The Second Generation Eurocodes

Key changes and benefits through design examples

Online, 3-5 June 2025

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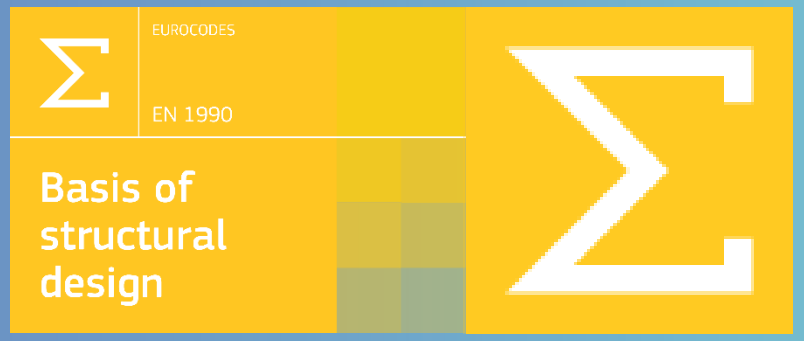
EN 1990 ‘Eurocode: Basis of structural and geotechnical design’

Paolo FORMICHI, Chair CEN/TC250/SC10

University of Pisa (IT)



Overview

- EN 1990 towards the Eurocodes 2G
- EN1990-1 Design of new structures
- Concluding remarks

→ **This presentation**

- EN1990-2 Assessment of existing structures
- Concluding remarks

→ **Following presentation by Thomas Lang**

EN 1990 towards the Eurocodes 2G

EUROPEAN STANDARD **EN 1990:2002+A1**

NORME EUROPÉENNE

EUROPÄISCHE NORM December 2005

ICS 91.010.30 Supersedes ENV 1991-1:1994
Incorporating corrigenda December 2008 and April 2010

English version

Eurocode - Basis of structural design

Eurocodes structuraux - Eurocodes: Bases de calcul des structures

Eurocode: Grundlagen der Tragwerksplanung

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COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: rue de Stassart, 36 B-1050 Brussels

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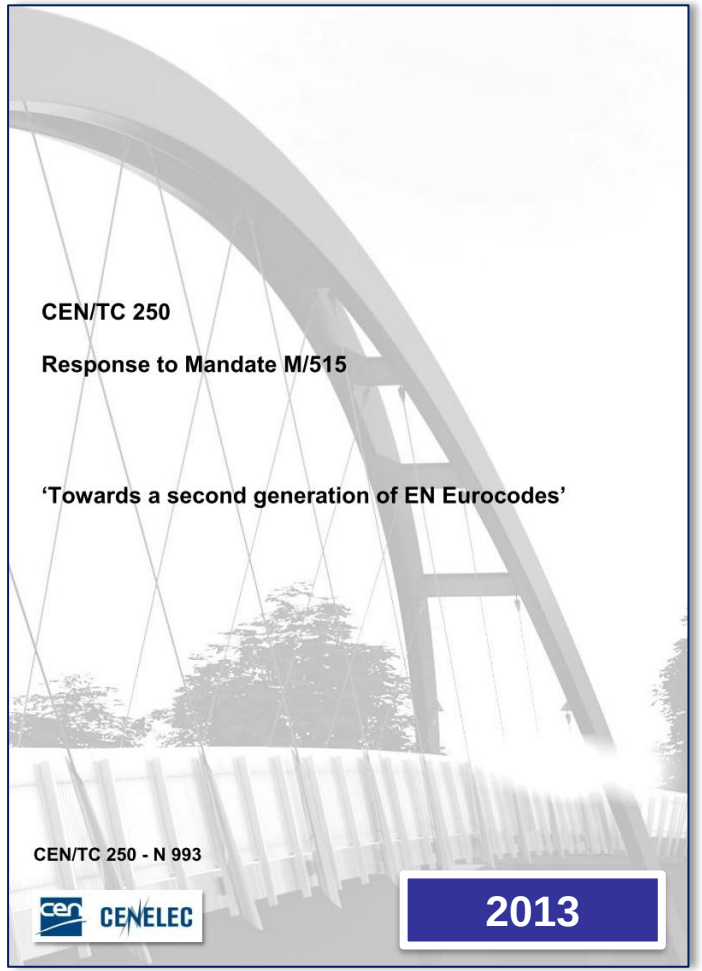
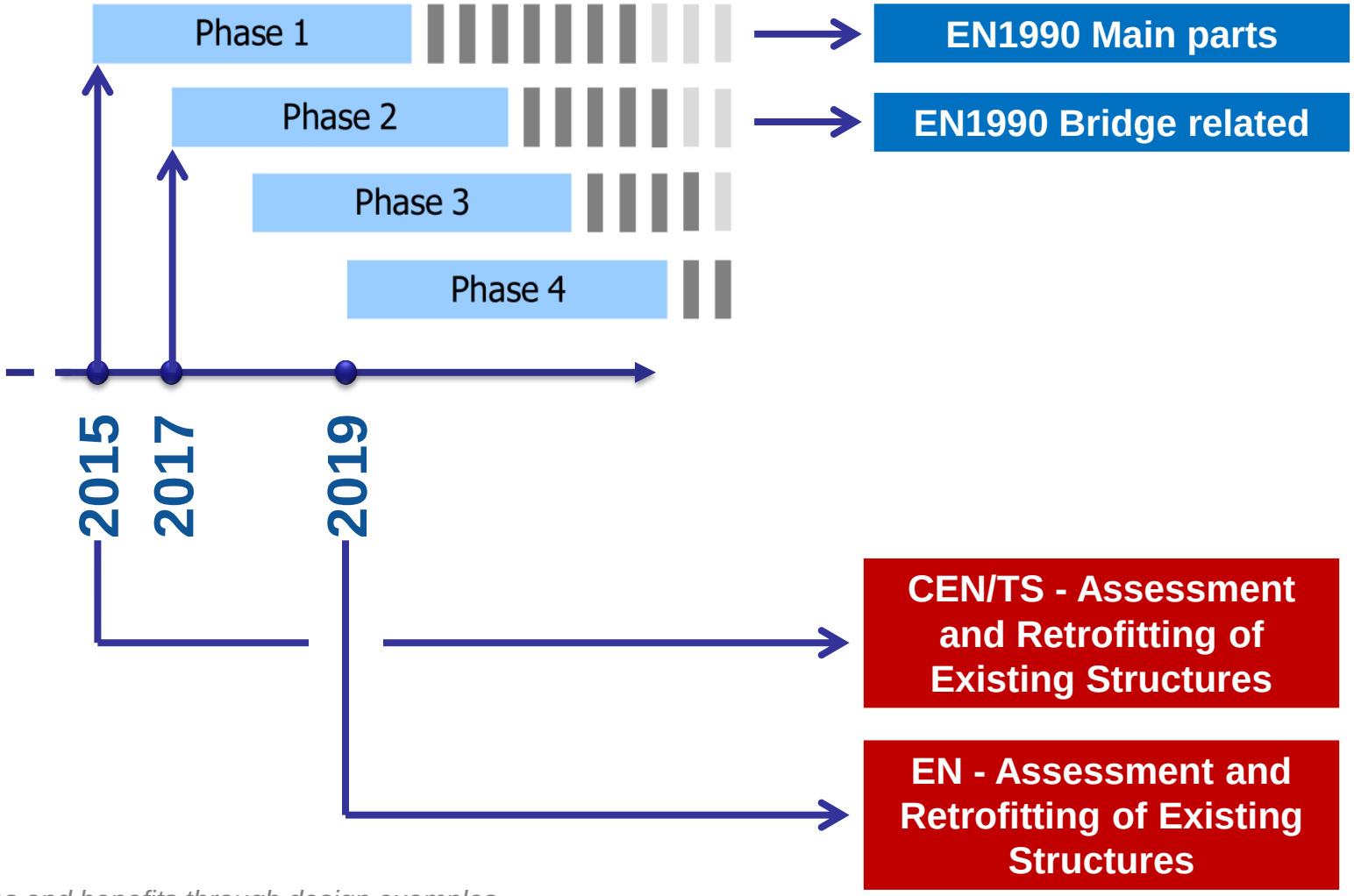
2002	Publication of EN1990 main text + Annexes (except A2)
2005	A1, including Annex A2 (BoD for Bridges)
2007	end of **5 years enquiry**, establishment of an Expert Group, active under TC250, CEN/TC agrees to the formation of an Expert Group to prepare the **first revision of EN 1990**.

→ **Short term** corrigenda revision by April 2010

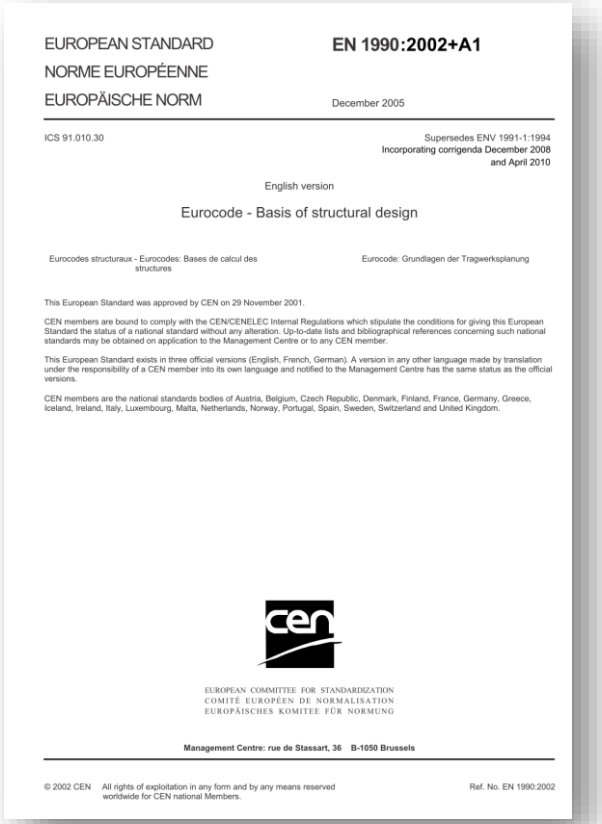
→ Report providing suggestions for **medium/long term technical revision**

EN 1990 towards the Eurocodes 2G





EN1990's revision under M/515



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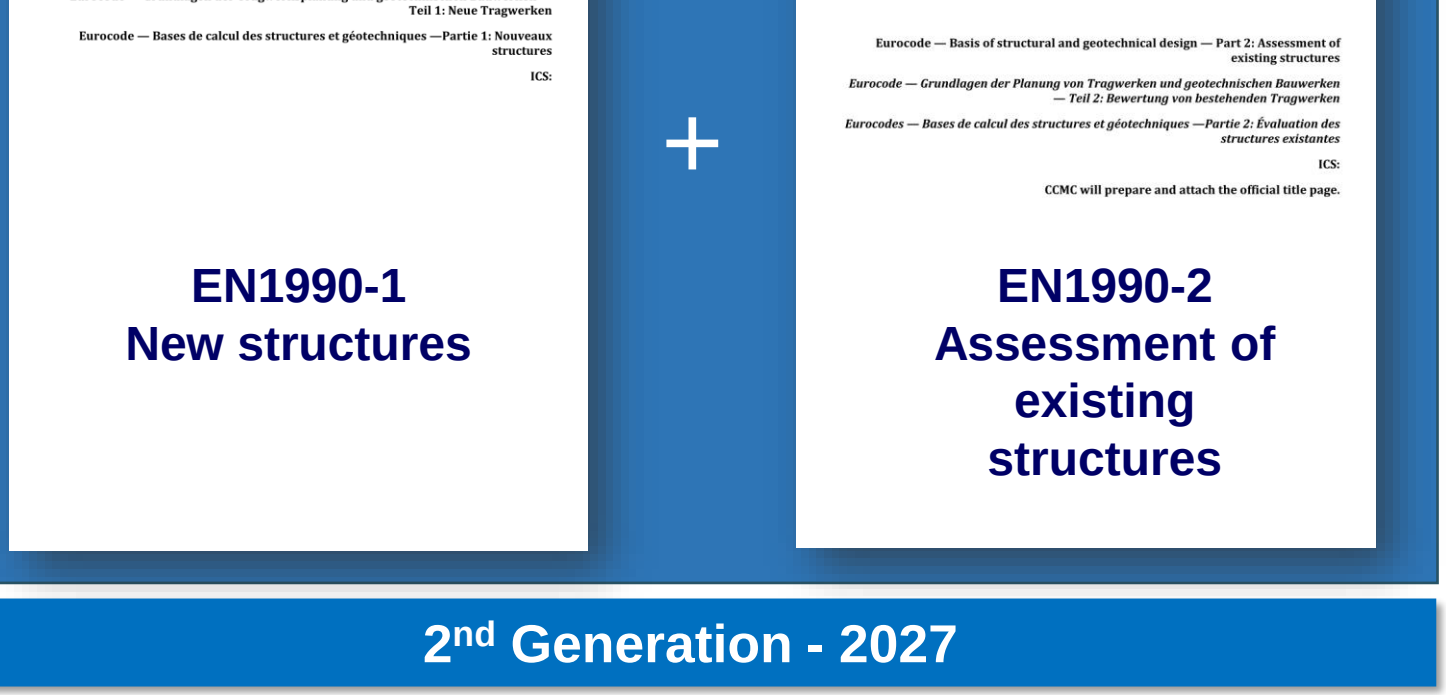
Ref. No. EN 1990:2002

1st Generation - 2002



CEN/TC 250
Date: 2024-12-17
FprEN 1990-1
Secretariat: BSI

Eurocode — Basis of structural and geotechnical design — Part 1: New structures

Eurocode — Grundlagen der Tragwerksplanung und geotechnischen Bauwerken — Teil 1: Neue Tragwerken

Eurocode — Bases de calcul des structures et géotechniques —Partie 1: Nouveaux structures

ICS:

EN1990-1
New structures

+

CEN/TC 250
Date: 2024-12-19
FprEN 1990-2:2024
Secretariat: BSI

Eurocode — Basis of structural and geotechnical design — Part 2: Assessment of existing structures

Eurocode — Grundlagen der Planung von Tragwerken und geotechnischen Bauwerken — Teil 2: Bewertung von bestehenden Tragwerken

Eurocodes — Bases de calcul des structures et géotechniques —Partie 2: Évaluation des structures existantes

ICS:

CCMC will prepare and attach the official title page.

EN1990-2
Assessment of existing structures

2nd Generation - 2027

EN1990's revision under M/515

18 mandated sub-tasks

EN1990 Main parts

Key objectives:

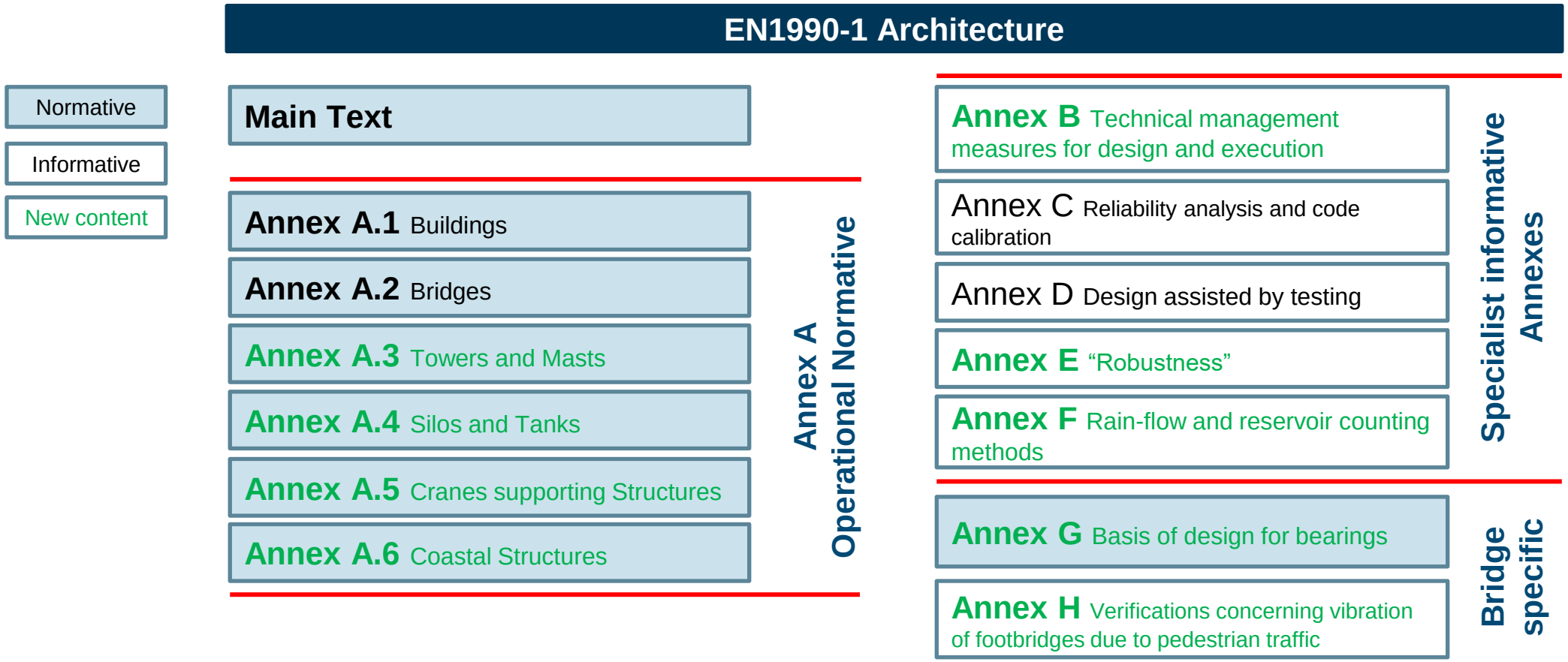
- Enhanced Ease of Use
- Evolution of management of structural reliability of construction
- Treatment of Robustness
- Sustainability
- ULS (Better guidance and increased clarity on EQU-STR-GEO ULS verification)
- Serviceability of buildings
- Fatigue verification
- Alignment with EN 1997

EN1990's revision under M/515

Additional Revision Tasks

- Assessment of Existing Structures
- New Annex A parts
  - Annex A.3 - Application for towers, masts and chimneys
  - Annex A.4 - Application for silos and tanks
  - Annex A.5 - Application for structures supporting cranes and other machines
  - Annex A.6 - Application for coastal structures

EN1990-1 Design of new structures



Key benefit: enhanced Ease of Use

EN1990-1 Design of new structures

1. Scope

1.1 Scope of prEN 1990-1

(1) This document establishes principles and requirements for the safety, serviceability, robustness and durability of structures, including geotechnical structures, appropriate to the consequences of failure.

(2) This document is also applicable for existing structures as specified in prEN 1990-2.

(3) This document is intended to be used in conjunction with the other Eurocodes for buildings and civil engineering works, including temporary structures.

(4) This document describes the basis for structural and geotechnical verification according to the limit state principle.

(5) The verification methods in this document are based primarily on the partial factor method.

NOTE 1 Alternative methods are given in the other Eurocodes for specific applications.

NOTE 2 The Annexes to this document also provide general guidance concerning the use of alternative methods.

Key revisions:

- Robustness explicitly mentioned
- Inclusion of “geotechnical structures”
- Link to new part EN1990-2 on assessment
- Partial factor method is the “default method”

Definitions

EN990:2002+A1:2005 (1st Generation)	EN1990-1 (2nd Generation)
--	**3.1.1.9** **elements other than structural** completion and finishing elements connected with the structure that are not classified as structural members and that have the lowest consequence of failure Note 1 to entry: See 4.3 for the classification of consequences of failure. EXAMPLE Roofing; surfacing and coverings; partitions and linings; kerbs; wall cladding; suspended ceilings; thermal insulation; bridge furniture, road surfacing; services fixed permanently to, or within, the structure such as equipment for lifts and moving stairways; heating, ventilating and air conditioning equipment; electrical equipment; pipes; cable trunking and conduits.

Key benefit:

- Clarification of the classification of elements as “structural” or “other than structural” **depending on their consequences of failure**

4. General Rules

4 General rules

4.2 Structural reliability

(1) The reliability required for structures within the scope of this document shall be achieved by design in accordance with the Eurocodes.

(2) Appropriate measures should be taken to avoid gross human errors and omissions and to limit their effects on the structural reliability.

NOTE 1 This document does not make allowance for gross human errors.

NOTE 2 Guidance on appropriate measures to limit the probability of occurring of gross human errors and omissions is given in Annex B.

(3) The choice of an appropriate level of reliability for the structure should take account of the following:

— possible consequences of failure in terms of risk to life, injury, and potential economic losses, see 4.3;

— the possible cause and mode of attaining a limit state;

NOTE 1 Examples of modes of attaining a limit state are failure modes with or without warnings, e.g. ductile or brittle failure.

— public aversion to failure;

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

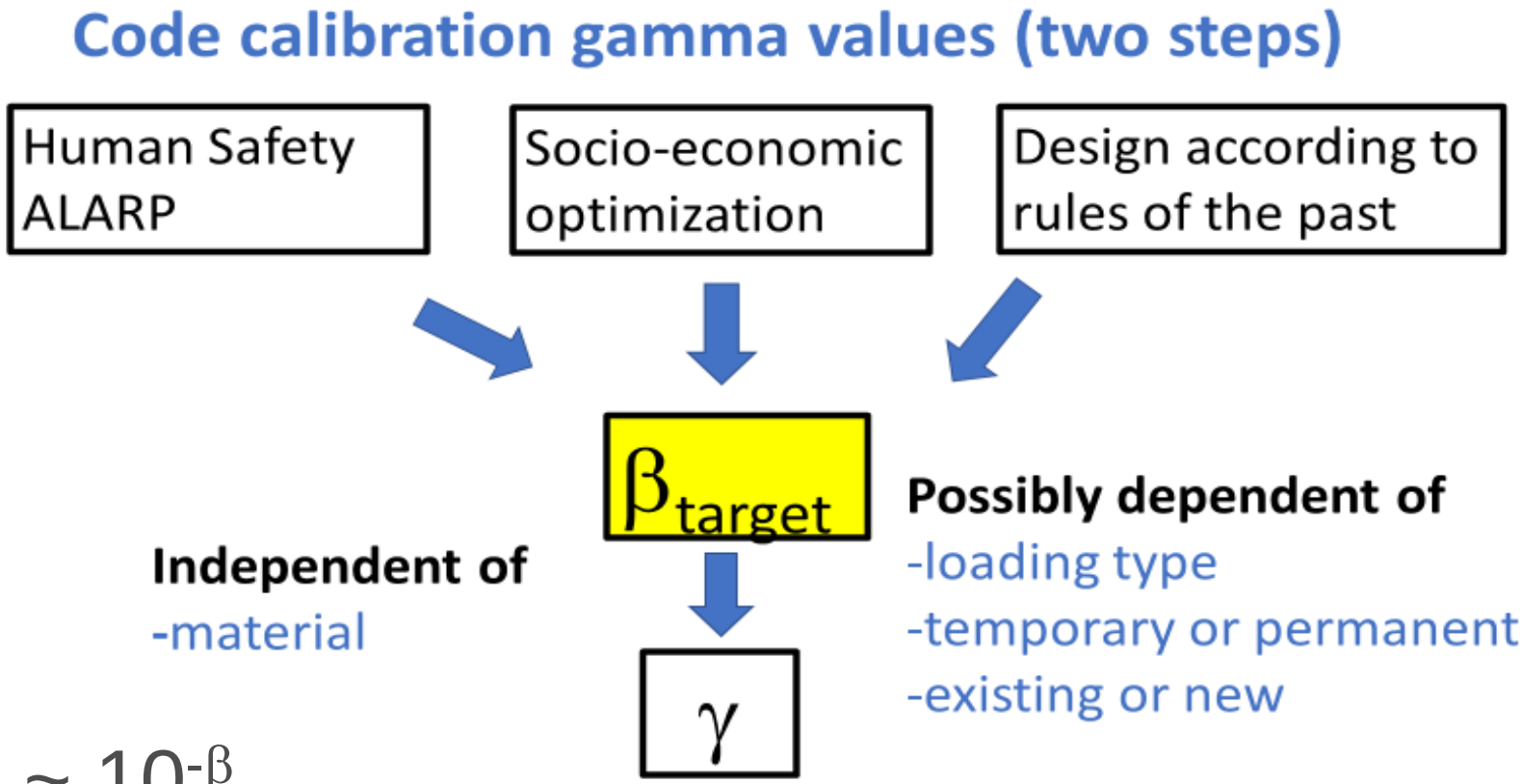
NOTE 2 Reliability levels can be set by the National Annex. Further guidance is given in Annex C.

NOTE 3 Different levels of reliability are commonly adopted for limit states relating to structural failure, serviceability, and durability.

Key revisions:

- New Annex B
- Improved guidance in Annex C to assist NSBs setting reliability targets

Structural reliability



$$P_f = \Phi(-\beta) \sim 10^{-\beta}$$

Reliability background of the Eurocodes, Vrouwenvelder, T. et al., 2024 – JRC publication (https://eurocodes.jrc.ec.europa.eu/publications/reliability-background-eurocodes)

Structural reliability

Table C.3 (NDP) — Target values for reliability index β for different consequence classes (for persistent and transient (fundamental) and fatigue design situations in ULS) relevant to structures in the scope of Clauses A.1 and A.2

Consequence class[a]	1-year reference period β	50-year reference period	
		β	$P_{f,50}$
CC3	5,2	4,3	$\sim 10^{-5}$
CC2	4,7	3,8	$\sim 10^{-4}$
CC1	4,2	3,3	$\sim 10^{-3}$

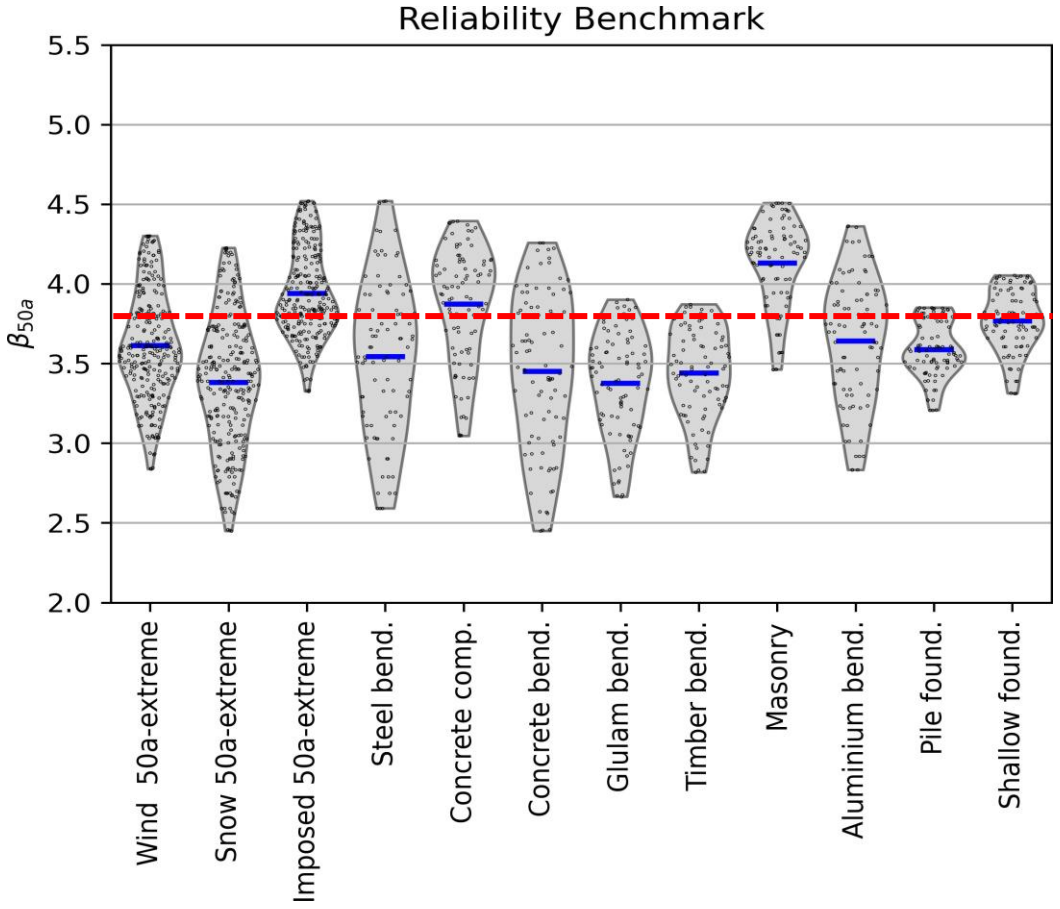
[a] Regarding CC0 and CC4, see also 4.3(2) and 4.3(3).

Responsibility to decide on the target reliability resides on the National Authorities (NDP)

$P_f = \Phi(-\beta) \sim 10^{-\beta}$

$\beta = 3,8$ "central" reference value in the Eurocodes

Structural reliability



"…on average a design according to ***the rules of the Eurocode (including the values 1,35 and 1,50 for the partial factors for permanent and variable actions) meets the target reliability level*** β ***= 3,8*** *for a design lifetime of 50 years with sufficient accuracy.*

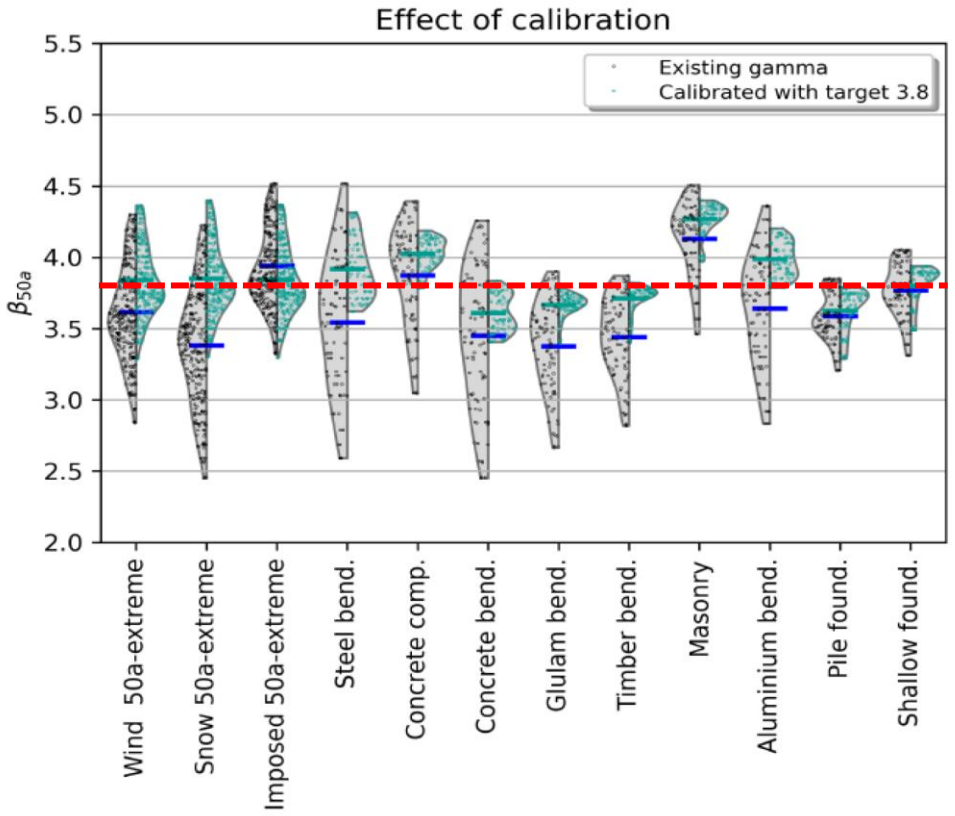
$$\gamma_G = 1.35 \qquad \gamma_Q = 1.50$$

...the values were considered as a ***good and acceptable compromise****."*

Reliability background of the Eurocodes, Vrouwenvelder, T. et al., 2024 – JRC publication (https://eurocodes.jrc.ec.europa.eu/publications/reliability-background-eurocodes)

Structural reliability

Figure B.1. Violin plots for the scatter in resulting β-values



Optimization method *(see Annex C to EN1990:2023)*

"…The result can be summarised as a drastic increase of the partial factor of the variable loads and some decrease of the partial factors for the permanent loads."

γ_G = 1,20; γ_Q = 1,94 for wind; γ_Q = 2,35 for snow and γ_Q = 1,60 for imposed loads

or γ_G = 1,20; γ_Q = 1,75 (single partial factor for variable actions)

*"But **for several reasons one should be careful with such a jump in dimensions in a new code**:*

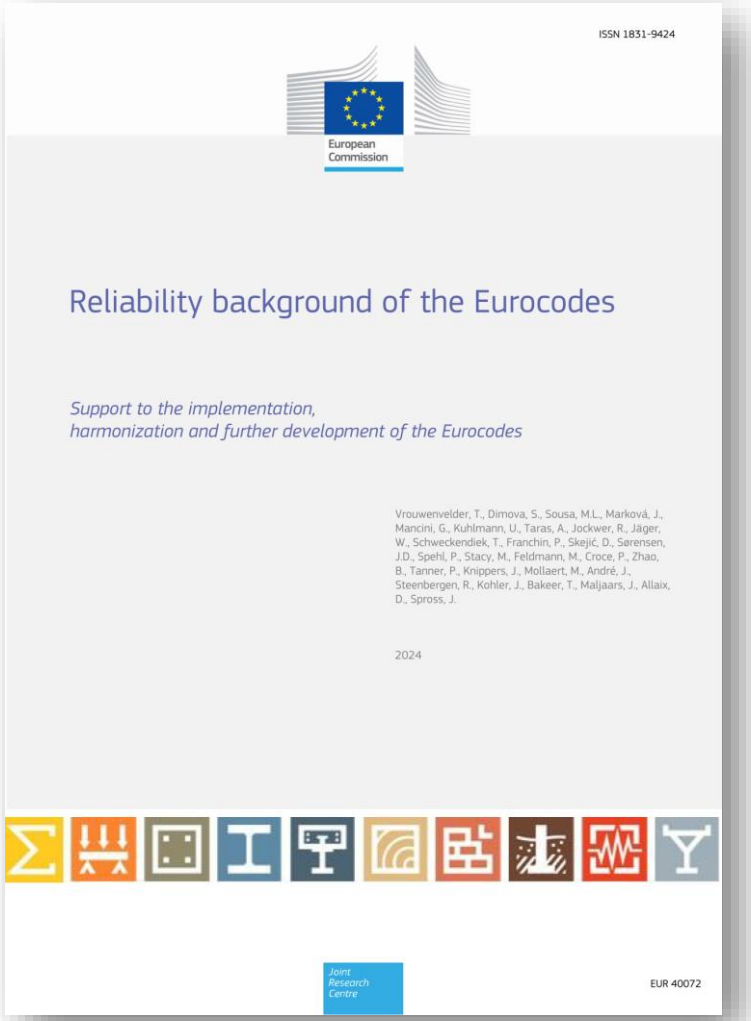
*(1) one may **question the theoretical basis**;*

***(2) there seems to be no urgent need from an unsatisfactory track record** and*

*(3) one should also **consider possibly far stretching economic consequences**."*

Reliability background of the Eurocodes, Vrouwenvelder, T. et al., 2024 – JRC publication (https://eurocodes.jrc.ec.europa.eu/publications/reliability-background-eurocodes)

JRC Report ‘Reliability Background of the Eurocodes’



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JRC Eurocodes website ‘Learning Corner’:
https://eurocodes.jrc.ec.europa.eu/publications/reliability-background-eurocodes

Consequence Classes

1st Generation

Table B1 - Definition of consequences classes

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

Key revisions / benefits:

- Comprehensive definition on CCs, generally valid for all types of structures
- Introduction of new upper (CC4) and lower (CC0) bound CCs
- Specific examples of classification are given in Annex A

2nd Generation

Table 4.1 (NDP) — Qualification of consequence classes

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 – High	High	Very great
CC2 – Normal	Medium	Considerable
CC1 – Low	Low	Small
CC0 – Lowest	Very low	Insignificant

[a] The consequence class is chosen based on the more severe of these two columns.

Consequence Classes

Example: buildings

Table A.1.1 (NDP) — Examples of buildings in different consequence classes

Consequence class	Description of consequence	Examples
CC4a	Highest	Nuclear power plant, dams
CC3	High	Buildings or parts of buildings where a very large number of people could be affected by failure, e.g. grandstands, concert halls, high-rise buildings
CC2	Normal	Buildings or parts of buildings not covered by CC1 or CC3
CC1	Low	Buildings or part of buildings where very few people could be affected by failure, e.g. agricultural buildings, storage buildings
CC0a	Lowest	Elements other than structural, see 3.1.1.7.

[a] For provisions concerning CC0 and CC4, see 4.3.

4.3(3) For consequence class CC0, either the Eurocodes or alternative provisions may be used.

Robustness

3.1.2.33
robustness
ability of a structure to withstand unforeseen adverse events without being damaged to an extent disproportionate to the original cause

4.4 Robustness

(1) A structure should be designed to have an adequate level of robustness so that during its design service life it will not be damaged by unforeseen adverse events to an extent disproportionate to the original cause.

NOTE 1 Progressive collapse is an example of a damage that is disproportionate to the original cause.

NOTE 2 For most structures, design in accordance with the Eurocodes is assumed to provide an adequate level of robustness without the need for any additional design measures to enhance structural robustness.

(2) Design measures to enhance structural robustness should be applied when specified by the relevant authority or, where not specified, as agreed for a specific project by the relevant parties.

NOTE 1 Guidance on additional design measures to enhance structural robustness for buildings and bridges is given in Annex E.

NOTE 2 Further guidance can be given in the National Annex.

Key revisions / benefits:

- Definition of robustness
- Robustness as explicit design requirement
- Most structures designed according to the Eurocodes exhibit "*adequate levels of robustness*"
- "*enhanced*" levels to be reached "*when specified*"
- Further guidance in new informative **Annex E**

Robustness

Annex E
(informative)

Additional guidance for enhancing the robustness of buildings and bridges

E.1 Use of this annex

(1) This Informative Annex provides additional guidance to that given in 4.4, for enhancing the robustness of buildings and bridges during execution and use.

NOTE 1 National choice on the application of this Informative Annex is given in the National Annex. If the National Annex contains no information on the application of this Informative Annex, it can be used.

NOTE 2 Although the guidance contained in this Informative Annex is for buildings and bridges, its principles can be applied to other types of structure.

E.2 Scope and field of application

(1) The aim of enhancing the robustness in accordance with this Informative Annex is:

— either to prevent disproportionate consequences as a result of hazardous events such as the failure or collapse of a structural member or part of a structure; or

— to provide some additional structural resistance to reduce the likelihood and extent of such an event.

NOTE Whilst the strategies and methods given in this Informative Annex enhance structural performance regarding robustness, they are not generally associated with a target level of reliability as in structural member design against identified actions and could involve consideration of a conditional reliability.

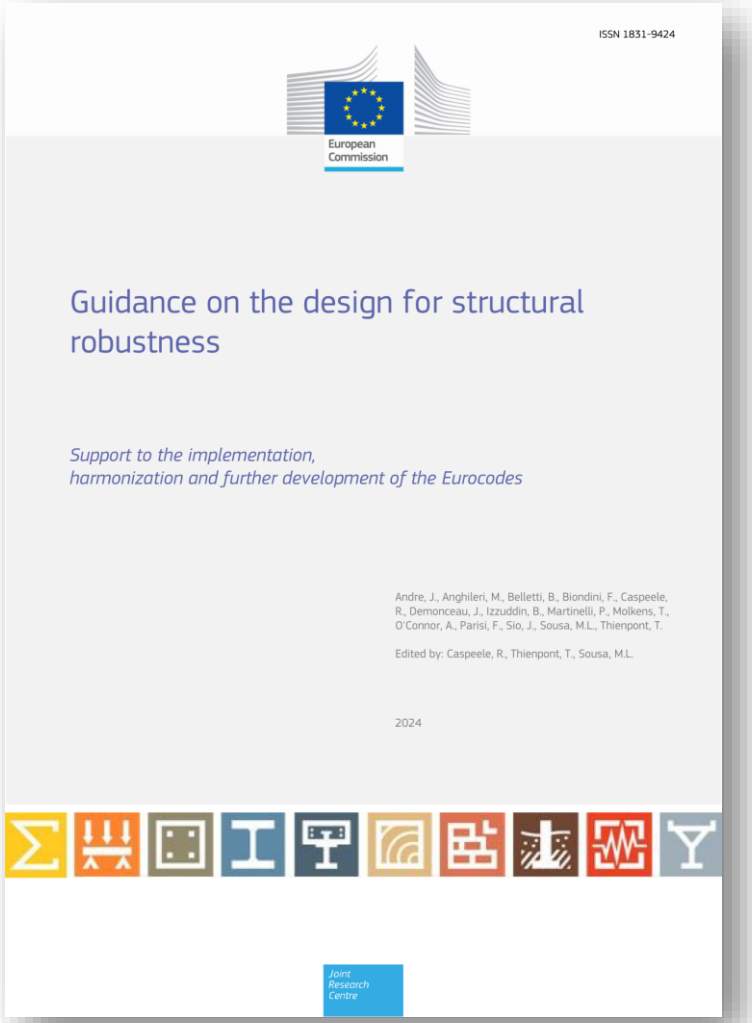
Robustness

Design Strategies

Table E.1 —Design for identified accidental actions and design strategies for enhanced robustness

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

Guidance on the design for structural robustness



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- JRC website 'Learning Corner': https://eurocodes.jrc.ec.europa.eu/publications/guidance-design-structural-robustness

Sustainability

4.7 Sustainability

(1) The structure should be designed to limit its adverse impact on non-renewable environmental resources, on society, and on economy during its entire life cycle, as specified by the relevant authority or, where not specified, as agreed for a specific project by the relevant parties.

NOTE 1 The adverse impact of a structure on its environment, on society, and on economy can be minimized by for example appropriate choice of construction process and environmentally compatible building materials, including their manufacture, design solutions, durability, recyclability, and reusability.

NOTE 2 Supplementary requirements to account for sustainability in the design can be given in the National Annex.

Quality management

Annex B
(informative)

Technical management measures for design and execution

DESIGN

DQL

DCL

EXECUTION

EXC

IL

B.2 Scope and field of application

(1) This Informative Annex provides a framework for technical management measures for

— design quality,

— design checking,

— execution quality,

— inspection during execution,

so that the intended level of structural reliability of a structure (or part of structure) that fulfils the provisions specified in the Eurocodes is achieved and the assumptions given in 1.2 are satisfied.

NOTE 1 The implementation of this Informative Annex depends on the legal system in force in each country. This Annex is provided as guidance to the writers of National Annexes that can enable a consistent approach to this subject.

Key benefit:

- Allow MS implementing a consistent approach to quality management

Verification by the partial factor method

Key revision / benefit:

- Clearer formulation of the fundamental inequality (8.1), generally valid
- Introduction of inequality (8.2) for ULS caused by excessive deformation (e.g. in EN1998 the deformation criterion is used as a mean to prevent brittle failures)

8.3 Verification of ultimate limit states (ULS)

8.3.1 General

(1) When checking ultimate limit states, the inequality given by Formula (8.1) shall be verified:

$$E_d \leq R_d \tag{8.1}$$

where

E_d is the design value of the effect of actions, defined in 8.3.2;

R_d is the design value of the corresponding resistance, defined in 8.3.5.

NOTE Verification of ULS can be carried out both at member level and at system level.

(2) When checking ultimate limit states caused by excessive deformation, the inequality given by Formula (8.2) shall be verified:

$$E_d \leq C_{d,ULS} \tag{8.2}$$

where, in addition to the symbols defined for Formula (8.1)

$C_{d,ULS}$ is the limiting design value for ultimate limit state of the excessive deformation that is considered to cause an ultimate limit state.

NOTE 1 In Formula (8.2), E_d is a displacement or strain, rather than a force or stress.

NOTE 2 In ductile materials, in particular, an ultimate limit state of excessive deformation can occur before rupture of the material.

(3) The design values of effects of actions and strength parameters to be used in verification of Formula (8.2) shall be obtained such that the required reliability level for ultimate limit states is obtained.

NOTE For guidance on the selection of $C_{d,ULS}$, see the other Eurocodes.

$$E_d = \gamma_{Sd} E\left\{\Sigma\left(\gamma_f \psi F_k\right); a_d; X_{Rd}\right\} \qquad (8.3)$$

Partial Factors on Actions γ_F

$$E_d = E\left\{\Sigma F_d; a_d; X_{Rd}\right\} = E\left\{\Sigma\left(\gamma_F \psi F_k\right); a_d; X_{Rd}\right\} \qquad (8.4)$$

$$\gamma_F = \gamma_f \cdot \gamma_{Sd}$$

- linear and non-linear structural systems;
- certain types of geotechnical structure, in accordance with the relevant part of EN 1997

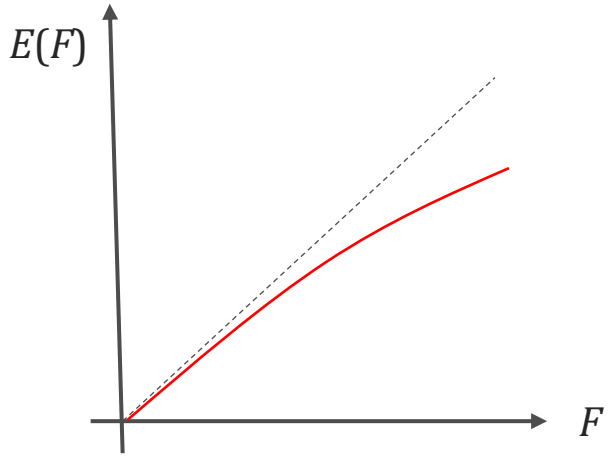
Partial Factors on Effects of Actions γ_E

$$E_d = \gamma_E E\left\{\Sigma F_{rep}; a_d; X_{rep}\right\} = \gamma_E E\left\{\Sigma\left(\psi F_k\right); a_d; X_{rep}\right\} \qquad (8.5)$$

$$\gamma_E = \gamma_f \cdot \gamma_{Sd}$$

- certain types of geotechnical structure, in accordance with the relevant part of EN 1997;
- ropes, cables and membrane structures, where the application of partial factors on the effects of actions is more adverse than the application of partial factors on actions.

- (8.4) is the most widely adopted simplification in current practice
- (8.4) may be unsafe in the non-linear case, where the action effect increase less than the actions, so-called "*underlinear*" load effect function → use of (8.3) or (8.5)
- Using the most adverse of (8.4) and (8.5) leads to uneconomic designs



Basic variables / Single-source principle

6.1.1 Classification of actions

(3) Actions that, owing to physical reasons, induce effects that are **strongly correlated with one another**, even when they originate in, or act on, different parts of the structure, or originate from different materials, may be treated as an action arising from a **single source**.

NOTE 1 This rule is commonly known as the 'single-source principle'.

NOTE 2 The single-source principle typically applies to the self-weight of the structure or the ground, including self-weight from different materials, as well as for water pressures acting on opposite sides of a structure with flow passing around or underneath.

(4) Climatic actions that act on different parts of a structure may be considered to come from a single-source.

Single-source principle

8.3.3 Design values of actions

8.3.3.1 Permanent actions

(3) Permanent actions that have both unfavourable and favourable effects may be considered as coming from a single-source, see 6.1.1, provided the design is not sensitive to spatial variation of those permanent actions.

EXAMPLE All actions originating from the self-weight of the structure, or the self-weight of different materials in the ground, are commonly considered to come from a single-source.

(4) Except as specified in (5), permanent actions from a single-source may be multiplied by a single partial factor, using Formula (8.6) if the resulting action-effect is unfavourable or Formula (8.7) if the resulting effect is favourable.

EXAMPLE The self-weight of the structure or ground can produce simultaneously both unfavourable and favourable effects. For simplicity, the self-weight can be considered as coming from a single source and therefore treated as a single action for design purposes.

(8.6) $G_{d} = \gamma_{G} G_{k}$

γ_G = 1,35 (NDP in Annex A)

Unfavourable effects

(8.7) $G_{d,fav} = \gamma_{G,fav} G_{k}$

$\gamma_{G,fav}$ = 1,00 (NDP in Annex A)

Used when the total contribution of a single permanent load source gives a **favourable** load effect

Single-source principle

8.3.3 Design values of actions

8.3.3.1 Permanent actions

(5) When verifying limit states involving loss of static equilibrium or uplift, if a permanent action that arises from a single-source (see 6.1.1) has both favourable and unfavourable effects, the design value of that part of the permanent action that causes an unfavourable (destabilizing) effect should be calculated from Formula (8.6), and the design value of that part of the permanent action that causes a favourable (stabilizing) effect should be calculated from Formula (8.7), replacing $\gamma_{G,fav}$ with the partial factor $\gamma_{G,stb}$ given by Formula (8.8):

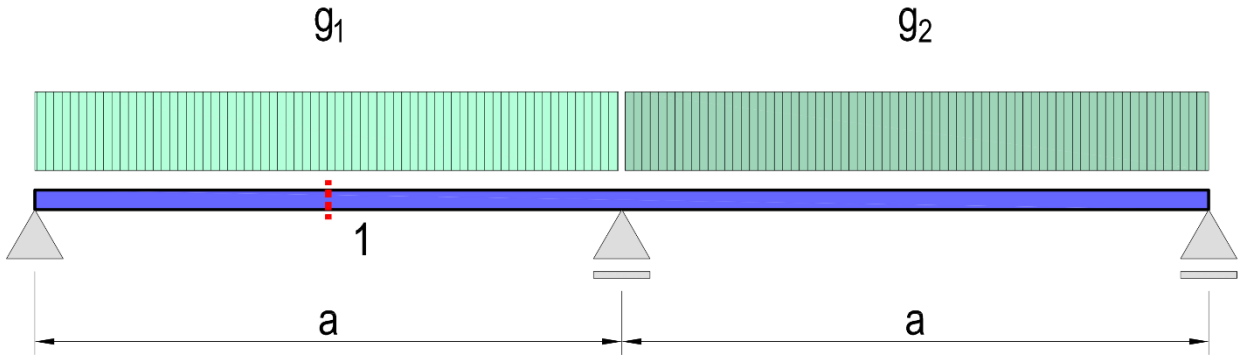
$$\gamma_{G,stb} = \gamma_G \rho \qquad (8.8)$$

$\rho = 0{,}85$ (NDP)

$\gamma_{G,stb} = 0{,}85 \times 1{,}35 \sim 1{,}15$

Used when verifying limit states involving **loss of static equilibrium** or **uplift** to calculate the design value of the permanent action arising from a single source that causes a **favourable** (stabilizing) load effect

Single-source principle – Example #1



Only permanent actions with spatial variation, same mean values = charact.

$$\mu(g_1) = \mu(g_2) = \mu(g) = g_k$$

$$\gamma_{\mathrm{G}} = 1{,}35$$

$$\gamma_{\mathrm{G},fav} = 1{,}00$$

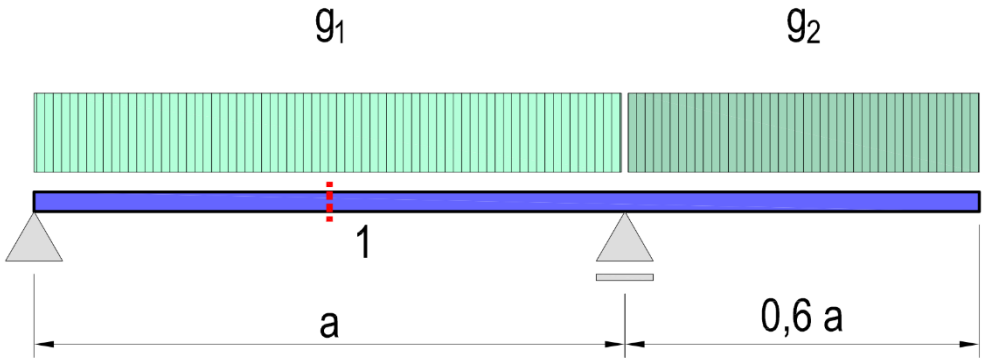
Single source $$\boldsymbol{M_{d,1}} = \left(\frac{5}{48} - \frac{1}{48}\right)\gamma_{\mathrm{G}} \cdot g_k \cdot a^2 = \frac{4}{48} \cdot 1{,}35 \cdot \mu(g) \cdot a^2 = \mathbf{0,1125} \cdot \boldsymbol{g_k} \cdot \boldsymbol{a^2}$$

NO Single-source $$\boldsymbol{M^*_{d,1}} = \frac{5}{48}\gamma_{\mathrm{G}} \cdot g_k \cdot a^2 - \frac{1}{48}\gamma_{\mathrm{G,fav}} \cdot g_k \cdot a^2 = \left(\frac{5}{48} \cdot 1{,}35 - \frac{1}{48} \cdot 1{,}00\right) \cdot g_k \cdot a^2 = \mathbf{0,1198} \cdot \boldsymbol{g_k} \cdot \boldsymbol{a^2}$$

- Negligible difference ~ 6% between the two values of M_{d}

Based on «Reliability background of the Eurocodes», Vrouwenvelder, T. et al., 2024 – JRC publication

Single-source principle – Example #2



Only permanent actions with spatial variation, same mean values = charact.

$$\mu(g_1) = \mu(g_2) = \mu(g) = g_k$$

$$\gamma_{\mathrm{G}} = 1{,}35$$

$$\gamma_{\mathrm{G},fav} = 1{,}00$$

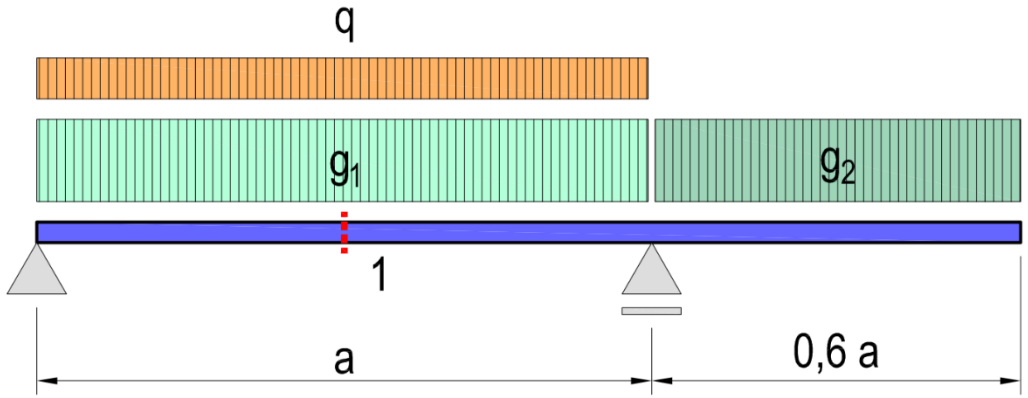
Single source $$\boldsymbol{M_{d,1}} = \frac{1}{8}\gamma_{\mathrm{G}} \cdot g_k \cdot a^2 - \frac{1}{4}\gamma_{\mathrm{G}} \cdot g_k \cdot (0{,}6\ a)^2 = \mathbf{0{,}047} \cdot \boldsymbol{g_k} \cdot \boldsymbol{a^2}$$

NO Single-source $$\boldsymbol{M^*_{d,1}} = \frac{1}{8}\gamma_{\mathrm{G}} \cdot g_k \cdot a^2 - \frac{1}{4}\gamma_{\mathrm{G,fav}} \cdot g_k \cdot (0{,}6\ a)^2 = \mathbf{0{,}079} \cdot \boldsymbol{g_k} \cdot \boldsymbol{a^2}$$

- Non-negligible difference ~68% between the two values of M_d

Based on «Reliability background of the Eurocodes», Vrouwenvelder, T. et al., 2024 – JRC publication

Single-source principle – Example #3



Permanent actions with spatial variation, same mean values = charact.

$$\mu(g_1) = \mu(g_2) = \mu(g) = g_k$$

Variable action q

$$q_k = 0{,}50 g_k$$

$\gamma_G = 1{,}35$

$\gamma_{G,fav} = 1{,}00$

$\gamma_Q = 1{,}50$

Single source (g_k) $\quad \boldsymbol{M_{d,1}} = \frac{1}{8}\gamma_G \cdot g_k \cdot a^2 - \frac{1}{4}\gamma_G \cdot g_k \cdot (0{,}6\,a)^2 + \frac{1}{8}\gamma_Q \cdot q_k \cdot a^2 = \mathbf{0{,}14} \cdot \boldsymbol{g_k} \cdot \boldsymbol{a^2}$

NO Single-source (g_k) $\quad \boldsymbol{M^*_{d,1}} = \frac{1}{8}\gamma_G \cdot g_k \cdot a^2 - \frac{1}{4}\gamma_{G,fav} \cdot g_k \cdot (0{,}6\,a)^2 + \frac{1}{8}\gamma_Q \cdot q_k \cdot a^2 = \mathbf{0{,}17} \cdot \boldsymbol{g_k} \cdot \boldsymbol{a^2}$

- difference ~21% between the two values of M_d
- difference reduces to ~13% for $q_k = g_k$

Based on «Reliability background of the Eurocodes», Vrouwenvelder, T. et al., 2024 – JRC publication

Single-source principle – Some considerations

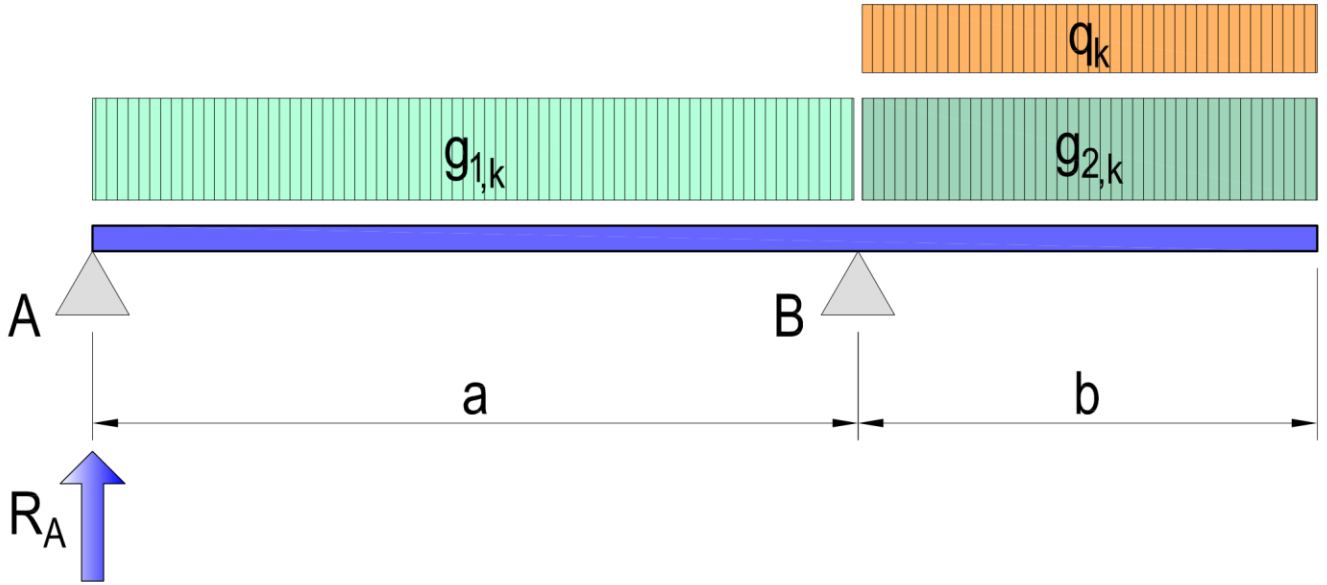
- The “single-source” principle is introduced (it was already present in EN1990:2002) to **simplify** the calculation of the unfavourable and favourable load effects induced by actions showing strong correlation (i.e. full correlation), e.g. self-weight
- Applying the “single-source” simplification requires engineering judgment as, in some specific cases, could lead to unconservative results
- The “single source” principle is **not applicable** to limit states involving loss of static equilibrium or uplift

Limit states involving equilibrium – Example #4

$a = 5m$

$\beta = \frac{b}{a}$

$\beta^2 = 0{,}5$



$g_{1,k} = g_{2,k} = g_k$

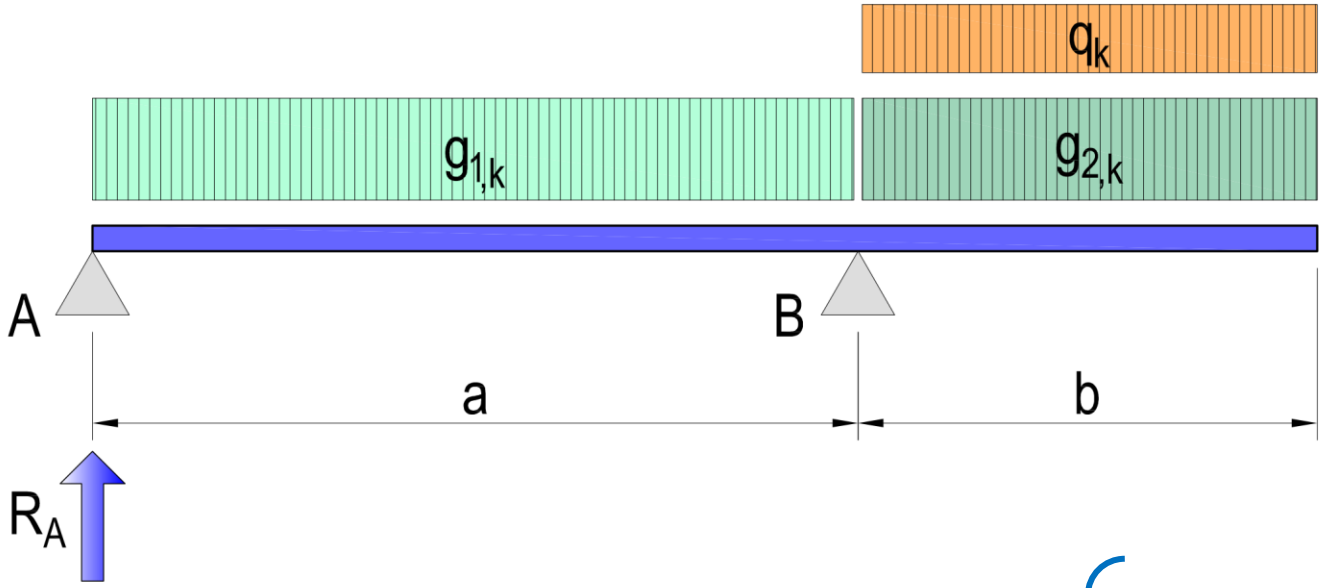
$x = \frac{q_k}{g_k}$

Limit states involving equilibrium – Example #4

$a = 5m$

$\beta = \frac{b}{a}$

$\beta^2 = 0{,}5$



$g_{1,k} = g_{2,k} = g_k$

$x = \frac{q_k}{g_k}$

$$R_A = \frac{a}{2}\left[\gamma_{G,stb} - \gamma_G \beta^2 - \gamma_Q x \beta^2\right]$$

$R_A > 0$ No anchor needed at support A

$R_A < 0$ Anchor needed at A

Limit states involving equilibrium – Example #4

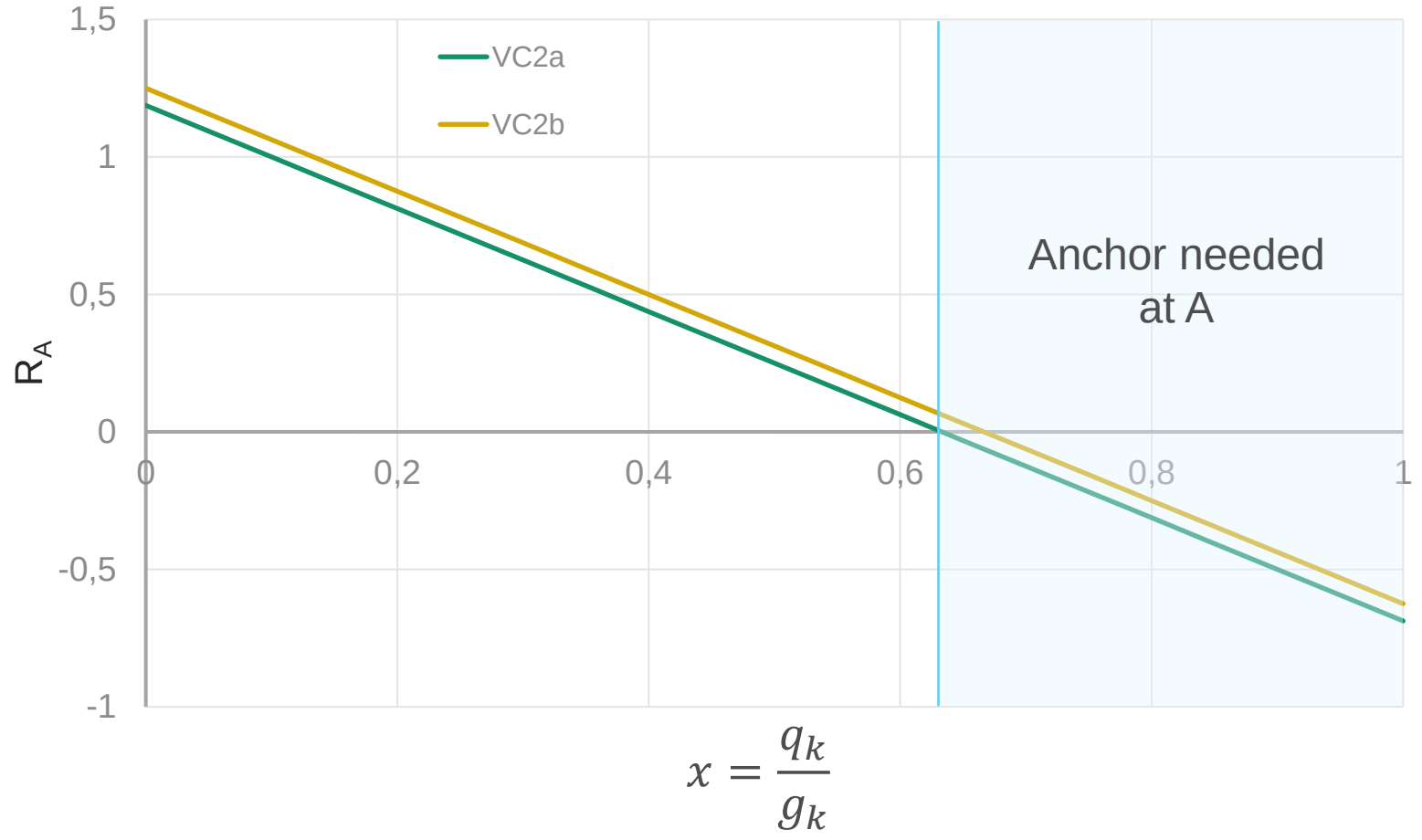
Table A.1.8 (NDP) — Partial factors on actions and effects for verification cases VC1 to VC4 for persistent and transient (fundamental) design situations

Action or effect				Partial factors γ_F and γ_E for verification cases				
Type	Group	Symbol	Resulting effect	Structural resistance[a]	Static equilibrium and uplift[b]		Geotechnical design	
Verification case				VC1[a]	VC2(a)[b]	VC2(b)[b]	VC3[c]	VC4[d]
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[l]	γ_{Gw}		$1{,}2k_F$	$1{,}2k_F$	1,0	1,0	
	All[f]	$\gamma_{G,stb}$	stabilizing[g]	not used	1,15[e]	1,0	not used	
	Water[l]	$\gamma_{Gw,stb}$			1,0[e]	1,0		
	All	$\gamma_{G,fav}$	favourable[h]	1,0	1,0	1,0	1,0	
Prestressing (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	$\gamma_{Q,red}$[j]
	Water[l]	γ_{Qw}		$1{,}35k_F$	$1{,}35k_F$	$1{,}35k_F$	1,15	1,0
	All	$\gamma_{Q,fav}$	favourable	0				
Effects of actions (E)		γ_E	unfavourable	γ_E is not applied				$1{,}35k_F$
		$\gamma_{E,fav}$	favourable					1,0

b Verification case VC2 is used for the combined verification of strength and static equilibrium, when the structure is sensitive to variations in permanent action arising from a single-source. Values of γ_F are taken from VC2(a) or VC2(b), whichever gives the less favourable outcome. See 8.3.3.1(5). Formula (8.4) is used for VC2.

$$\gamma_{G,stb} = \gamma_G \; 0{,}85 \sim 1{,}15$$

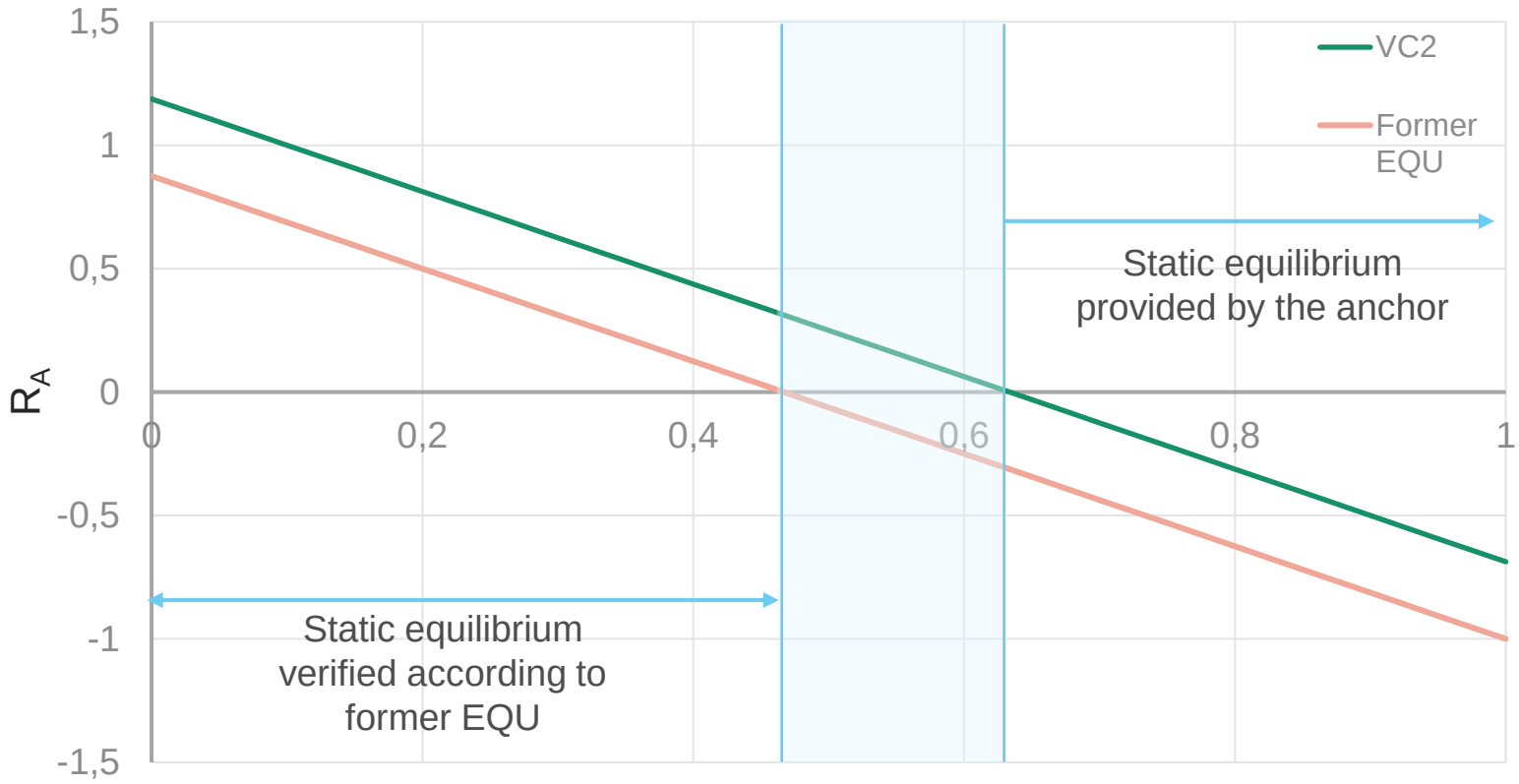
Limit states involving equilibrium – Example #4



VC2a
$x = 0{,}633$

VC2b
$x = 0{,}667$

Limit states involving equilibrium – Example #4



$$x = \frac{q_k}{g_k}$$

VC2a

$x = 0{,}63$

Former EQU

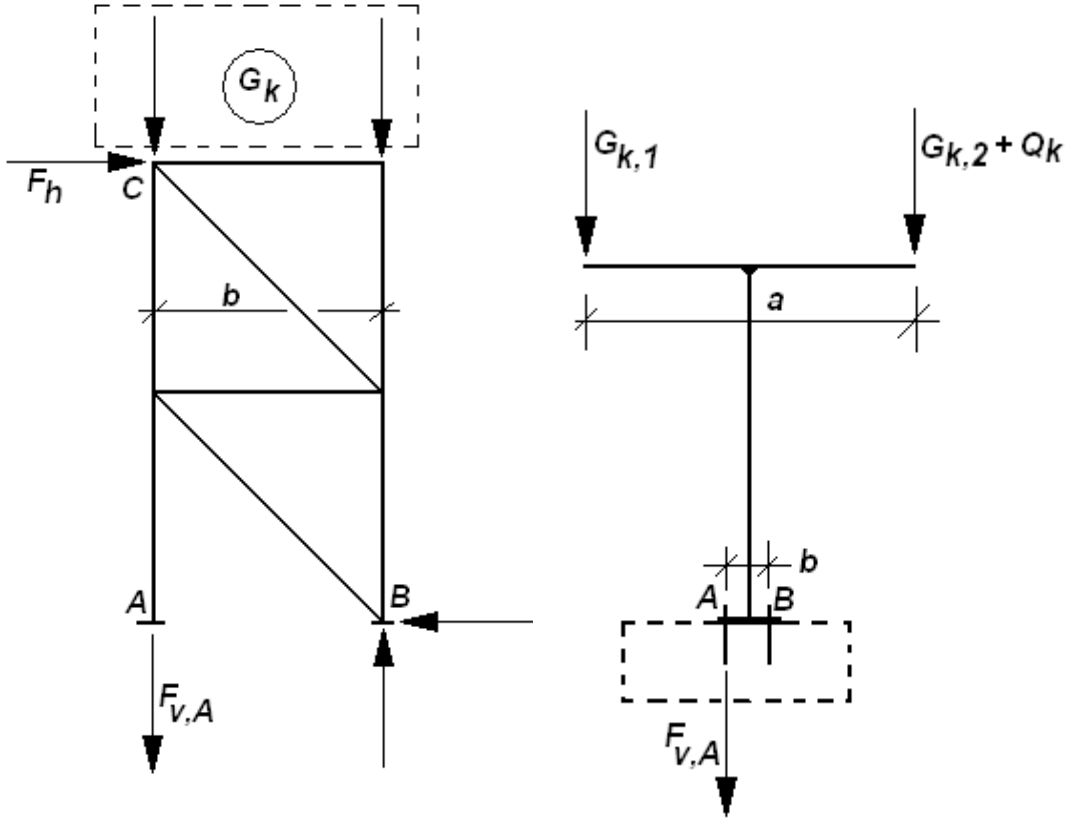
$x = 0{,}47$

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

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

Verification of static equilibrium in EN1990 2G

- The formulation given eliminates the inconsistencies detected in the application of the different combinations in EN1990 1G (EQU, STR, etc.), when a structural member is needed to provide equilibrium
- $\gamma_{G,stb}$ > 1,0 may appear counter-intuitive
- The former sets of partial factors for permanent actions in EQU verifications (0,9 – 1,1) did not follow the calibration methods for other ULS
- The single-source principle shall not be applied to permanent actions in structures sensitive to their variations



A.1 General application and application for buildings

Table A.1.8 (NDP) — Partial factors on actions and effects for verification cases VC1 to VC4 for persistent and transient (fundamental) design situations

Action or effect				Partial factors γ_F and γ_E for verification cases				
Type	Group	Symbol	Resulting effect	Structural resistance[a]	Static equilibrium and uplift[b]		Geotechnical design	
Verification case				VC1[a]	VC2(a)[b]	VC2(b)[b]	VC3[c]	VC4[d]
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[l]	γ_{Gw}		$1{,}2k_F$	$1{,}2k_F$	1,0	1,0	
	All[f]	$\gamma_{G,stb}$	stabilizing[g]	not used	$1{,}15^e$	1,0	not used	
	Water[l]	$\gamma_{Gw,stb}$			$1{,}0^e$	1,0		
	All	$\gamma_{G,fav}$	favourable[h]	1,0	1,0	1,0	1,0	
Prestressing (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	$\gamma_{Q,red}$[j]
	Water[l]	γ_{Qw}		$1{,}35k_F$	$1{,}35k_F$	$1{,}35k_F$	1,15	1,0
	All	$\gamma_{Q,fav}$	favourable	0				
Effects of actions (E)		γ_E	unfavourable	γ_E is not applied				$1{,}35k_F$
		$\gamma_{E,fav}$	favourable					1,0

[a] Verification case VC1 is used both for structural and geotechnical design. Formula (8.4) is used for VC1.

[b] Verification case VC2 is used for the combined verification of strength and static equilibrium, when the structure is sensitive to variations in permanent action arising from a single-source. Values of γ_F are taken from VC2(a) or VC2(b), whichever gives the less favourable outcome. See 8.3.3.1(5). Formula (8.4) is used for VC2.

[c] Verification case VC3 is typically used for the design of slopes and embankments, spread foundations, and gravity retaining structures. See the relevant part of EN 1997 for details. Formula (8.4) is used for VC3.

[d] Verification case VC4 is typically used for the design of transversally loaded piles and embedded retaining walls and (in some countries) gravity retaining structures. See EN 1997 (all parts) for details. Formula (8.5) is used for VC4.

[e] The values of $\gamma_{G,stb}$ = 1,15 and 1,0 are based on $\gamma_{G,inf}$ = 1,35 ρ and 1,2 ρ with ρ = 0,85.

[f] Applied to all actions except water actions.

[g] Applied to the stabilizing part of an action originating from a single source.

[h] Applied to actions whose entire effect is favourable and independent of the unfavourable action.

[j] $\gamma_{Q,red} = \gamma_{Q,1} / \gamma_{G,1}$ where $\gamma_{Q,1}$ = corresponding value of γ_Q from VC1 and $\gamma_{G,1}$ = corresponding value of γ_G from VC1.

[k] For the definition of γ_P where γ_P is materially dependent, see other relevant Eurocodes.

[l] For water actions induced by waves and currents, see Clause A.6.

Key revision / benefit:

- Comprehensive set of PFs needed for design
- Verification Cases covering different ULS, including geotechnical design
- Water actions introduced
- K_F introduced in the table to clarify its application

A.1 General application and application for buildings

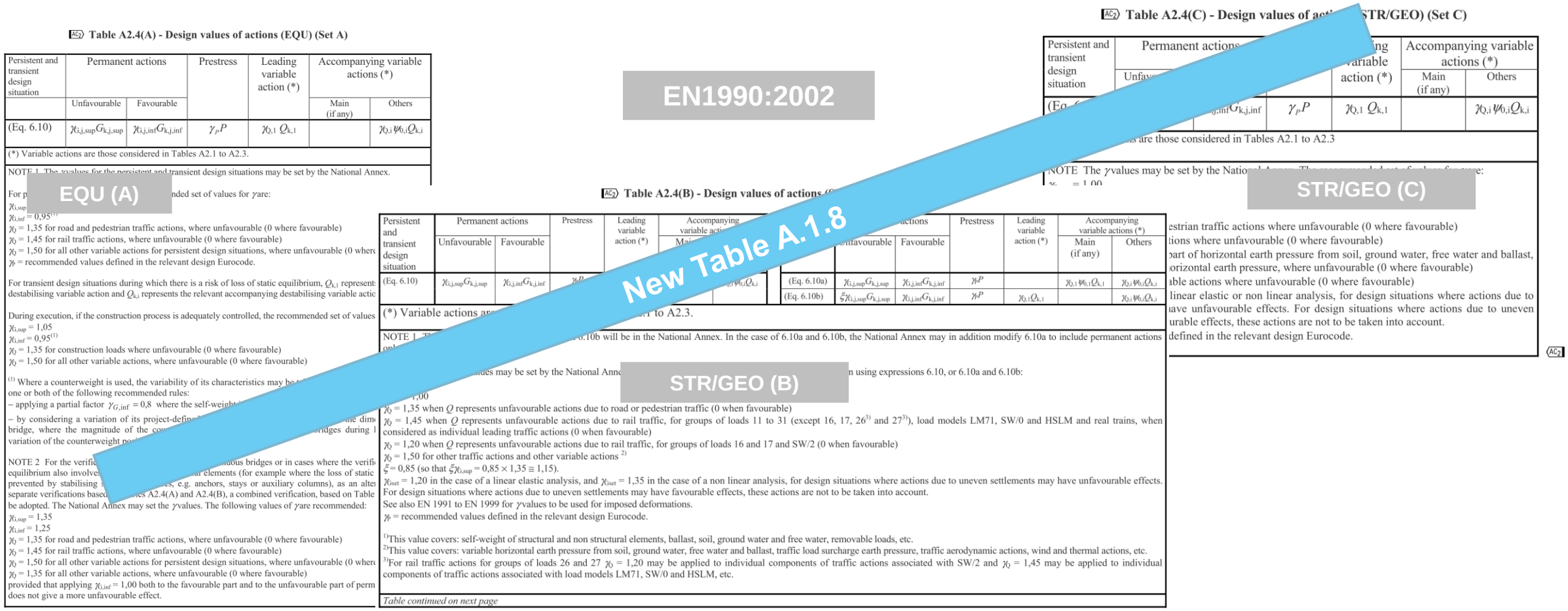


Table A2.4(A) - Design values of actions (EQU) (Set A)

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

(*) Variable actions are those considered in Tables A2.1 to A2.3.

NOTE 1 The γ values for the persistent and transient design situations may be set by the National Annex.

For p… nded set of values for γ are:
$\gamma_{G,sup}$ …
$\gamma_{G,inf} = 0,95$ (1)
$\gamma_Q = 1,35$ for road and pedestrian traffic actions, where unfavourable (0 where favourable)
$\gamma_Q = 1,45$ for rail traffic actions, where unfavourable (0 where favourable)
$\gamma_Q = 1,50$ for all other variable actions for persistent design situations, where unfavourable (0 where…
γ_P = recommended values defined in the relevant design Eurocode.

For transient design situations during which there is a risk of loss of static equilibrium, $Q_{k,1}$ represents destabilising variable action and $Q_{k,i}$ represents the relevant accompanying destabilising variable actic…

During execution, if the construction process is adequately controlled, the recommended set of values
$\gamma_{G,sup} = 1,05$
$\gamma_{G,inf} = 0,95$ (1)
$\gamma_Q = 1,35$ for construction loads where unfavourable (0 where favourable)
$\gamma_Q = 1,50$ for all other variable actions, where unfavourable (0 where favourable)

(1) Where a counterweight is used, the variability of its characteristics may be … one or both of the following recommended rules:
– applying a partial factor $\gamma_{G,inf} = 0,8$ where the self-weight …
– by considering a variation of its project-defin… the dim… bridge, where the magnitude of the co… …ridges during … variation of the counterweight no…

NOTE 2 For the verifi… …dous bridges or in cases where the verifi… equilibrium also involve… …al elements (for example where the loss of static … prevented by stabilising … …es, e.g. anchors, stays or auxiliary columns), as an alte… separate verifications based … …es A2.4(A) and A2.4(B), a combined verification, based on Table … be adopted. The National Annex may set the γ values. The following values of γ are recommended:
$\gamma_{G,sup} = 1,35$
$\gamma_{G,inf} = 1,25$
$\gamma_Q = 1,35$ for road and pedestrian traffic actions, where unfavourable (0 where favourable)
$\gamma_Q = 1,45$ for rail traffic actions, where unfavourable (0 where favourable)
$\gamma_Q = 1,50$ for all other variable actions for persistent design situations, where unfavourable (0 where…
$\gamma_Q = 1,35$ for all other variable actions, where unfavourable (0 where favourable)
provided that applying $\gamma_{G,inf} = 1,00$ both to the favourable part and to the unfavourable part of perm… does not give a more unfavourable effect.

Table A2.4(B) - Design values of actions (…

Persistent and transient design situation	Permanent actions		Prestress	Leading variable action (*)	Accompanying variable acti…	
	Unfavourable	Favourable			Ma…	
(Eq. 6.10)	$\gamma_{G,j,sup} G_{k,j,sup}$	$\gamma_{G,j,inf} G_{k,j,inf}$	$\gamma_P P$			$\gamma_{Q,i} \psi_{0,i} Q_{k,i}$
(Eq. 6.10a)	$\gamma_{G,j,sup} G_{k,j,sup}$	$\gamma_{G,j,inf} G_{k,j,inf}$	$\gamma_P P$			$\gamma_{Q,1} \psi_{0,1} Q_{k,1}$ / $\gamma_{Q,i} \psi_{0,i} Q_{k,i}$
(Eq. 6.10b)	$\xi \gamma_{G,j,sup} G_{k,j,sup}$	$\gamma_{G,j,inf} G_{k,j,inf}$	$\gamma_P P$	$\gamma_{Q,1} Q_{k,1}$		$\gamma_{Q,i} \psi_{0,i} Q_{k,i}$

(*) Variable actions ar… …1 to A2.3.

NOTE 1 T… …6.10b will be in the National Annex. In the case of 6.10a and 6.10b, the National Annex may in addition modify 6.10a to include permanent actions on…

…ues may be set by the National Anne… …n using expressions 6.10, or 6.10a and 6.10b:
…1,00
$\gamma_Q = 1,35$ when Q represents unfavourable actions due to road or pedestrian traffic (0 when favourable)
$\gamma_Q = 1,45$ when Q represents unfavourable actions due to rail traffic, for groups of loads 11 to 31 (except 16, 17, 26[3] and 27[3]), load models LM71, SW/0 and HSLM and real trains, when considered as individual leading traffic actions (0 when favourable)
$\gamma_Q = 1,20$ when Q represents unfavourable actions due to rail traffic, for groups of loads 16 and 17 and SW/2 (0 when favourable)
$\gamma_Q = 1,50$ for other traffic actions and other variable actions [2]
$\xi = 0,85$ (so that $\xi \gamma_{G,sup} = 0,85 \times 1,35 \cong 1,15$).
$\gamma_{Gset} = 1,20$ in the case of a linear elastic analysis, and $\gamma_{Gset} = 1,35$ in the case of a non linear analysis, for design situations where actions due to uneven settlements may have unfavourable effects. For design situations where actions due to uneven settlements may have favourable effects, these actions are not to be taken into account.
See also EN 1991 to EN 1999 for γ values to be used for imposed deformations.
γ_P = recommended values defined in the relevant design Eurocode.

[1] This value covers: self-weight of structural and non structural elements, ballast, soil, ground water and free water, removable loads, etc.
[2] This value covers: variable horizontal earth pressure from soil, ground water, free water and ballast, traffic load surcharge earth pressure, traffic aerodynamic actions, wind and thermal actions, etc.
[3] For rail traffic actions for groups of loads 26 and 27 $\gamma_Q = 1,20$ may be applied to individual components of traffic actions associated with SW/2 and $\gamma_Q = 1,45$ may be applied to individual components of traffic actions associated with load models LM71, SW/0 and HSLM, etc.

Table continued on next page

Table A2.4(C) - Design values of acti… STR/GEO) (Set C)

Persistent and transient design situation	Permanent actions			Leading variable action (*)	Accompanying variable actions (*)	
	Unfav…				Main (if any)	Others
(Eq. …	…,inf $G_{k,j,inf}$	$\gamma_P P$		$\gamma_{Q,1} Q_{k,1}$		$\gamma_{Q,i} \psi_{0,i} Q_{k,i}$

…s are those considered in Tables A2.1 to A2.3

NOTE The γ values may be set by the Natio… …= 1,00

…estrian traffic actions where unfavourable (0 where favourable)
…tions where unfavourable (0 where favourable)
…part of horizontal earth pressure from soil, ground water, free water and ballast, …orizontal earth pressure, where unfavourable (0 where favourable)
…able actions where unfavourable (0 where favourable)
…linear elastic or non linear analysis, for design situations where actions due to …ave unfavourable effects. For design situations where actions due to uneven …urable effects, these actions are not to be taken into account.
…defined in the relevant design Eurocode.

EN1990:2002

EQU (A)

STR/GEO (B)

STR/GEO (C)

New Table A.1.8

A.1 General application and application for buildings

A.1.8 Serviceability criteria for buildings

A.1.8.1 General

(1) Serviceability criteria should be specified for each building project in accordance with 5.4.

NOTE 1 Serviceability criteria for buildings can include, for example, floor deflection and stiffness; differential settlements; storey sway or/and building sway; roof deflection and stiffness; vibration frequency and amplitude/acceleration; and concrete crack width.

NOTE 2 Limiting values can be defined in the National Annex.

NOTE 3 Design values of serviceability criteria for non-industrial buildings, expressed independently of structural materials, are defined in A.1.8.2 for deformations. Industrial buildings include storage buildings.

NOTE 4 Design values of serviceability criteria for geotechnical structures are given in A.1.8.4.

(2) Depending on specific characteristics of the structural system and its material, other limiting values may be specified and agreed by the relevant parties involved in the design.

Vertical deflections and Horizontal displacements

Vibrations

Limiting foundation movements

A.1 General application and application for buildings

NDP

Vertical deflections

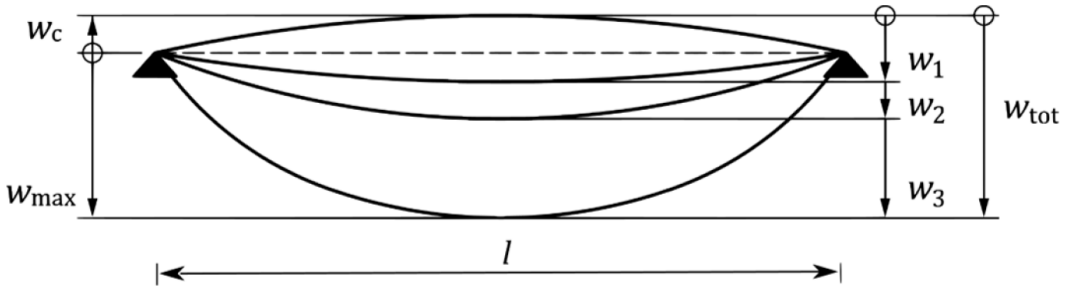


Table A.1.10 (NDP) — Suggested maximum vertical deflections for non-industrial buildings

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

[a] l = span (or, for cantilever, twice the length); w_1, w_2, w_3, w_{max} are defined in Figure A.1.1.

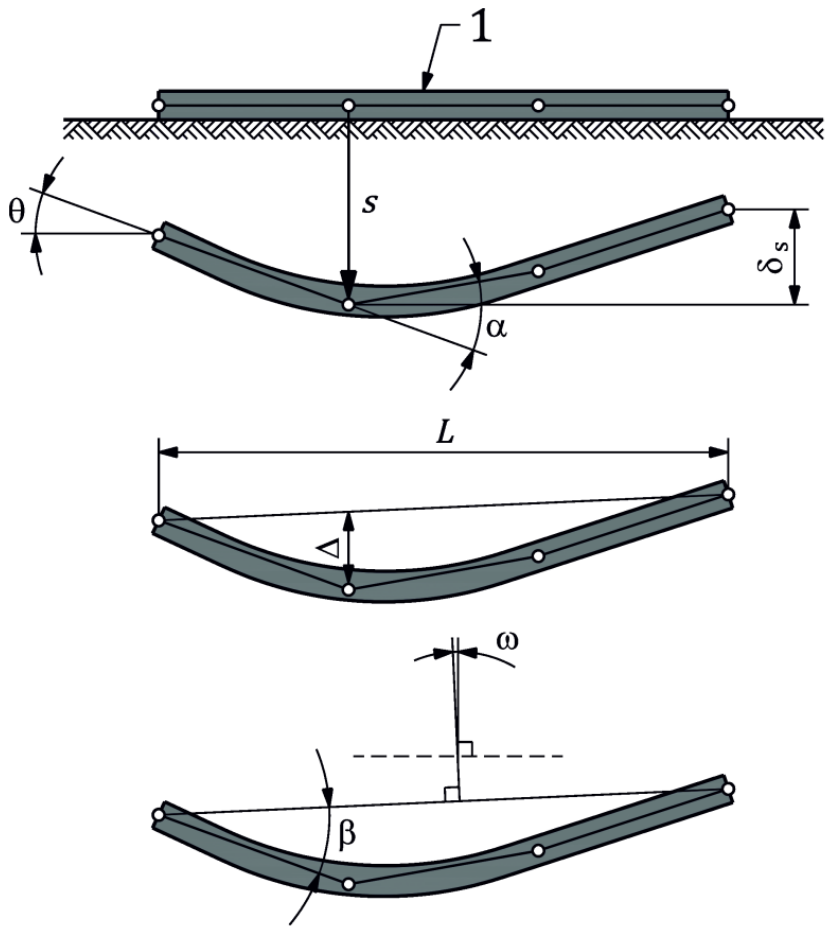
[b] Small tiles: sides less than 10 cm.

A.1 General application and application for buildings

EN1997-1:2024

3.1.7 Terms relating to structural deformation and ground movement

Limiting foundation movements



$\Delta s_{Cd,SLS}$ differential settlement

$\omega_{Cd,SLS}$ tilt

$\beta_{Cd,SLS}$ angular distortion

Table A.1.12 —Classification of structural sensitivity to foundation movement

Structural sensitivity class	Description of sensitivity
SSC5	Highest
SSC4	High
SSC3	Normal
SSC2	Low
SSC1	Lowest

Key revision / benefit:

- Inclusion of serviceability criteria limiting foundation movements
- Consistency with EN1997 definitions and provisions

Concluding remarks

- EN 1990 2G:
  - EN1990-1 Design of new structures
  - EN1990-2 Assessment of existing structures
- Enhanced ease of use, not limiting the completeness of provisions
- Application rules for a wider set of structures
- Enhanced provisions on robustness
- Sustainability
- Alignment with EN1997 geotechnical design
- Background document on reliability bases to assist users and NSBs

Thank you!

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