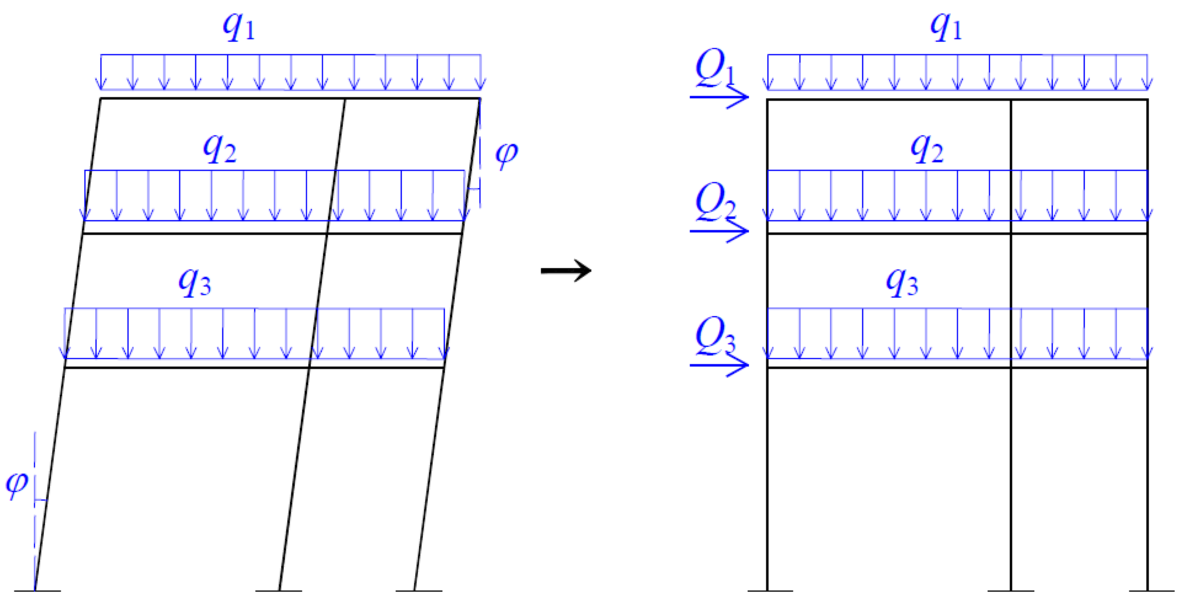


Figure: Evaluation of the imperfections of a frame structure

Section 4: Basic variables

Actions and environmental influences

Actions are sets of forces, imposed displacements or accelerations.

Actions are classified by their variation in time:

- 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.
- Seismic actions (Ae)

A variable action has 4 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 $\psi_2 Q_k$

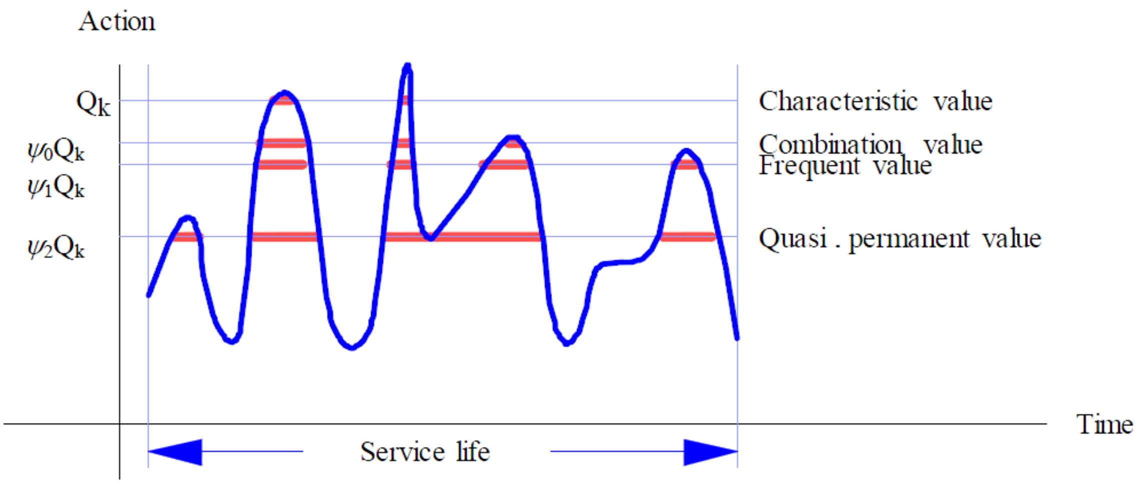


Figure: Schematic representation of a variable load and its representative values

Action	ψ_0	ψ_1	ψ_2
Imposed loads in buildings, category (see EN 1991-1-1)			
Category A : domestic, residential areas	0,7	0,5	0,3
Category B : office areas	0,7	0,5	0,3
Category C : congregation areas	0,7	0,7	0,6
Category D : shopping areas	0,7	0,7	0,6
Category E : storage areas	1,0	0,9	0,8
Category F : traffic area, vehicle weight ≤ 30kN	0,7	0,7	0,6
Category G : traffic area, 30kN < vehicle weight ≤ 160kN	0,7	0,5	0,3
Category H : roofs	0	0	0
Snow loads on buildings (see EN 1991-1-3)*			
Finland, Iceland, Norway, Sweden	0,70	0,50	0,20
Remainder of CEN Member States, for sites located at altitude H > 1000 m a.s.l.	0,70	0,50	0,20
Remainder of CEN Member States, for sites located at altitude H ≤ 1000 m a.s.l.	0,50	0,20	0
Wind loads on buildings (see EN 1991-1-4)	0,6	0,2	0
Temperature (non-fire) in buildings (see EN 1991-1-5)	0,6	0,5	0
NOTE The ψ values may be set by the National annex. * For countries not mentioned below, see relevant local conditions.			

Table A1.1 Recommended values of ψ factors for buildings

Material and product properties

Properties of materials (including soil and rock) or products should be represented by characteristic values. When a limit state verification is sensitive to the variability of a material property, upper and lower characteristic values of the material property should be taken into account.

Geometrical data

Geometrical data are generally random variables. In comparison with actions and material properties their variability can in most cases be considered small or negligible. Such quantities can be assumed to be non-random and as specified on the design drawings (e.g. effective span, effective flange widths).

However, when deviations of certain dimensions have a significant effect on actions, on action effects and on the resistance of a structure, then the geometrical quantities have to be considered as random variables or be taken into account in the models for actions or structural properties (e.g. eccentricities, inclinations, curvatures affecting columns and walls).

Relevant values of some geometric quantities and their deviations are provided in Eurocodes 2 to 9.

Section 5: Structural Analysis and design assisted by testing

In this section principles and rules to execute an analysis of the construction are explained.

Reference is being made towards annex D. Some information about design assisted by testing is given in this annex.

Section 6: Verification by the partial factor method

General

When using the partial factor method, it shall be verified that, in all relevant design situations, no relevant limit state is exceeded.

For the selected design situations and the relevant limit states the individual actions for the critical load cases should be combined as detailed in this section. However actions that cannot occur simultaneously, for example due to physical reasons, should not be considered together in combination.

Limitations

The use of the Application Rules given in EN 1990 is limited to ultimate and serviceability limit state verifications of structures subject to static loading, including cases where the dynamic effects are assessed using equivalent quasi-static loads and dynamic amplification factors, including wind or traffic loads.

For non-linear analysis and fatigue the specific rules given in various Parts of EN 1991 to EN 1999 should be applied.

Design values

The **design value of an action F_d** is expressed by the following relation:

$$F_d = \gamma_f \cdot F_{rep}$$

Where F_{rep} indicates the representative value of an action and γ_f is a partial factor for the action. F_{rep} is calculated as:

$$F_{rep} = \Psi \cdot F_k$$

Where F_k is the characteristic value of the action and Ψ is a reduction factor equal or less than 1.

The **design value of a material or product property X_d** can be expressed in general terms as :

$$X_d = \eta \cdot \frac{X_k}{\gamma_m}$$

where :

X_k is the characteristic value of the material or product property

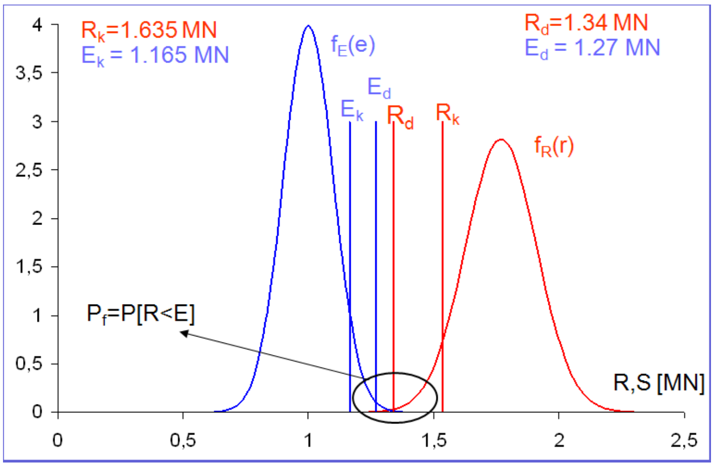
η is the mean value of the conversion factor taking into account:

- volume and scale effects
- effects of moisture and temperature
- any other relevant parameters

γ_m is the partial factor for the material or product property

The **design resistance R_d** may be obtained directly from the characteristic value of a material or product resistance R_k and the partial factor for the material γ_M :

$$R_d = \frac{R_k}{\gamma_M}$$

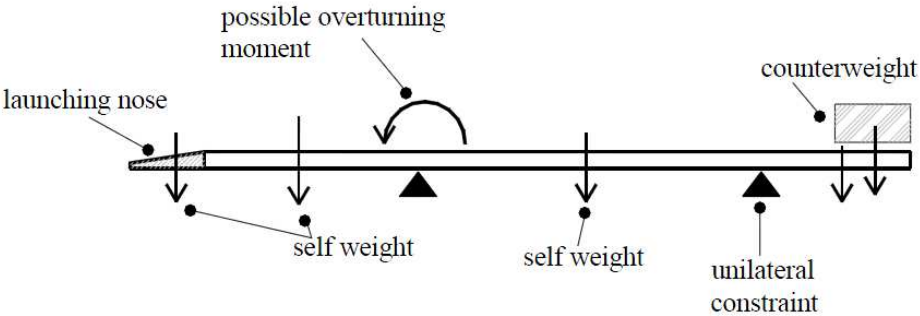


Ultimate limit state

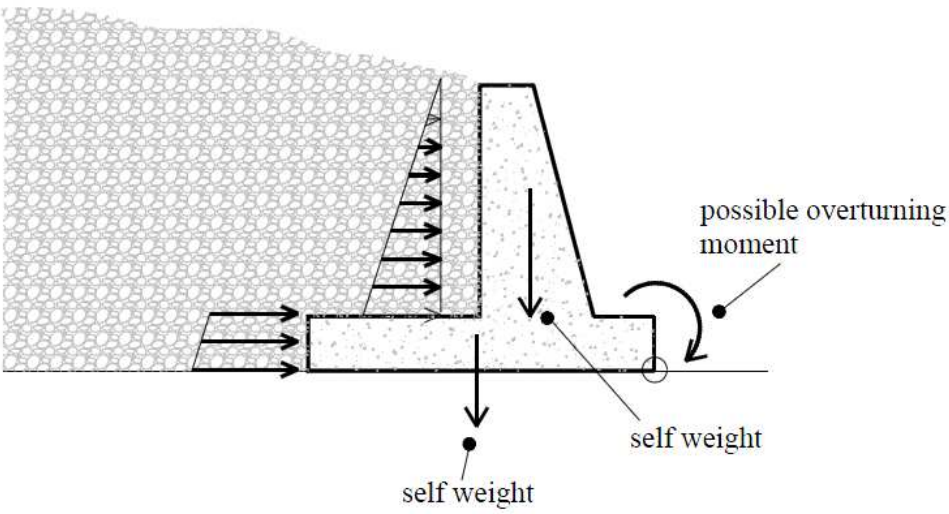
In EC 1990 the following limit states are verified, where relevant:

- 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

For stabilizing actions lower design values need to be assumed, whereas for destabilizing actions higher design values need to be taken into account.



Example of an EQU limite state - bridge construction



Example of an EQU limite state - Retaining wall

- 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.

For a limit state of static equilibrium of the structure (EQU), it shall be verified that :

$$E_{d,dst} \leq E_{d,stb} \qquad (6.7)$$

where :

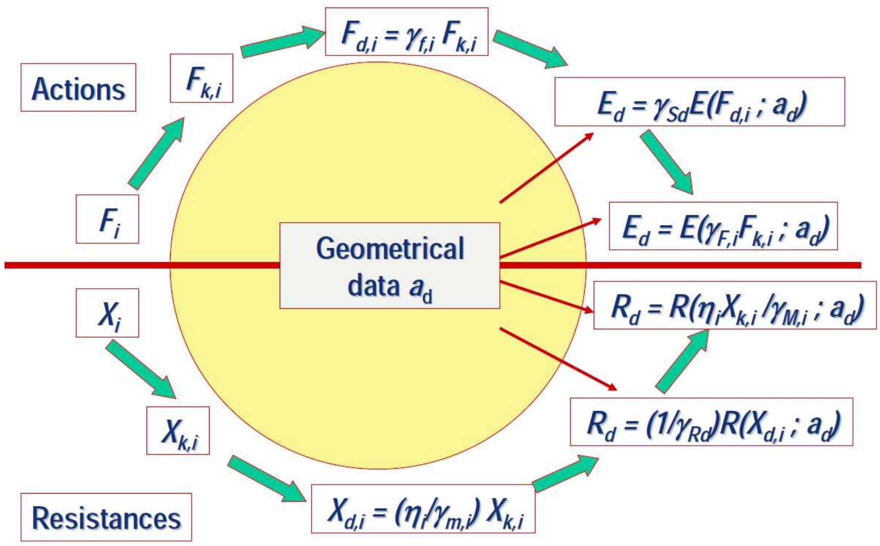
- $E_{d,dst}$ is the design value of the effect of destabilizing actions ;
- $E_{d,stb}$ is the design value of the effect of stabilizing actions.

When considering a limit state of rupture or excessive deformation (STR and/or GEO), it shall be verified that:

$$E_d \leq R_d \qquad (6.8)$$

where:

- E_d is the design value of the effect of actions such as internal force, moment or a vector representing several internal forces or moments
- 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, EN1992 to EN1999.

Combination of actions for fundamental design situations

The fundamental (persistent and transient) design situations for ultimate limit state verification (excluding those relating to fatigue) are represented as follows **(equation 6.10)**:

$$\sum_{j\geq 1} \gamma_{G,j} G_{k,j} + \gamma_P P + \gamma_{Q,1} Q_{k,1} + \sum_{i>1} \gamma_{Q,i} \Psi_{0,i} Q_{k,i}$$

This combination assumes that a number of variable actions are action simultaneously. $Q_{k,1}$ is the dominant variable action and this is combined with the combination value of the accompanying variable actions $Q_{k,i}$.

P is a relevant value for prestressing actions

Alternatively, EN allows the use of the following equations together **(equation 6.10a and 6.10b)**:

$$\sum_{j\geq 1}\gamma_{G,j}G_{k,j}+\gamma_P P+\gamma_{Q,1}\Psi_{0,1}Q_{k,1}+\sum_{i>1}\gamma_{Q,i}\Psi_{0,i}Q_{k,i}$$

$$\sum_{j\geq 1}\xi_j\gamma_{G,j}G_{k,j}+\gamma_P P+\gamma_{Q,1}Q_{k,1}+\sum_{i>1}\gamma_{Q,i}\Psi_{0,i}Q_{k,i}$$

The more unfavorable of the expressions 6.10a and 6.10b may be applied instead of expression 6.10, but only under conditions defined by the National Annex.

Static equilibrium (EQU) for building structures should be verified using the design values of actions in Table A1.2(A).

Persistent and transient design situations	Permanent actions		Leading variable action (*)	Accompanying variable actions	
	Unfavourable	Favourable		Main (if any)	Others
(Eq. 6.10)	$\gamma_{Gj,sup}G_{kj,sup}$	$\gamma_{Gj,inf}G_{kj,inf}$	$\gamma_{Q,1}\ Q_{k,1}$		$\gamma_{Q,i}\psi_{0,i}Q_{k,i}$

(*) Variable actions are those considered in Table A1.1

NOTE 1 The γ values may be set by the National annex. The recommended set of values for γ are :

$\gamma_{Gj,sup} = 1{,}10$

$\gamma_{Gj,inf} = 0{,}90$

$\gamma_{Q,1} = 1{,}50$ where unfavourable (0 where favourable)

$\gamma_{Q,i} = 1{,}50$ where unfavourable (0 where favourable)

NOTE 2 In cases where the verification of static equilibrium also involves the resistance of structural members, as an alternative to two separate verifications based on Tables A1.2(A) and A1.2(B), a combined verification, based on Table A1.2(A), may be adopted, if allowed by the National annex, with the following set of recommended values. The recommended values may be altered by the National annex.

$\gamma_{Gj,sup} = 1{,}35$

$\gamma_{Gj,inf} = 1{,}15$

$\gamma_{Q,1} = 1{,}50$ where unfavourable (0 where favourable)

$\gamma_{Q,i} = 1{,}50$ where unfavourable (0 where favourable)

provided that applying $\gamma_{Gj,inf} = 1{,}00$ both to the favourable part and to the unfavourable part of permanent actions does not give a more unfavourable effect.

Table A1.2(A) - Design values of actions (EQU) (Set A)

Design of structural members (STR,) not involving geotechnical actions should be verified using the design values of actions from Table A1.2(B).

Table A1.2(B) - Design values of actions (STR/GEO) (Set B)

Persistent and transient design situations	Permanent actions		Leading variable action	Accompanying variable actions (*)	
	Unfavourable	Favourable		Main (if any)	Others
(Eq. 6.10)	$\gamma_{Gj,sup}G_{kj,sup}$	$\gamma_{Gj,inf}G_{kj,inf}$	$\gamma_{Q,1}Q_{k,1}$		$\gamma_{Q,i}\psi_{0,i}Q_{k,i}$

Persistent and transient design situations	Permanent actions		Leading variable action (*)	Accompanying variable actions (*)	
	Unfavourable	Favourable	Action	Main	Others
(Eq. 6.10a)	$\gamma_{Gj,sup}G_{kj,sup}$	$\gamma_{Gj,inf}G_{kj,inf}$		$\gamma_{Q,1}\psi_{0,1}Q_{k,1}$	$\gamma_{Q,i}\psi_{0,i}Q_{k,i}$
(Eq. 6.10b)	$\xi\gamma_{Gj,sup}G_{kj,sup}$	$\gamma_{Gj,inf}G_{kj,inf}$	$\gamma_{Q,1}Q_{k,1}$		$\gamma_{Q,i}\psi_{0,i}Q_{k,i}$

(*) Variable actions are those considered in Table A1.1

NOTE 1 The choice between 6.10, or 6.10a and 6.10b will be in the National annex. In case of 6.10a and 6.10b, the National annex may in addition modify 6.10a to include permanent actions only.

NOTE 2 The γ and ξ values may be set by the National annex. The following values for γ and ξ are recommended when using expressions 6.10, or 6.10a and 6.10b.

$\gamma_{Gj,sup} = 1,35$

$\gamma_{Gj,inf} = 1,00$

$\gamma_{Q,1} = 1,50$ where unfavourable (0 where favourable)

$\gamma_{Q,i} = 1,50$ where unfavourable (0 where favourable)

$\xi = 0,85$ (so that $\xi\gamma_{Gj,sup} = 0,85 \times 1,35 \cong 1,15$).

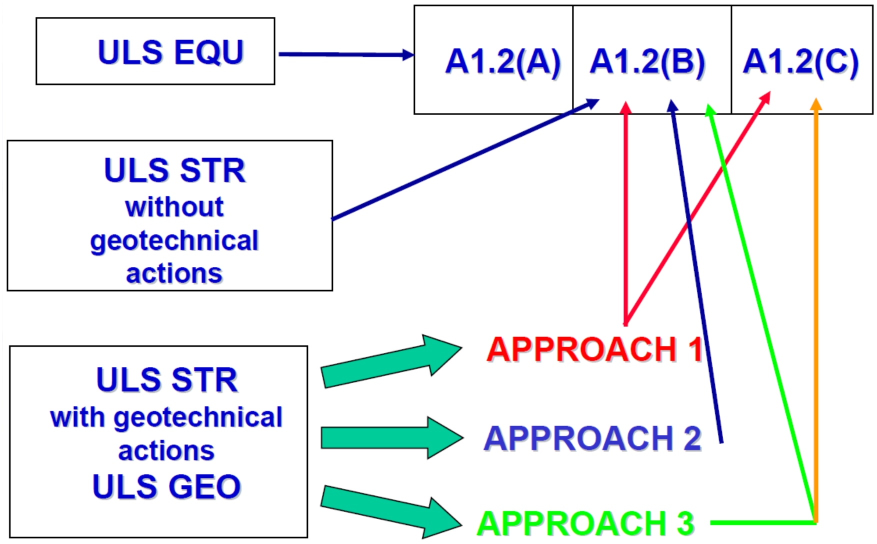
See also EN 1991 to EN 1999 for γ values to be used for imposed deformations.

NOTE 3 The characteristic values of all permanent actions from one source are multiplied by $\gamma_{G,sup}$ if the total resulting action effect is unfavourable and $\gamma_{G,inf}$ if the total resulting action effect is favourable. For example, all actions originating from the self weight of the structure may be considered as coming from one source ; this also applies if different materials are involved.

NOTE 4 For particular verifications, the values for γ_G and γ_Q may be subdivided into γ_g and γ_q and the model uncertainty factor γ_{Sd}. A value of γ_{Sd} in the range 1,05 to 1,15 can be used in most common cases and can be modified in the National annex.

Design of structural members (footings, piles, basement walls, etc.) (STR) involving geotechnical actions and the resistance of the ground (GEO) should be verified using one of the following three approaches supplemented, for geotechnical actions and resistances, by EN 1997 :

- Approach 1: Applying in separate calculations design values from Table A1.2(C) and Table A1.2(B) to the geotechnical actions as well as the other actions on/from the structure. In common cases, the sizing of foundations is governed by Table A1.2(C) and the structural resistance is governed by Table A1.2(B)
- Approach 2 : Applying design values from Table A1.2(B) to the geotechnical actions as well as the other actions on/from the structure
- Approach 3 : Applying design values from Table A1.2(C) to the geotechnical actions and, simultaneously, applying partial factors from Table A1.2(B) to the other actions on/from the structure



The use of approaches 1, 2 or 3 is chosen in the National annex.

Persistent and transient design situation	Permanent actions		Leading variable action (*)	Accompanying variable actions (*)	
	Unfavourable	Favourable		Main (if any)	Others
(Eq. 6.10)	$\gamma_{Gj,sup} G_{kj,sup}$	$\gamma_{Gj,inf} G_{kj,inf}$	$\gamma_{Q,1}\, Q_{k,1}$		$\gamma_{Q,i} \psi_{0,i} Q_{k,i}$

(*) Variable actions are those considered in Table A1.1

NOTE The γ values may be set by the National annex. The recommended set of values for γ are :
$\gamma_{Gj,sup} = 1,00$
$\gamma_{Gj,inf} = 1,00$
$\gamma_{Q,1} = 1,30$ where unfavourable (0 where favourable)
$\gamma_{Q,i} = 1,30$ where unfavourable (0 where favourable)

Table A1.2(C) - Design values of actions (STR/GEO) (Set C)

Comparison between the combinations “(6.10)” and “(6.10a) and (6.10b)” has been done by H.Gulvanession and M.Holicky (Ref. [5]):

- Case A:

$$\sum_{j\geq1}\gamma_{G,j}G_{k,j}+\gamma_P P+\gamma_{Q,1}Q_{k,1}+\sum_{i>1}\gamma_{Q,i}\,\Psi_{0,i}Q_{k,i} \qquad (6.10)$$

- Case B:

$$\sum_{j\geq1}\gamma_{G,j}G_{k,j}+\gamma_P P+\gamma_{Q,1}\,\Psi_{0,1}Q_{k,1}+\sum_{i>1}\gamma_{Q,i}\,\Psi_{0,i}Q_{k,i} \qquad (6.10a)$$

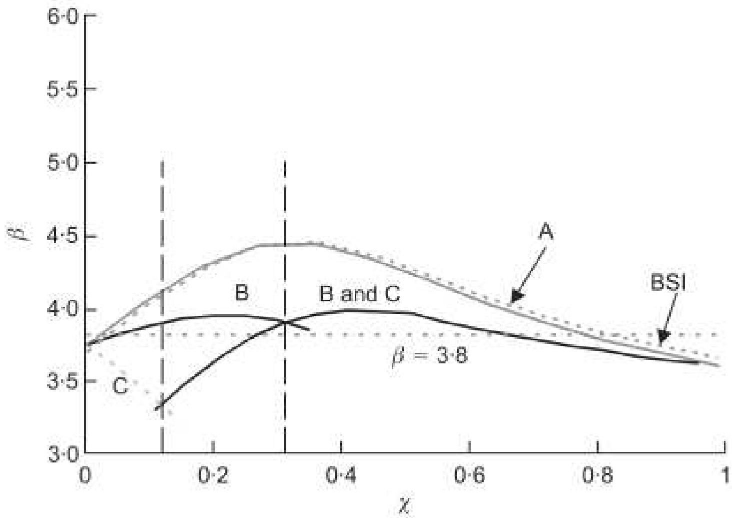
$$\sum_{j\geq1}\xi_j\gamma_{G,j}G_{k,j}+\gamma_P P+\gamma_{Q,1}Q_{k,1}+\sum_{i>1}\gamma_{Q,i}\,\Psi_{0,i}Q_{k,i} \qquad (6.10b)$$

- Case C:

$$\sum_{j\geq1}\gamma_{G,j}G_{k,j}+\gamma_P P \qquad (6.10a\ modified)$$

$$\sum_{j\geq1}\xi_j\gamma_{G,j}G_{k,j}+\gamma_P P+\gamma_{Q,1}Q_{k,1}+\sum_{i>1}\gamma_{Q,i}\,\Psi_{0,i}Q_{k,i} \qquad (6.10b)$$

Comparison between the three cases:



Ref.[4]: Fig.5

The factor χ is an action effects ratio: $\chi = (Q_k + W_k) / (G_k + Q_k + W_k)$

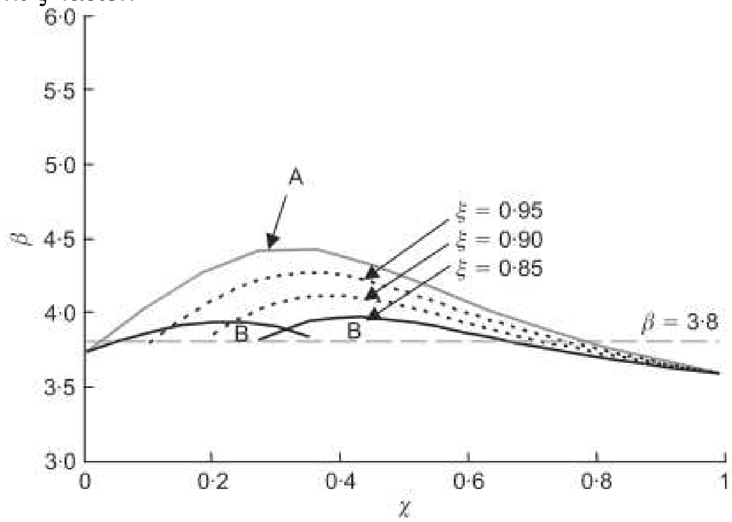
With:

G_k Characteristic value of the permanent action G

Q_k Characteristic value of the variable action Q

W_k Characteristic value of the variable action W

And with a different ξ–factor:



Ref.[4]: Fig 8

Conclusion:

- Case A seems to be fully acceptable ($\beta > 3{,}8$) in the interval $0 < \chi < 0{,}8$. However the reliability level varies considerably with χ, indicating possible uneconomic designs for $0{,}2 < \chi < 0{,}5$.
- Case B is acceptable in a slightly shorter range of χ ($0 < \chi < 0{,}7$) than Case A. Obviously, Case B leads to a more economic design than Case A.
- Case C gives lower reliability levels particularly for the interval $0 < \chi < 0{,}7$ and the authors do not recommend its use unless the partial factors γ are increased.

Combination of actions for accidental design situations

The load combination for verification of structure in accidental design situations can be written as:

$$\sum_{j\geq 1} G_{k,j} + P + A_d + (\Psi_{1,1}\ or\ \Psi_{2,1})Q_{k,1} + \sum_{i>1} \Psi_{2,i}Q_{k,i}$$

The choice between $\Psi_{1,1}Q_{k,1}$ or $\Psi_{2,1}Q_{k,1}$ should be related to the relevant accidental design situation (impact, fire or survival after an accidental event or situation). Guidance is given in the relevant parts of EN 1991 to EN 1999.

Combinations of actions for accidental design situations should either:

- involve an explicit accidental action *A* (fire or impact), or
- refer to a situation after an accidental event (*A* = 0).

Combination of actions for seismic design situations

The load combination for verification of structure in seismic design situations can be expressed as:

$$\sum_{j\geq 1} G_{k,j} + P + A_{Ed} + \sum_{i\geq 1} \Psi_{2,i}Q_{k,i}$$

A_{Ed} is a seismic action arising due to earthquake ground motions.

Design situation	Permanent actions		Leading accidental or seismic action	Accompanying variable actions (**)	
	Unfavourable	Favourable		Main (if any)	Others
Accidental (*) (Eq. 6.11a/b)	$G_{kj,sup}$	$G_{kj,inf}$	A_d	ψ_{11} or $\psi_{21} Q_{k1}$	$\psi_{2,i}\ Q_{k,i}$
Seismic (Eq. 6.12a/b)	$G_{kj,sup}$	$G_{kj,inf}$	$\gamma_I A_{Ek}$ or A_{Ed}		$\psi_{2,i}\ Q_{k,i}$

(*) In the case of accidental design situations, the main variable action may be taken with its frequent or, as in seismic combinations of actions, its quasi-permanent values. The choice will be in the National annex, depending on the accidental action under consideration. See also EN 1991-1-2.

(**) Variable actions are those considered in Table A1.1.

Table A1.3 - Design values of actions for use in accidental and seismic combinations of actions

Serviceability limit state

It shall be verified that:

$$C_d \geq E_d$$

C_d is the serviceability constraint, for example the admissible deflection, crack width, local stress or acceleration. E_d is the design value of the effects of actions specified in the serviceability criterion, determined on the basis of the relevant combination.

Combinations of actions that should be applied for verification of the serviceability limit states depend on a character of action effects. Three different types of load effects are recognized in EN 1990: irreversible, reversible and long-term effects. This leads to 3 different load combinations:

- The **characteristic combination** is mainly used in case where exceeding a limit state causes permanent local damage or permanent unacceptable deformation. (irreversible limit states).

$$\sum_{j\geq 1} G_{k,j} + P + Q_{k,1} + \sum_{i>1} \Psi_{0,i} Q_{k,i}$$

- The **frequent combination** is mainly used in case where exceeding a limit state causes local damage, large deformations or vibrations which are temporary. (reversible limit states)

$$\sum_{j\geq 1} G_{k,j} + P + \Psi_{1,1} Q_{k,1} + \sum_{i>1} \Psi_{2,i} Q_{k,i}$$

- The **quasi-permanent combination** is used where long-term effects are important.

$$\sum_{j\geq 1} G_{k,j} + P + \sum_{i\geq 1} \Psi_{2,i} Q_{k,i}$$

Unless stated otherwise (e.g. in EN 1991 to 1999), the partial factors for serviceability limit states are equal to 1.0.

Combination	Permanent actions G_d		Variable actions Q_d	
	Unfavourable	Favourable	Leading	Others
Characteristic	$G_{kj,sup}$	$G_{kj,inf}$	$Q_{k,1}$	$\psi_{0,i}Q_{k,i}$
Frequent	$G_{kj,sup}$	$G_{kj,inf}$	$\psi_{1,1}Q_{k,1}$	$\psi_{2,i}Q_{k,i}$
Quasi-permanent	$G_{kj,sup}$	$G_{kj,inf}$	$\psi_{2,1}Q_{k,1}$	$\psi_{2,i}Q_{k,i}$

Table A1.4 - Design values of actions for use in the combination of actions

Serviceability limit states in buildings should take into account criteria related, for example, to floor stiffness, differential floor levels, storey sway or/and building sway and roof stiffness. Stiffness criteria may be expressed in terms of limits for vertical deflections and for vibrations. Sway criteria may be expressed in terms of limits for horizontal displacements.

The serviceability criteria should be specified for each project.

Vertical and horizontal deformations should be calculated in accordance with EN 1992 to EN 1999, by using the appropriate combinations of actions. Special attention should be given to the distinction between reversible and irreversible limit states.

Vertical deflections are represented schematically in Figure. A1.1

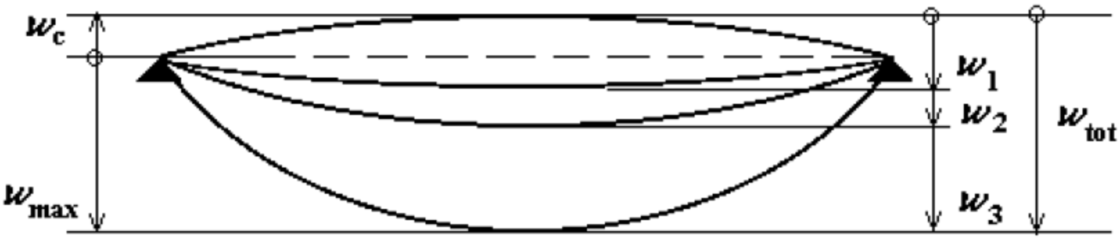


Figure A1.1 - Definitions of vertical deflections

w_c	Precamber in the unloaded structural member
w_1	Initial part of the deflection under permanent loads of the relevant combination of actions
w_2	Long-term part of the deflection under permanent loads
w_3	Additional part of the deflection due to the variable actions of the relevant combination of actions
w_{tot}	Total deflection as sum of $w1$, $w2$, $w3$
w_{max}	Remaining total deflection taking into account the precamber

If the functioning or damage of the structure or to finishes, or to non-structural members (*e.g.* partition walls, claddings) is being considered, the verification for deflection should take account of those effects of permanent and variable actions that occur after the execution of the member or finish concerned.

If the appearance of the structure is being considered, the quasi-permanent combination should be used.

If the comfort of the user, or the functioning of machinery are being considered, the verification should take account of the effects of the relevant variable actions.

Long term deformations due to shrinkage, relaxation or creep should be considered where relevant, and calculated by using the effects of the permanent actions and quasi-permanent values of the variable actions.

Horizontal displacements are represented schematically in Figure A1.2.

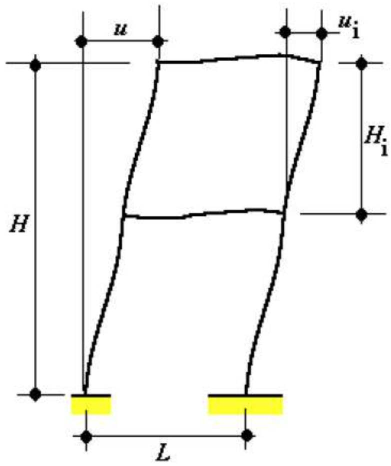


Figure A1.2 - Definition of horizontal displacements

u	Overall horizontal displacement over the building height H
u_i	Horizontal displacement over a storey height H_i

The natural frequency of vibrations of the structure or structural member should be kept above appropriate values which depend upon the function of the building and the source of the vibration.

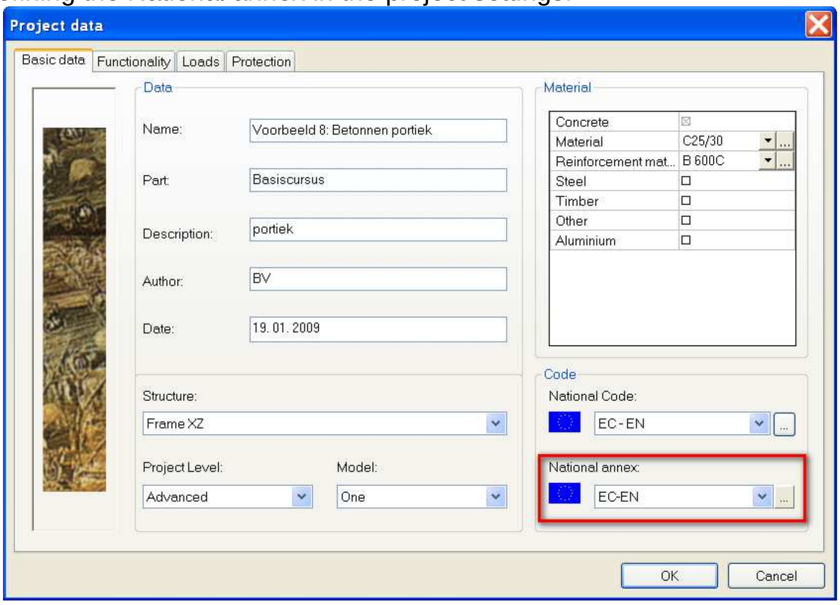
If the natural frequency of vibrations of the structure is lower than the appropriate value, a more refined analysis of the dynamic response of the structure, including the consideration of damping, should be performed.

Possible sources of vibration that should be considered include walking, synchronised movements of people, machinery, ground borne vibrations from traffic and wind actions.

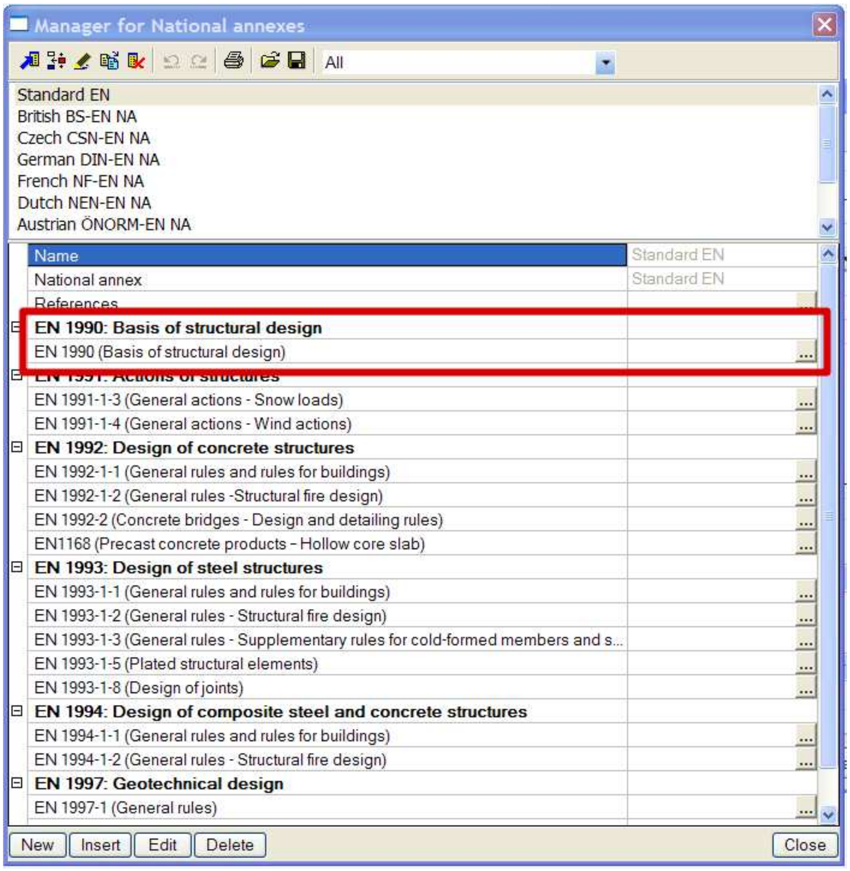
Example: Combinations in Scia Engineer according to the EN 1990

In Scia Engineer, combinations can be generated very easily:

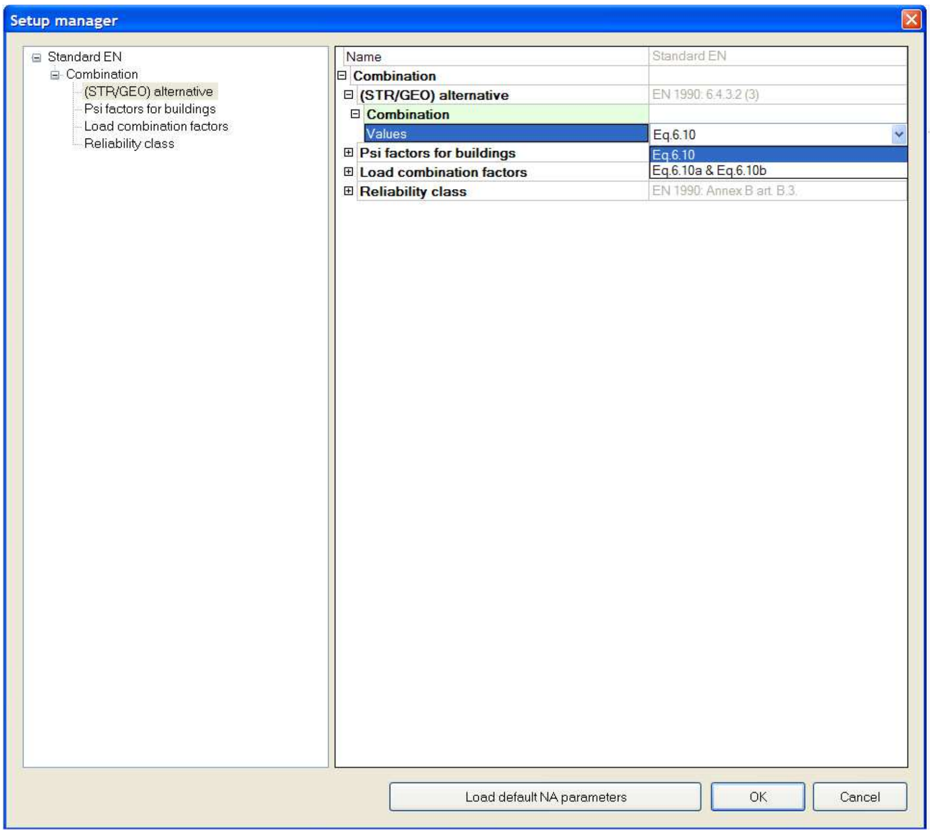
First the settings according the Eurocode 1990 have to be checked and changed if necessary. This can be done by defining the National annex in the project settings:



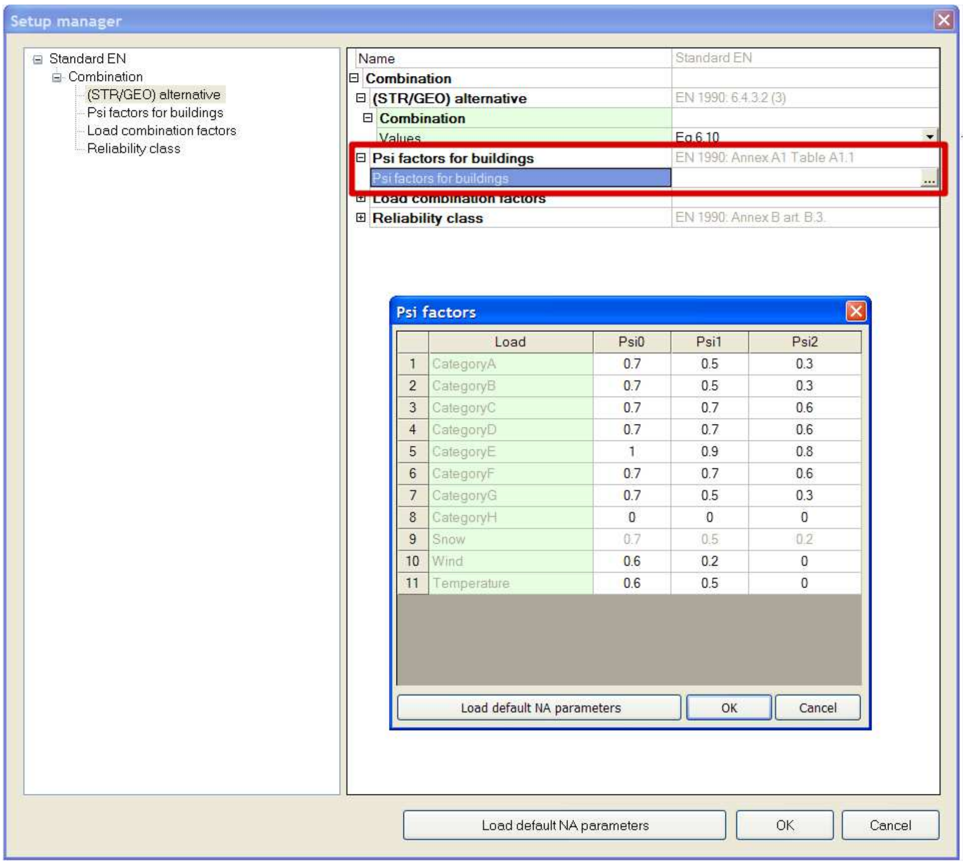
In the manager for national annexes, the choice can be made which code has to be modified.



The ULS combination for fundamental situations can be made according to equation 6.10 or according to equation 6.10.a & 6.10.b

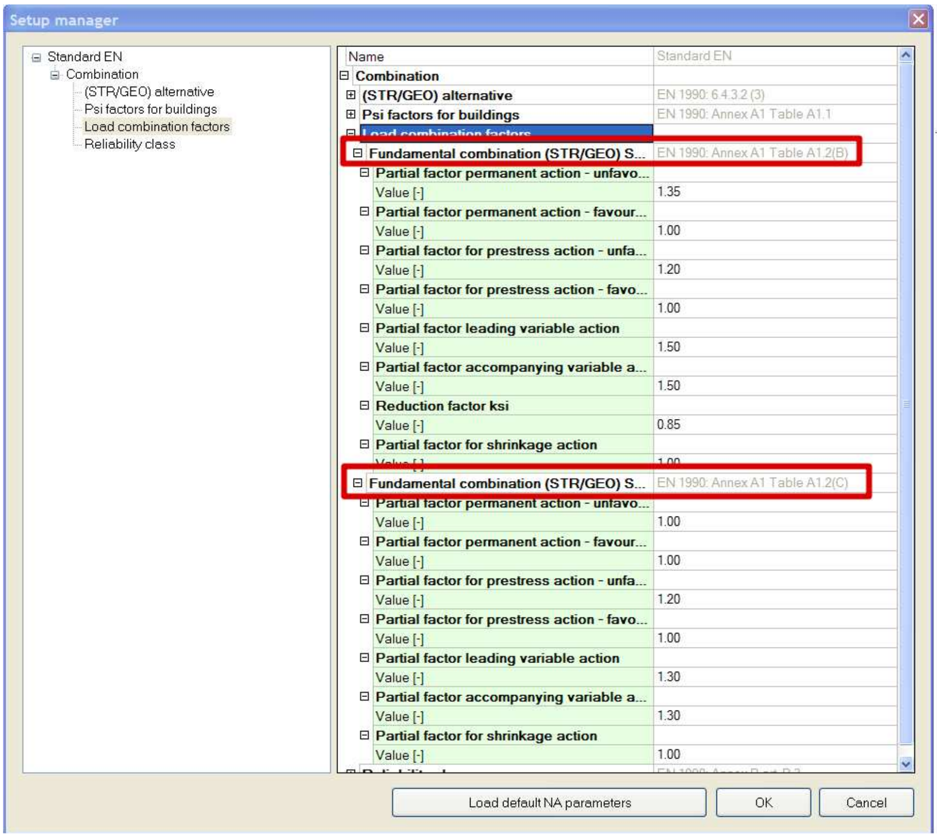


The reduction factors for different categories of loads can be set:

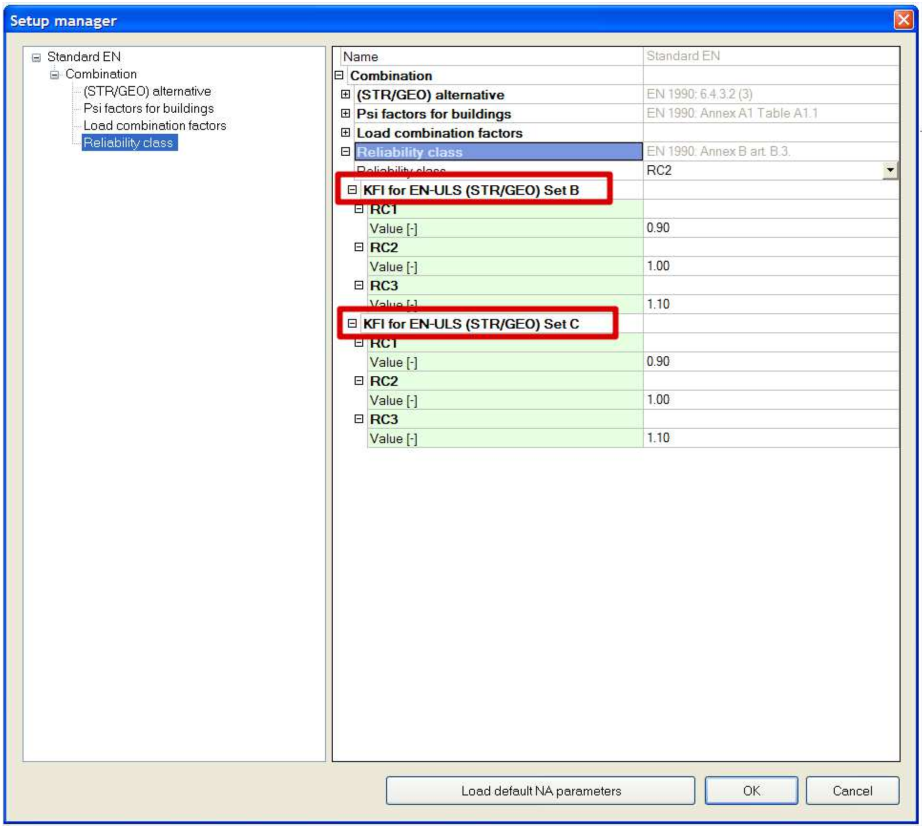


Each load will be assigned to a load case. This load case will be linked to a load group. The load group contains a parameter load type. Hereby the proper reduction factor is applied.

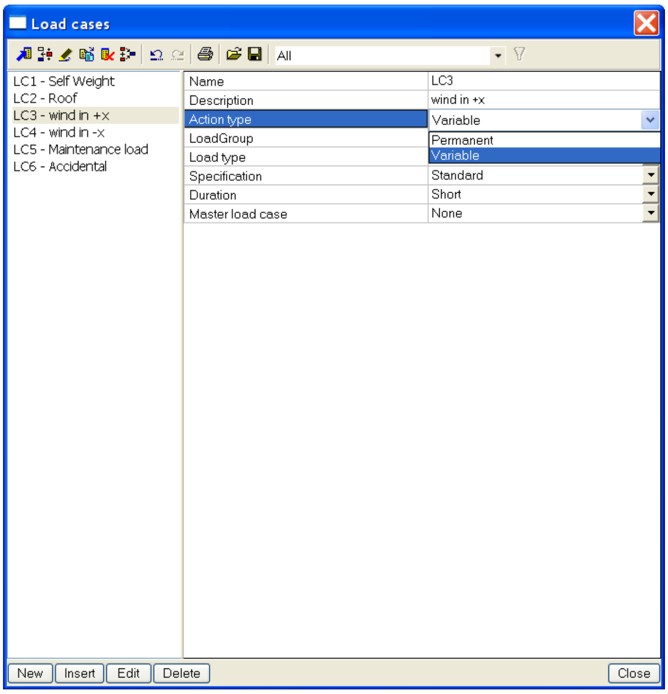
Also the safety factors according the Eurocode 1990 can be specified.



And the reliability class:

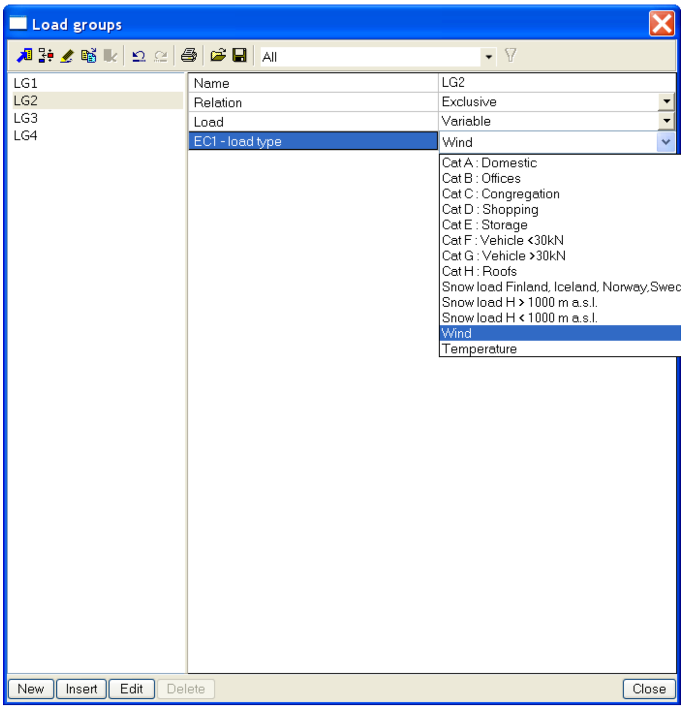


In the following example, 6 load cases are defined which are assigned to 4 load groups. It should be noticed that always an action type is chosen (permanent or variable). A permanent load case can only be linked to a permanent load group, also a variable load case is always linked to variable load group.



Load cases

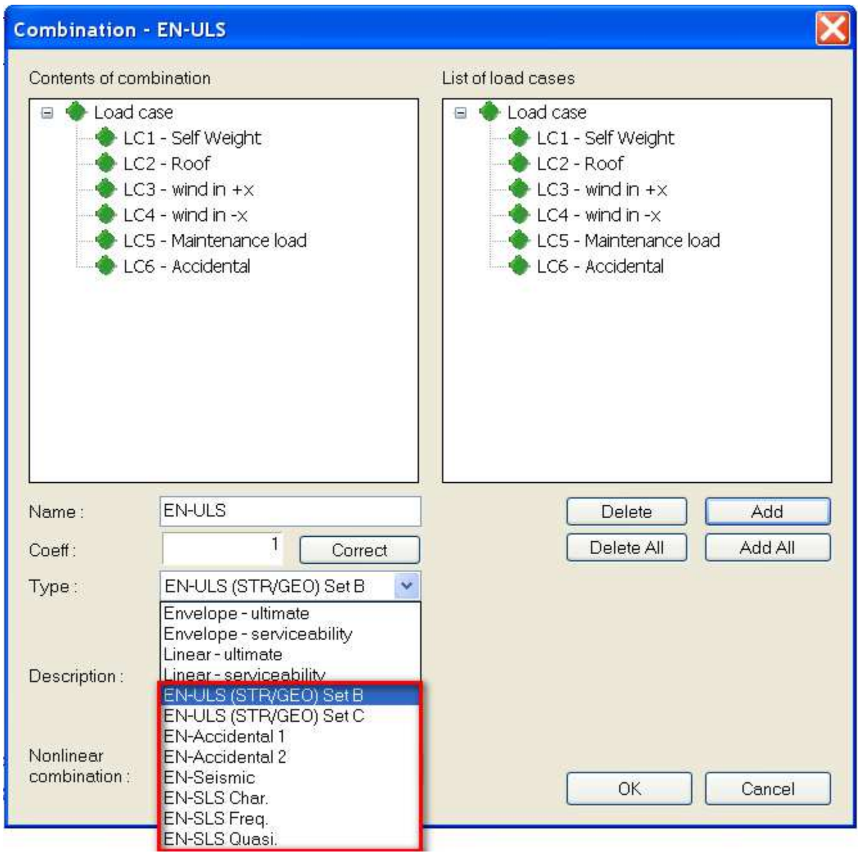
Name	Description	Action type	LoadGroup	Load type	Spec	Direction	Duration	Master load case
LC1	Self Weight	Permanent	LG1	Self weight		-Z		
LC2	Roof	Permanent	LG1	Standard				
LC3	wind in +x	Variable	LG2	Static	Standard		Short	None
LC4	wind in -x	Variable	LG2	Static	Standard		Short	None
LC5	Maintenance load	Variable	LG3	Static	Standard		Short	None
LC6	Accidental	Variable	LG4	Static	Standard		Short	None



Load groups

Name	Load	Relation	EC-load type
LG1	Permanent		
LG2	Variable	Exclusive	Wind
LG3	Variable	Standard	Cat A : Domestic
LG4	Accidental	Exclusive	

For variable load groups a relation (standard, exclusive or together) has to be defined. This relation provides restrictions to which load cases from the same load group can appear together or not.
For instance, LG 2 has an exclusive relation and the 2 wind load cases (LC3 and LC4) which are assigned to this group cannot appear together.
When the load cases and load groups are defined, different types of combinations according to EN 1990 can be made:



After the EN-combination is defined, it contains all possible combinations. In the background it consist every possible combination for its type. However it can be extracted to linear combinations, to view results for each combination.

In the following tables the first line shows the type of combination with its content, from the second row the extracted combinations are shown with their multiplication factor.

Combinations

EN-ULS	**EN-ULS (STR/GEO) Set B**	LC1 - Self Weight LC2 - Roof LC3 - wind in +x LC4 - wind in -x LC5 - Maintenance load LC6 - Accidental	1.00 1.00 1.00 1.00 1.00 1.00
EN-ULS1	Linear - ultimate	LC1 - Self Weight LC2 - Roof	1.35 1.35
EN-ULS2	Linear - ultimate	LC1 - Self Weight LC2 - Roof	1.00 1.00
EN-ULS3	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC5 - Maintenance load	1.35 1.35 1.05
EN-ULS4	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC3 - wind in +x	1.35 1.35 1.50
EN-ULS5	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC4 - wind in -x	1.35 1.35 1.50
EN-ULS6	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC3 - wind in +x LC5 - Maintenance load	1.35 1.35 1.50 1.05
EN-ULS7	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC4 - wind in -x LC5 - Maintenance load	1.35 1.35 1.50 1.05
EN-ULS8	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC5 - Maintenance load	1.00 1.00 1.05
EN-ULS9	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC3 - wind in +x	1.00 1.00 1.50
EN-ULS10	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC4 - wind in -x	1.00 1.00 1.50
EN-ULS11	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC3 - wind in +x LC5 - Maintenance load	1.00 1.00 1.50 1.05
EN-ULS12	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC4 - wind in -x LC5 - Maintenance load	1.00 1.00 1.50 1.05
EN-ULS13	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC3 - wind in +x	1.35 1.35 0.90
EN-ULS14	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC4 - wind in -x	1.35 1.35 0.90
EN-ULS15	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC5 - Maintenance load	1.35 1.35 1.50
EN-ULS16	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC3 - wind in +x LC5 - Maintenance load	1.35 1.35 0.90 1.50
EN-ULS17	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC4 - wind in -x LC5 - Maintenance load	1.35 1.35 0.90 1.50
EN-ULS18	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC3 - wind in +x	1.00 1.00 0.90
EN-ULS19	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC4 - wind in -x	1.00 1.00 0.90
EN-ULS20	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC5 - Maintenance load	1.00 1.00 1.50
EN-ULS21	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC3 - wind in +x LC5 - Maintenance load	1.00 1.00 0.90 1.50
EN-ULS22	Linear - ultimate	LC1 - Self Weight	1.00

		LC2 - Roof LC4 - wind in -x LC5 - Maintenance load	1.00 0.90 1.50
EN-ULS23	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC3 - wind in +x LC5 - Maintenance load	1.35 1.35 0.90 1.05
EN-ULS24	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC4 - wind in -x LC5 - Maintenance load	1.35 1.35 0.90 1.05
EN-ULS25	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC3 - wind in +x LC5 - Maintenance load	1.00 1.00 0.90 1.05
EN-ULS26	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC4 - wind in -x LC5 - Maintenance load	1.00 1.00 0.90 1.05

Name	Type	Load cases	Coeff. [-]
EN-Accidental	**EN-Accidental 1**	LC1 - Self Weight LC2 - Roof LC3 - wind in +x LC4 - wind in -x LC5 - Maintenance load LC6 - Accidental	1.00 1.00 1.00 1.00 1.00 1.00
EN-Accidental 1	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC3 - wind in +x	1.00 1.00 0.20
EN-Accidental 2	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC4 - wind in -x	1.00 1.00 0.20
EN-Accidental 3	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC5 - Maintenance load	1.00 1.00 0.30
EN-Accidental 4	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC3 - wind in +x LC5 - Maintenance load	1.00 1.00 0.20 0.30
EN-Accidental 5	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC4 - wind in -x LC5 - Maintenance load	1.00 1.00 0.20 0.30
EN-Accidental 6	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC6 - Accidental	1.00 1.00 1.00
EN-Accidental 7	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC3 - wind in +x LC6 - Accidental	1.00 1.00 0.20 1.00
EN-Accidental 8	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC4 - wind in -x LC6 - Accidental	1.00 1.00 0.20 1.00
EN-Accidental 9	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC5 - Maintenance load LC6 - Accidental	1.00 1.00 0.30 1.00
EN-Accidental 10	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC3 - wind in +x LC5 - Maintenance load LC6 - Accidental	1.00 1.00 0.20 0.30 1.00
EN-Accidental 11	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC4 - wind in -x LC5 - Maintenance load LC6 - Accidental	1.00 1.00 0.20 0.30 1.00
EN-Accidental 12	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC5 - Maintenance load	1.00 1.00 0.50
EN-Accidental 13	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC5 - Maintenance load LC6 - Accidental	1.00 1.00 0.50 1.00

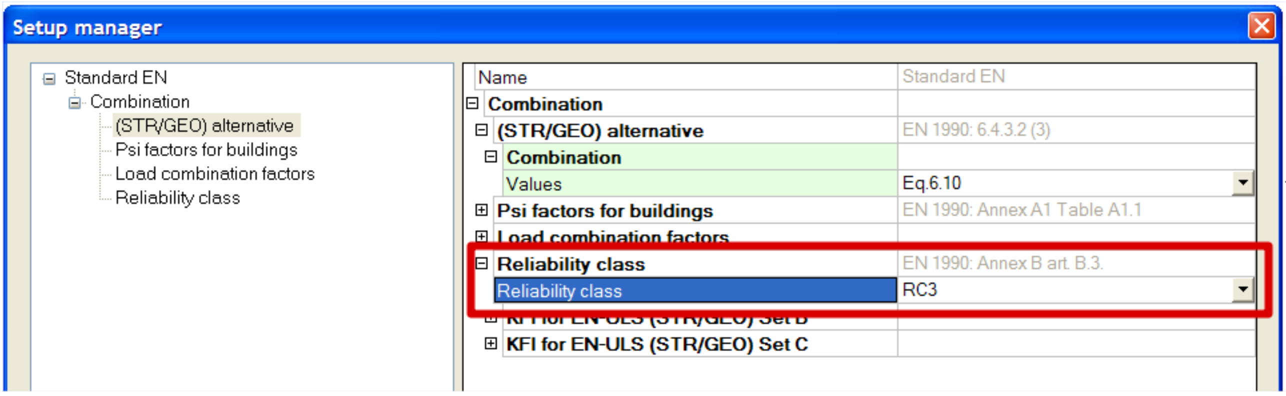
EN-SLS Characteristic	**EN-SLS Char.**	LC1 - Self Weight LC2 - Roof LC3 - wind in +x LC4 - wind in -x LC5 - Maintenance load LC6 - Accidental	1.00 1.00 1.00 1.00 1.00 1.00
EN-SLS Characteristic1	Linear - serviceability	LC1 - Self Weight LC2 - Roof LC5 - Maintenance load	1.00 1.00 0.70
EN-SLS Characteristic2	Linear - serviceability	LC1 - Self Weight LC2 - Roof LC3 - wind in +x	1.00 1.00 1.00
EN-SLS Characteristic3	Linear - serviceability	LC1 - Self Weight LC2 - Roof LC4 - wind in -x	1.00 1.00 1.00
EN-SLS Characteristic4	Linear - serviceability	LC1 - Self Weight LC2 - Roof LC3 - wind in +x LC5 - Maintenance load	1.00 1.00 1.00 0.70
EN-SLS Characteristic5	Linear - serviceability	LC1 - Self Weight LC2 - Roof LC4 - wind in -x LC5 - Maintenance load	1.00 1.00 1.00 0.70
EN-SLS Characteristic6	Linear - serviceability	LC1 - Self Weight LC2 - Roof LC3 - wind in +x	1.00 1.00 0.60
EN-SLS Characteristic7	Linear - serviceability	LC1 - Self Weight LC2 - Roof LC4 - wind in -x	1.00 1.00 0.60
EN-SLS Characteristic8	Linear - serviceability	LC1 - Self Weight LC2 - Roof LC5 - Maintenance load	1.00 1.00 1.00
EN-SLS Characteristic9	Linear - serviceability	LC1 - Self Weight LC2 - Roof LC3 - wind in +x LC5 - Maintenance load	1.00 1.00 0.60 1.00
EN-SLS Characteristic10	Linear - serviceability	LC1 - Self Weight LC2 - Roof LC4 - wind in -x LC5 - Maintenance load	1.00 1.00 0.60 1.00
EN-SLS Characteristic11	Linear - serviceability	LC1 - Self Weight LC2 - Roof LC3 - wind in +x LC5 - Maintenance load	1.00 1.00 0.60 0.70
EN-SLS Characteristic12	Linear - serviceability	LC1 - Self Weight LC2 - Roof LC4 - wind in -x LC5 - Maintenance load	1.00 1.00 0.60 0.70

EN-SLS Frequent	**EN-SLS Freq.**	LC1 - Self Weight LC2 - Roof LC3 - wind in +x LC4 - wind in -x LC5 - Maintenance load LC6 - Accidental	1.00 1.00 1.00 1.00 1.00 1.00
EN-SLS Frequent1	Linear - serviceability	LC1 - Self Weight LC2 - Roof LC3 - wind in +x	1.00 1.00 0.20
EN-SLS Frequent2	Linear - serviceability	LC1 - Self Weight LC2 - Roof LC4 - wind in -x	1.00 1.00 0.20
EN-SLS Frequent3	Linear - serviceability	LC1 - Self Weight LC2 - Roof LC3 - wind in +x LC5 - Maintenance load	1.00 1.00 0.20 0.30
EN-SLS Frequent4	Linear - serviceability	LC1 - Self Weight LC2 - Roof LC4 - wind in -x LC5 - Maintenance load	1.00 1.00 0.20 0.30
EN-SLS Frequent5	Linear - serviceability	LC1 - Self Weight LC2 - Roof LC5 - Maintenance load	1.00 1.00 0.50

EN-SLS Quasi Perm	**EN-SLS Quasi.**	LC1 - Self Weight LC2 - Roof LC3 - wind in +x LC4 - wind in -x LC5 - Maintenance load	1.00 1.00 1.00 1.00 1.00

		LC6 - Accidental	1.00
EN-SLS Quasi Perm1	Linear - serviceability	LC1 - Self Weight	1.00
		LC2 - Roof	1.00
EN-SLS Quasi Perm2	Linear - serviceability	LC1 - Self Weight	1.00
		LC2 - Roof	1.00
		LC5 - Maintenance load	0.30

And now we change the reliability class to RC3 and recalculate the first combination (EN-ULS (STR/GEO) Set B):



			Coefficients RC=2	Coefficients RC=3
EN-ULS	**EN-ULS (STR/GEO) Set B**	LC1 - Self Weight	1.00	1.00
		LC2 - Roof	1.00	1.00
		LC3 - wind in +x	1.00	1.00
		LC4 - wind in -x	1.00	1.00
		LC5 - Maintenance load	1.00	1.00
		LC6 - Accidental	1.00	1.00
EN-ULS1	Linear - ultimate	LC1 - Self Weight	1.35	1.49
		LC2 - Roof	1.35	1.49
EN-ULS2	Linear - ultimate	LC1 - Self Weight	1.00	1.00
		LC2 - Roof	1.00	1.00
EN-ULS3	Linear - ultimate	LC1 - Self Weight	1.35	1.49
		LC2 - Roof	1.35	1.49
		LC5 - Maintenance load	1.05	1.15
EN-ULS4	Linear - ultimate	LC1 - Self Weight	1.35	1.49
		LC2 - Roof	1.35	1.49
		LC3 - wind in +x	1.50	1.65
EN-ULS5	Linear - ultimate	LC1 - Self Weight	1.35	1.49
		LC2 - Roof	1.35	1.49
		LC4 - wind in -x	1.50	1.65
EN-ULS6	Linear - ultimate	LC1 - Self Weight	1.35	1.49
		LC2 - Roof	1.35	1.49
		LC3 - wind in +x	1.50	1.65
		LC5 - Maintenance load	1.05	1.15
EN-ULS7	Linear - ultimate	LC1 - Self Weight	1.35	1.49
		LC2 - Roof	1.35	1.49
		LC4 - wind in -x	1.50	1.65
		LC5 - Maintenance load	1.05	1.15
EN-ULS8	Linear - ultimate	LC1 - Self Weight	1.00	1.00
		LC2 - Roof	1.00	1.00
		LC5 - Maintenance load	1.05	1.15
EN-ULS9	Linear - ultimate	LC1 - Self Weight	1.00	1.00
		LC2 - Roof	1.00	1.00
		LC3 - wind in +x	1.50	1.65
EN-ULS10	Linear - ultimate	LC1 - Self Weight	1.00	1.00
		LC2 - Roof	1.00	1.00
		LC4 - wind in -x	1.50	1.65
EN-ULS11	Linear - ultimate	LC1 - Self Weight	1.00	1.00
		LC2 - Roof	1.00	1.00
		LC3 - wind in +x	1.50	1.65
		LC5 - Maintenance load	1.05	1.15
EN-ULS12	Linear - ultimate	LC1 - Self Weight	1.00	1.00
		LC2 - Roof	1.00	1.00
		LC4 - wind in -x	1.50	1.65
		LC5 - Maintenance load	1.05	1.15
EN-ULS13	Linear - ultimate	LC1 - Self Weight	1.35	1.49
		LC2 - Roof	1.35	1.49
		LC3 - wind in +x	0.90	0.99
EN-ULS14	Linear - ultimate	LC1 - Self Weight	1.35	1.49

		LC2 - Roof LC4 - wind in -x	1.35 0.90	1.49 0.99
EN-ULS15	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC5 - Maintenance load	1.35 1.35 1.50	1.49 1.49 1.65
EN-ULS16	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC3 - wind in +x LC5 - Maintenance load	1.35 1.35 0.90 1.50	1.49 1.49 0.99 1.65
EN-ULS17	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC4 - wind in -x LC5 - Maintenance load	1.35 1.35 0.90 1.50	1.49 1.49 0.99 1.65
EN-ULS18	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC3 - wind in +x	1.00 1.00 0.90	1.00 1.00 0.99
EN-ULS19	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC4 - wind in -x	1.00 1.00 0.90	1.00 1.00 0.99
EN-ULS20	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC5 - Maintenance load	1.00 1.00 1.50	1.00 1.00 1.65
EN-ULS21	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC3 - wind in +x LC5 - Maintenance load	1.00 1.00 0.90 1.50	1.00 1.00 0.99 1.65
EN-ULS22	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC4 - wind in -x LC5 - Maintenance load	1.00 1.00 0.90 1.50	1.00 1.00 0.99 1.65
EN-ULS23	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC3 - wind in +x LC5 - Maintenance load	1.35 1.35 0.90 1.05	1.49 1.49 0.99 1.15
EN-ULS24	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC4 - wind in -x LC5 - Maintenance load	1.35 1.35 0.90 1.05	1.49 1.49 0.99 1.15
EN-ULS25	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC3 - wind in +x LC5 - Maintenance load	1.00 1.00 0.90 1.05	1.00 1.00 0.99 1.15
EN-ULS26	Linear - ultimate	LC1 - Self Weight LC2 - Roof LC4 - wind in -x LC5 - Maintenance load	1.00 1.00 0.90 1.05	1.00 1.00 0.99 1.15

References

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[3] EN 1990 Eurocode "Basis of structural design" – the innovative head Eurocode
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[4] Eurocodes: using reliability analysis to combine action effects
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