Overview of the Evolution of EN 1990: Eurocode - Basis of structural and geotechnical design

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Issue 1
Date: 15/10/2020

Structure of this slide deck

→ General overview of the Evolution of EN 1990

- First edition: main part, Annexes A.1, B, C, D, E and F (Package 1)
- Future revisions:
  - Inclusion of Annexes A.2, G and H (Package 2a – bridges related parts)
  - Inclusion of remaining parts: Annexes A.3 – A.6 (Package 2b)

Publication plan

Package 1 | Package 2a | Package 2b

EN1990 Main Text

- A.1 Buildings
- A.2 Bridges
- A.3 Towers, masts, chimneys
- A.4 Silos and tanks
- A.5 Structures supporting cranes
- A.6 Coastal structures
- B Management
- C Reliability bases
- D Design assisted by testing
- E Robustness
- F Rain-flow and reservoir method..
- G Design for bearings
- H Vibrations in footbridges

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Agenda – Evolution of EN 1990

- → Key changes to EN 1990
- → New content included in the scope of EN 1990
- → How ease of use has been enhanced

Key changes to EN 1990 (1)

- More consistent approach for ULS verification
- Inclusion of basis of design rules for geotechnical design and alignment with EN 1997
- More guidance on serviceability of buildings related to deflection limits, vibrations and foundation movements
- Improved provisions on non-linear analysis
- Improved provisions on fatigue verification including new Annex F
- Evolution of Annex B on management of structural reliability of construction works

Key changes to EN 1990 (2)

- Evolution of Annex C on reliability analysis and code calibration
- New informative Annex E on Robustness
- Transfer of basis of design rules from EN 1991-1-6, EN 1991-3, EN 1991-4, EN 1993-3-1, EN 1993-3-2 and EN 1991-7
- Sustainability

Classification of consequences of failure

- Use of the consequence class:
  - determine the value of consequence factor k_F
  - determine management measures to achieve intended structural reliability
  - modify acceptable failure probability levels P_f or target reliability indices β
  - direct assessment of the design values for ULS verifications
  - choose design methods for enhancing robustness
- The Eurocodes cover design rules for structures in CC1 to CC3.
  - additional provisions can be needed for CC4, alternative provisions may be used for CC0, elements other than structural may be classified as CC0

Consequence class	Indicative qualification of consequences	
	Loss of human life or personal injury[a]	Economic, social or environmental consequences[a]
CC4 – Highest	Extreme	Huge
CC3 – Higher	High	Very great
CC2 – Normal	Medium	Considerable
CC1 – Lower	Low	Small
CC0 – Lowest	Very low	Insignificant

Strategies for designing for identified accidental actions and for general enhanced robustness

Design for accidental actions (EN 1991) Explicit design of the structure (e.g. against explosion, impact)		**Design for enhanced robustness (EN 1990)** Strategies based on limiting the extent of damage		
Design structure to resist the action[a]	Prevent or reduce the action e.g. protective measures, control of events	Alternative load paths either providing adequate deformation capacity and ductility or applying prescriptive design rules	Key elements i.e. designing selected members to resist notional action(s)	Segmentation i.e. separation into parts

[a] Structural design against identified accidental actions can incorporate specifically designed members, which fail partially or fully, provided their failure does not lead to further structural collapse as agreed with the authorities (for strategies and methods to limit the extent of damages, see E.3 and E.4).

Quality management

→ Measures that should be implemented:

- organizational procedures in design, execution, use, and maintenance
- controls at the stages of design, detailing, execution, use, and maintenance

→ Annex B: 4-level informative framework for technical management measures:

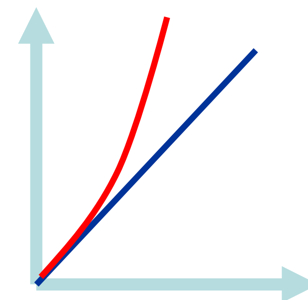
- design quality
- design checking
- execution quality
- inspection during execution

Consequence class	Minimum design quality level (DQL)	Minimum design check level (DCL)	Minimum execution class (EXC)	Minimum inspection level (IL)
CC3	DQL3	DCL3	See relevant execution standards[a]	IL3
CC2	DQL2	DCL2		IL2
CC1	DQL1	DCL1		IL1

Verification of ULS by the partial factor method

→ Use of partial factors for actions (γ_F):

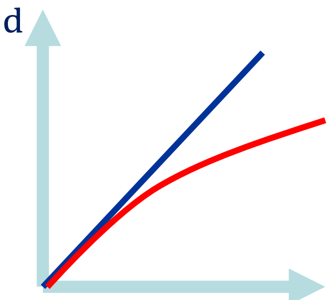
- linear structural systems
- non-linear structural systems in which an increase in action causes a disproportionally larger increase in the effects of actions
- certain types of geotechnical structure



$$E_d = E\{\Sigma F_d; a_d; X_{Rd}\} = E\{\Sigma(\gamma_F \psi F_k); a_d; X_{Rd}\}$$

→ Use of partial factors for effects of actions (γ_E):

- non-linear structural systems involving a single predominant action in which an increase in action causes a disproportionally smaller increase in its effect
- certain types of geotechnical structure



$$E_d = \gamma_E E\{\Sigma F_{rep}; a_d; X_{rep}\} = \gamma_E E\{\Sigma(\psi F_k); a_d; X_{rep}\}$$

Rules for combination of actions in EN 1990:2002

6.4 Ultimate limit states

6.4.1 General

(1)P The following ultimate limit states shall be verified as relevant :

a) EQU : Loss of static equilibrium of the structure or any part of it considered as a rigid body, where :
- AC2 minor variations in the value or the spatial distribution of permanent actions from a single source are significant, and AC2
- the strengths of construction materials or ground are generally not governing ;

b) 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 ;

c) GEO : Failure or excessive deformation of the ground where the strengths of soil or rock are significant in providing resistance ;

d) FAT : Fatigue failure of the structure or structural members.

EQU

STR/GEO (B)

STR/GEO (C)

- Enhanced clarity for geotechnical and mixed EQU/STR verifications

ULS – Combination of actions

$$\sum F_\mathrm{d} = \sum_\mathrm{i} \gamma_\mathrm{G,i} G_\mathrm{k,i} + \gamma_\mathrm{Q,1} Q_\mathrm{k,1} + \sum_\mathrm{j>1} \gamma_\mathrm{Q,j} \psi_\mathrm{0,j} Q_\mathrm{k,j} + (\gamma_\mathrm{P} P_\mathrm{k}) \qquad (8.12)$$

Former (6.10)

or

$$\sum F_\mathrm{d} = \begin{cases} \sum_\mathrm{i} \gamma_\mathrm{G,i} G_\mathrm{k,i} + \gamma_\mathrm{Q,1} \psi_\mathrm{0,1} Q_\mathrm{k,1} + \sum_\mathrm{j>1} \gamma_\mathrm{Q,j} \psi_\mathrm{0,j} Q_\mathrm{k,j} + (\gamma_\mathrm{P} P_\mathrm{k}) & (8.13a) \\ \sum_\mathrm{i} \xi_\mathrm{i} \gamma_\mathrm{G,i} G_\mathrm{k,i} + \gamma_\mathrm{Q,1} Q_\mathrm{k,1} + \sum_\mathrm{j>1} \gamma_\mathrm{Q,j} \psi_\mathrm{0,j} Q_\mathrm{k,j} + (\gamma_\mathrm{P} P_\mathrm{k}) & (8.13b) \end{cases}$$

Former (6.10a, 6.10b)

or

$$\sum F_\mathrm{d} = \begin{cases} \sum_\mathrm{i} \gamma_\mathrm{G,i} G_\mathrm{k,i} + (\gamma_\mathrm{P} P_\mathrm{k}) & (8.14a) \\ \sum_\mathrm{i} \xi_\mathrm{i} \gamma_\mathrm{G,i} G_\mathrm{k,i} + \gamma_\mathrm{Q,1} Q_\mathrm{k,1} + \sum_\mathrm{j>1} \gamma_\mathrm{Q,j} \psi_\mathrm{0,j} Q_\mathrm{k,j} + (\gamma_\mathrm{P} P_\mathrm{k}) & (8.14b) \end{cases}$$

Former (6.10a, mod., 6.10b)

<table>
<tr><th>Design situation</th><th colspan="5">Fundamental (persistent/ transient) design situations</th></tr>
<tr><td>Formula for combination of actions</td><td>(8.12)</td><td>(8.13a)</td><td>(8.13b)</td><td>(8.14a)</td><td>(8.14b)</td></tr>
<tr><td>Permanent ($G_{d,i}$)</td><td>$\gamma_{G,i} G_{k,i}$</td><td>$\gamma_{G,i} G_{k,i}$</td><td>$\xi \gamma_{G,i} G_{k,i}$</td><td>$\gamma_{G,i} G_{k,i}$</td><td>$\xi \gamma_{G,i} G_{k,i}$</td></tr>
<tr><td>Leading variable ($Q_{d,1}$)</td><td>$\gamma_{Q,1} Q_{k,1}$</td><td rowspan="2">$\gamma_{Q,j} \psi_{0,j} Q_{k,j}$</td><td>$\gamma_{Q,1} Q_{k,1}$</td><td rowspan="2">-</td><td>$\gamma_{Q,1} Q_{k,1}$</td></tr>
<tr><td>Accompanying variable ($Q_{d,j}$)</td><td>$\gamma_{Q,j} \psi_{0,j} Q_{k,j}$</td><td>$\gamma_{Q,j} \psi_{0,j} Q_{k,j}$</td><td>$\gamma_{Q,j} \psi_{0,j} Q_{k,j}$</td></tr>
<tr><td>Prestressing (P_d)</td><td>$\gamma_P P_k$</td><td>$\gamma_P P_k$</td><td>$\gamma_P P_k$</td><td>$\gamma_P P_k$</td><td>$\gamma_P P_k$</td></tr>
</table>

ULS – Combination of actions

Table A.1.3 — Combinations of actions for ultimate limit states when using Formula (8.12)

Design situation	Fundamental (persistent/ transient)[a]	Accidental[b]	Seismic[c]	Fatigue[d]
General formula for effects of actions	(8.4)			
Formula for combination of actions	(8.12)	(8.15)	(8.16)	(8.17)
Permanent ($G_{d,i}$)	$\gamma_{G,i} G_{k,i}$	$G_{k,i}$	$G_{k,i}$	$G_{k,i}$
Leading variable ($Q_{d,1}$)	$\gamma_{Q,1} Q_{k,1}$	$\psi_{1,1} Q_{k,1}$ or $\psi_{2,1} Q_{k,1}$	$\psi_{2,j} Q_{k,j}$	$\psi_{2,j} Q_{k,j}$
Accompanying variable ($Q_{d,j}$)	$\gamma_{Q,j} \psi_{0,j} Q_{k,j}$	$\psi_{2,j} Q_{k,j}$		
Prestressing (P_d)	$\gamma_P P_k$	P_k	P_k	P_k
Accidental (A_d)	-	A_d	-	-
Seismic (A_{Ed})	-	-	$A_{Ed,ULS}$	-
Fatigue (Q_{fat})	-	-	-	Q_{fat}

[a] For persistent and transient design situations, when $\gamma_{Q,j}\psi_{0,j} \approx 1$ the design value of the accompanying variable action can be approximated by its characteristic value.

[b] In accidental design situations, the choice between ψ_1 and ψ_2 depends on details of the design situation, e.g. impact, fire, or survival after an accidental event or situation. Further guidance is given in the other Eurocodes and in the National Annex.

[c] Depending on the magnitude of $A_{Ed,ULS}$, the seismic combination of actions covers both the near collapse (NC) and significant damage (SD) ultimate limit states defined in EN 1998.

[d] See 8.3.4.5 for conditions of use.

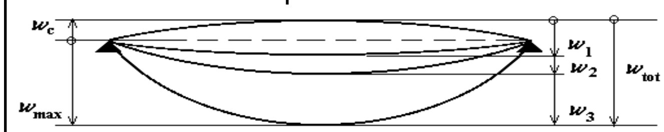
Partial factors – prEN 1990

Table A.1.8 (NDP) — Partial factors on actions and effects for fundamental (persistent and transient) design situations

Action or effect				Partial factors γ_F and γ_E for Design Cases 1 to 4				
Type	**Group**	**Symbol**	**Resulting effect**	**Structural resistance**	**Static equilibrium and uplift**		**Geotechnical design**	
Design case				**DC1**[a]	**DC2(a)**[b]	**DC2(b)**[b]	**DC3**[c]	**DC4**[d]
Formula				**(8.4)**	**(8.4)**		**(8.4)**	**(8.5)**
Permanent action (G_k)	All[f]	γ_G	unfavourable /destabilizing	$1{,}35K_F$	$1{,}35K_F$	1,0	1,0	G_k is not factored
	Water	$\gamma_{G,w}$		$1{,}2K_F$	$1{,}2K_F$	1,0	1,0	
	All[f]	$\gamma_{G,stb}$	stabilizing[g]	not used	1,15 [e]	1,0	not used	
	Water[l]	$\gamma_{G,w,stb}$			1,0 [e]	1,0		
	All	$\gamma_{G,fav}$	favourable[h]	1,0	1,0	1,0	1,0	
Prestress (P_k)		γ_P [k]						
Variable action (Q_k)	All[f]	γ_Q	unfavourable	$1{,}5K_F$	$1{,}5K_F$	$1{,}5K_F$	1,3	$\gamma_{Q,1}/\gamma_{G,1}$ [j]
	Water[l]	$\gamma_{Q,w}$		$1{,}35K_F$	$1{,}35K_F$	$1{,}35K_F$	1,15	1,0
	All	$\gamma_{Q,fav}$	favourable	0				
Effects of actions (E)		γ_E	unfavourable	effects are not factored				$1{,}35K_F$
		$\gamma_{E,fav}$	favourable					1,0

Suggested maximum vertical deflections for non-industrial buildings

Serviceability criteria	Limiting damage to elements other than structural	Comfort of users	Appearance
Combination of actions to be considered	**Characteristic, Formula (8.29)**	**Frequent, Formula (8.30)**	**Quasi-permanent, Formula (8.31)**
Not accessible roof	<u>Roofing</u> rigid roofing: $w_2+w_3 \leq L/250$ resilient roofing: $w_2+w_3 \leq L/125$ <u>Ceiling</u> plastered ceiling: $w_2+w_3 \leq L/350$ false ceiling: $w_2+w_3 \leq L/250$	$w_2+w_3 \leq L/300$	$w_1+w_2-w_c \leq L/250$
Floor, accessible roof	<u>Internal partition walls</u> not reinforced: — partitions of brittle material or non-flexible: $w_2+w_3 \leq L/500$ — partitions of non-brittle materials: $w_{max} \leq L/400$ reinforced walls: $w_2+w_3 \leq L/350$ removable walls: $w_2+w_3 \leq L/250$ <u>Flooring</u>: — tiles rigidly fixed: $w_2+w_3 \leq L/500$ — small tilesb or deflection not fully transmitted: $w_2+w_3 \leq L/350$ — resilient flooring: $w_2+w_3 \leq L/250$ <u>Ceiling</u> plastered ceiling: $w_2+w_3 \leq L/350$ false ceiling: $w_2+w_3 \leq L/250$	$w_2+w_3 \leq L/300$	$w_1+w_2-w_c \leq L/250$
Structural frames	<u>Windows</u>: — no loose joints (no clearance between glass and frame): $w_2+w_3 \leq L/1000$ — with loose joints: $w_2+w_3 \leq L/350$		



a L = span (or, for cantilever, twice the length); w1, w2, w3, wmax are defined in Figure A.1.1.

b Small tiles: sides less than 10 cm.

Suggested maximum permitted horizontal displacements for non-industrial buildings

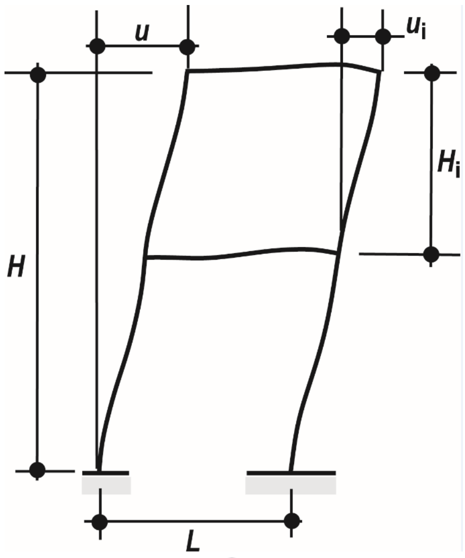


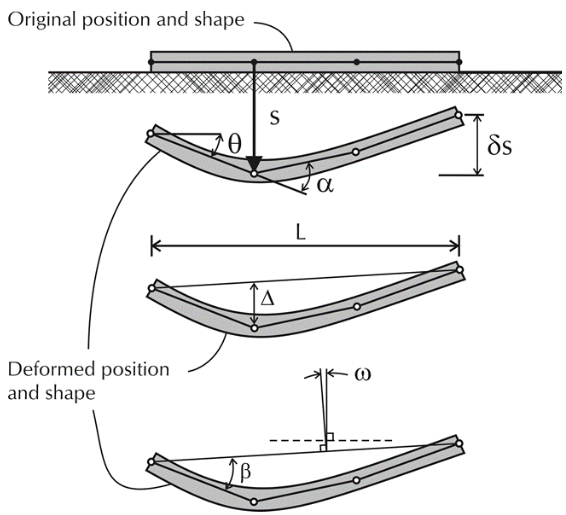
Table A.1.11 (NDP) —Maximum permitted horizontal displacements for non-industrial buildings

Serviceability criteria[a]	No damage to elements other than structural	Comfort of users	Appearance
Combination of actions to be considered	**Characteristic Formula (8.29)**	**Frequent Formula (8.30)**	**Quasi-permanent Formula (8.31)**
Overall horizontal displacement u	Single-storey buildings: $u \leq H/400$ Multi-storey buildings: $u \leq H/500$	$u \leq H/250$	
Horizontal displacement u_i over a storey height	Brittle partition walls: $u_i \leq H_i/500$ $u_i \leq 6\text{mm}$ No brittle partition walls: $u_i \leq H_i/200$	$u_i \leq H_i/250$	$u_i \leq H_i/250$

[a] H = height of building; H_i = storey height; u_i and u are defined in Figure A.1.2.

Limiting foundation movements

Structural sensitivity class	Description of sensitivity
SSC5	Highest
SSC4	Higher
SSC3	Normal
SSC2	Lower
SSC1	Lowest



Structural sensitivity class	Description of sensitivity	Maximum differential settlement[a] $\Delta s_{Cd,SLS}$
SSC5	Highest	10 mm
SSC4	Higher	15 mm
SSC3	Normal	30 mm
SSC2	Lower	60 mm
SSC1	Lowest	100 mm

Structural sensitivity class	Description of sensitivity	Maximum angular distortion[a] $\beta_{Cd,SLS}$
SSC5	Highest	0,05 %
SSC4	Higher	0,075 %
SSC3	Normal	0,15 %
SSC2	Lower	0,3 %
SSC1	Lowest	0,5 %

Structural sensitivity class	Description of sensitivity	Maximum tilt[a] $\omega_{Cd,SLS}$
SSC5	Highest	0,1 %
SSC4	Higher	0,2 %
SSC3	Normal	0,3 %
SSC2	Lower	0,4 %
SSC1	Lowest	0,5 %

New content included in scope of EN 1990

- Basis of geotechnical design
- Application rules for (next packages):
  - Towers, masts and chimneys (new Annex A.3)
  - Silos and tanks (new Annex A.4)
  - Structures supporting cranes (new Annex A.5)
  - Coastal structures (new Annex A.6)
- Bridge related parts:
  - Annex G Basis of design for bearings
  - Annex H Verifications concerning vibration of footbridges due to pedestrian traffic
- Annex F Rain-flow and reservoir counting methods for high-cycle fatigue design

How ease of use has been enhanced (1)

- Improved accessibility to technical provisions and ease of navigation through organization in main text, operational annexes and specialists' annexes
- Comprehensive Main text supplemented by Annex A parts to serve as the reference text for day-to-day use (design service life, combination rules, partial factors, etc.)
- Improvements to reduce ambiguities

How ease of use has been enhanced (2)

- Nationally Determined Parameters (NDPs) introduced in the main text where relevant (in the 2002 version NDPs were confined to Annexes)
- Enhanced consistency with other Eurocodes
- Consistent use of verbal forms throughout the document
- Extensive use of synoptic tables with combination of actions and partial factors

Organization of the standard