Overview of the Evolution of EN 1991: Eurocode 1 – Actions on structures

2020-09-21

Issue 1
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Structure of this slide deck

- General overview of the evolution of EN 1991
- Specific overview of the evolution of EN 1991 parts:
  - *EN 1991-1-2*
  - *EN 1991-1-3*
  - *EN 1991-1-4*
  - *EN 1991-1-5*
  - *EN 1991-1-8*
  - *EN 1991-1-9*
  - *EN 1991-2*
  - *EN 1991-4*

General overview of the Evolution of EN 1991: Eurocode 1 – Actions on structures

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Agenda – Evolution of EN XXXX

- → Key changes to EN 1991
- → New content included in the scope of EN 1991
- → How ease of use has been enhanced

The following slides provide a general overview of the evolution of EN 1991. Complementary slides provide greater details for individual Eurocode Parts.

Key changes to EN 1991

- Revision of the current standard following the principle of "evolution, not revolution" by means of :
- Updating to (well established and generally acceptable) State of the Art
- Reduction of the National Determined Parameters (NDP) while ensuring an adequate flexibility for their choice
- Enhancing the "ease of use"
- Implementing some necessary changes in order to cover as appropriate items associated with geotechnical structures (as a result of the change of scope of TC 250)
- Introduction of new parts

New content included in scope of EN XXXX

→ Incorporation in EN 1991of two new parts based on relevant ISO standards, namely :

- EN 1991-1-8 on “Actions from waves and currents on coastal structures”
- EN 1991-1-9 on “Atmospheric icing”

How ease of use has been enhanced

→ Ease of Use is improved by means of the following:

- drafting is targeted to the primary users' category, i.e. practitioners and competent engineers; information relevant for NSBs to prepare their National Annexes is mainly presented either in notes or in informative annexes
- improving the application of drafting rules according to the updated CEN/CENELEC Internal Regulations (with the support of the ad-hoc document N 1250 v 9.1)
- clarity and understandability of provisions is improved by reordering of clauses, in alignment with other EN1991 parts and in accordance with the presentation of concepts related to actions in EN1990, to improve consistency between the Eurocodes

How ease of use has been enhanced

- a common structure of the introductory general sections (e.g. classification of actions, design situations, modelling) implemented for most of the EN 1991 Parts
- alleviating and restructuring the documents so that the coverage of the most common cases is included in the main part while specific cases are covered in annexes
- provisions are presented according to the order in their use to facilitate the navigation throughout the documents

How ease of use has been enhanced

- alternative application rules, as well the introduction of NDPs, are limited to a necessary minimum
- innovations when introduced (usually following relevant systematic review comments) where based on an appropriate review of recent international literature and international standards and a consolidated state-of-the-art

Overview of the Evolution of EN 1991-1-2: Eurocode 1 - Actions on structures –Part 1-2: General actions – Actions on structures exposed to fire

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Agenda – Evolution of EN 1991-1-2: Actions on structures exposed to fire

- Key changes to EN 1991-1-2
- New content included in the scope of EN 1991-1-2
- How ease of use has been enhanced

Key changes to EN 1991-1-2

- Clarification/update of some definitions
- Scope clarified, in particular the non coverage of:
  - the possible installation and maintenance of sprinkler systems;
  - conditions on occupancy of building or fire compartment;
  - the use of approved insulation and coating materials, including their maintenance
- Formulae and relevant diagrams are given for the determination of the reduction factor η_{fi} (see next 3 slides)

Key changes to EN 1991-1-2

→ **6.3.2 Simplified rules**

(1) Where indirect fire actions need not be explicitly considered, effects of actions may be determined by analysing the structure for combined actions according to 6.3.1 for t = 0 only. These effects of actions $E_{\mathrm{fi,d}}$ may be applied as constant throughout fire exposure.

(2) As a further simplification to (1), effects of actions may be deduced from those determined in normal temperature design using Formula (6.1):

$$\boldsymbol{E}_{\mathbf{fi,d,t}} = \boldsymbol{E}_{\mathbf{fi,d}} = \boldsymbol{\eta}_{\mathbf{fi}} \cdot \boldsymbol{E}_{\mathbf{d}} \qquad (6.1)$$

where

E_{d} is the design value of the relevant effects of actions for fundamental (persistent and transient) design situations according to EN 1990;

$E_{\mathrm{fi,d}}$ is the corresponding constant design value in the fire situation;

η_{fi} is a reduction factor

Key changes to EN 1991-1-2

→ (3) For the combination of actions given by Formula (8.12) in EN 1990, the reduction factor η_{fi} should be taken as:

$$\eta_{fi} = \frac{G_k + \psi_{fi} Q_{k,1}}{\gamma_G G_k + \gamma_{Q,1} Q_{k,1}} \qquad (6.2)$$

where

$Q_{k,1}$ is the characteristic value of the leading variable action 1;

G_k is the characteristic value of the permanent action;

γ_G is the partial factor for the permanent action;

$\gamma_{Q,1}$ is the partial factor for the leading variable action 1;

ψ_{fi} is the combination factor for variable actions in the fire situation, given either by $\psi_{1,1}$ or $\psi_{2,1}$, see EN 1991-1-2;

→ Similar formulations are specified for the combinations of actions given by Formulae (8.13a) and (8.13b) in EN 1990

Key changes to EN 1991-1-2

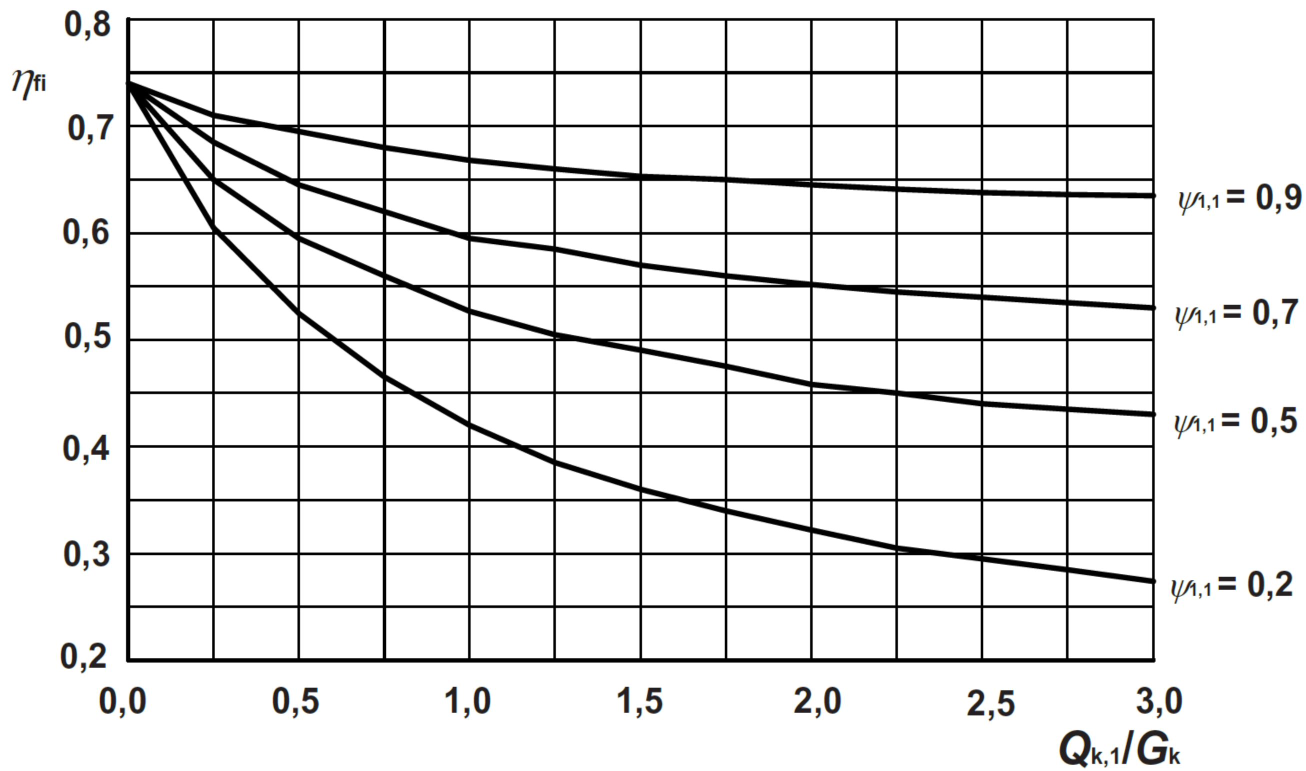

Figure 6.1 – Examples of reduction factor η_{fi} versus load ratio $Q_{k,1}/G_k$ according to Formula (6.2)

Key changes to EN 1991-1-2

→ The scope and field of application of Annex C (informative) on localised fires is clarified, as follows:

(1) The thermal action of a localised fire can be represented as a virtual solid flame, following the method described in this annex.

(2) The methodology given in this informative annex is valid if the following conditions are met:
- diameter of the fire is limited by $\leq 10m$;
- rate of heat release of the fire is limited by $Q \leq 50MW$

NOTE : The methodology does not consider the impact of the smoke layer see 3.3.2 (4)

Key changes to EN 1991-1-2

→ The scope and field of application of Annex C on localised fires is clarified, as follows (cont'd):

(3) Differences should be made regarding:

- the relative height of the flame to the ceiling
- the position of the structural element to the geometry of the flame
- the position of the structural element to the ceiling level

→ To note also that the status of all the Annexes A to G remained unchanged, i.e. informative

Key changes to EN 1991-1-2

→ Modification of formula (E.6) for the evaluation of the maximum rate of heat release, Qmax, as follows :

(5) If the fire is ventilation controlled, this plateau level should be reduced following the available oxygen content, either automatically in case of the use of a computer program based on one zone model or by the simplified expression:

$$Q_{max} = 1{,}57 \cdot m_{O_2} \cdot A_v \cdot \sqrt{h_{eq}} \quad \text{[MW]} \qquad \text{(E.6)}$$

where

A_v is the opening area [m2]

h_{eq} is the mean height of the openings [m]

m_{O_2} is the oxygen consumption factor with $m_{O_2} = 0{,}8$.

Key changes to EN 1991-1-2

→ Introduction of an updated and detailed factor $\delta_n = \prod_{i=1}^{10} \delta_{ni}$ taking into account the different active fire fighting measures i (sprinkler, detection, automatic alarm transmission, firemen …) in the formula (E.1) for the evaluation of the design value of the fire load $q_{f,d}$:

$$q_{f,d} = q_{f,k} \cdot m \cdot \delta_{q1} \cdot \delta_{q2} \cdot \boldsymbol{\delta_n} \cdot \delta_{q3} \ [\mathrm{MJ/m^2}] \qquad \text{(E.1)}$$

δ_{ni} Function of Active Fire Fighting Measures																
Automatic Fire Suppression				Automatic Fire Detection & Alarm				Manual Fire Suppression								
Automatic Water Extinguishing System	Independent Water Supplies			Automatic Fire Detection & Alarm			Automatic Alarm Transmission To Fire Brigade	Fire Brigade		Safe Access Route			Fire Fighting Devices		Smoke Exhaust System	
	0	1	2	By heat	By smoke	By heat & smoke		Work FB	Off Site FB	Improved	Standard	Difficult	present	not present	present	not present
δ_{n1}	δ_{n2}			δ_{n3}			δ_{n4}	δ_{n5}		δ_{n6}			δ_{n7}		δ_{n8}	
0,61	1	0,87	0,7	0,9	0,73	0,73	0,87	0,61	0,78 / 0,84	0,9	1	1,5	1	1,5	1	1,5

TABLE E.2 - Factors δ_{ni}

New content included in scope of EN 1991-1-2

TABLE E.3 – Factor δ_{q3}

Consequence Class	Examples of buildings	δ_{q3}
CC3	Grandstands, public buildings where consequences of failure are high (e.g. a concert hall)	1.19
CC2	Residential and office buildings, public buildings where consequences of failure are medium (e.g. an office building)	1
CC1	Agricultural buildings, buildings where people do not normally enter (e.g. storage buildings, greenhouses)	0.83

New content included in scope of EN 1991-1-2

- A substantial extension of the Annex C on a localised fire represented by a virtual solid flame (see next 4 slides)
- Introduction in Table E.3 of a new factor (δ_{q3}), for the determination of the design value of the fire load $q_{f,d}$, in order to take into account the consequence class of the building, as defined in EN 1990 (see previous slide)
- Introduction in Annex G of a model for the evaluation of the virtual solid flame used in the determination of the "configuration factor" (expressing the diffusely radiated energy of heat transfer from one surface to another)

New content included in scope of EN 1991-1-2

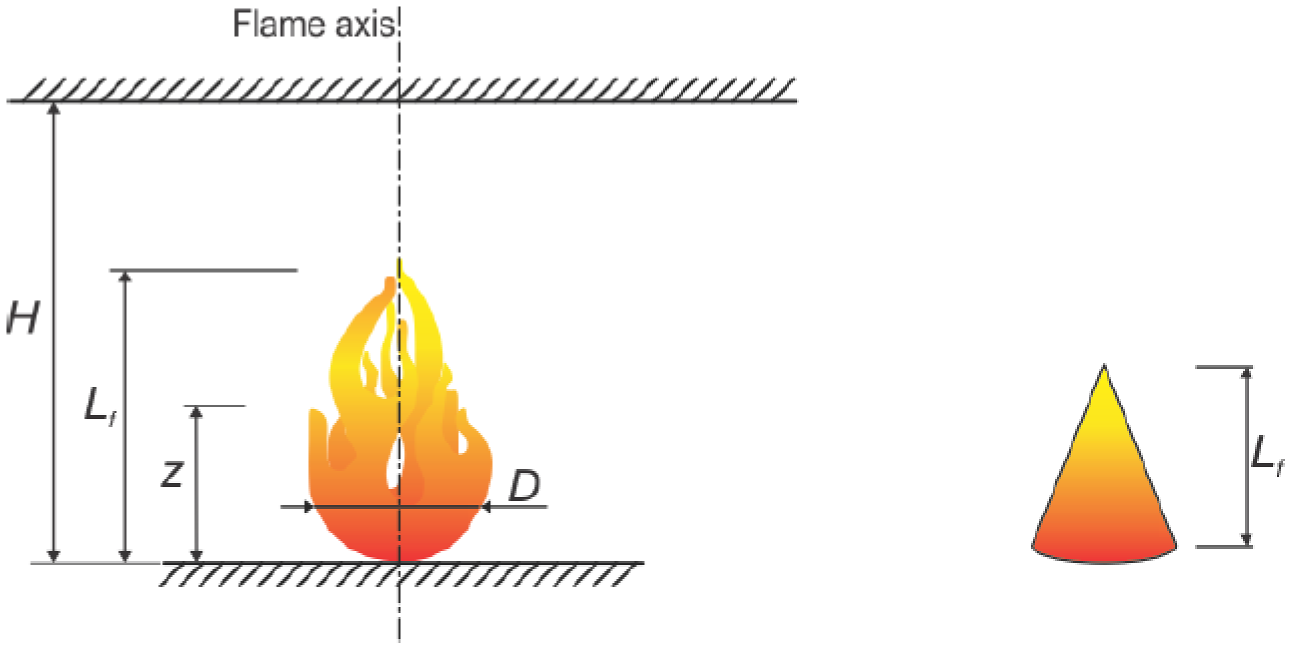

Figure C.1: Height of the virtual flame L_f

Figure C.1: Height of the virtual flame L_f

New content included in scope of EN 1991-1-2

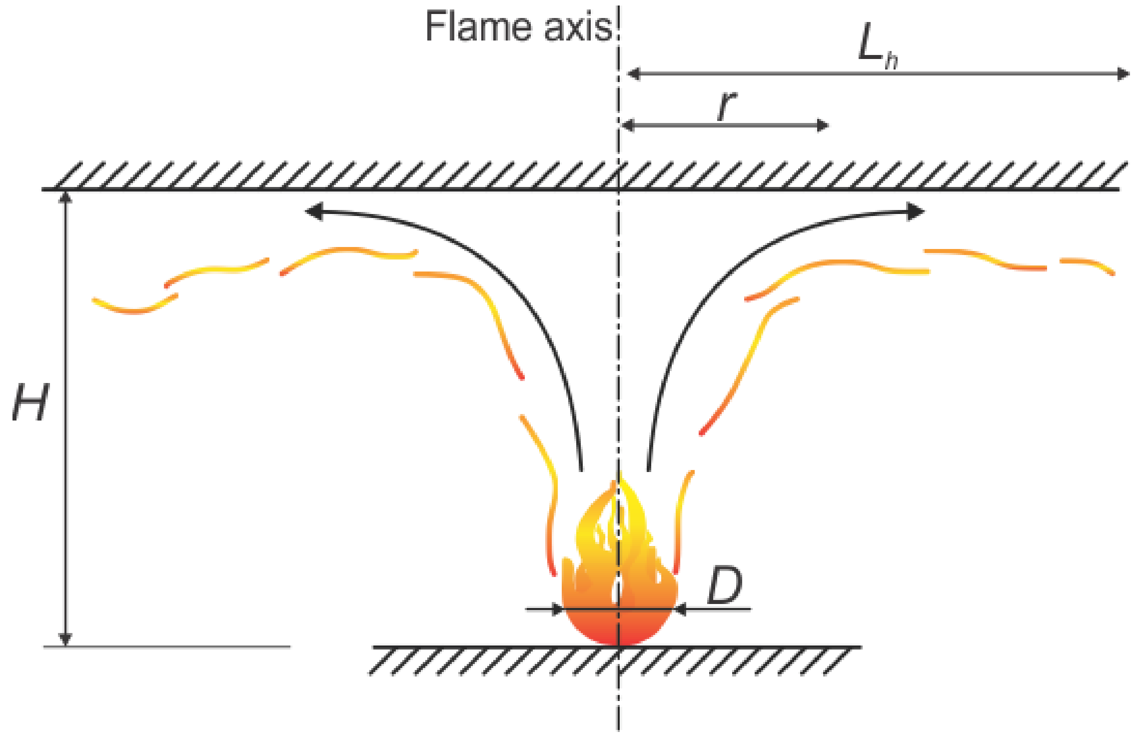

Figure C.5: Flame impacting the ceiling

New content included in scope of EN 1991-1-2

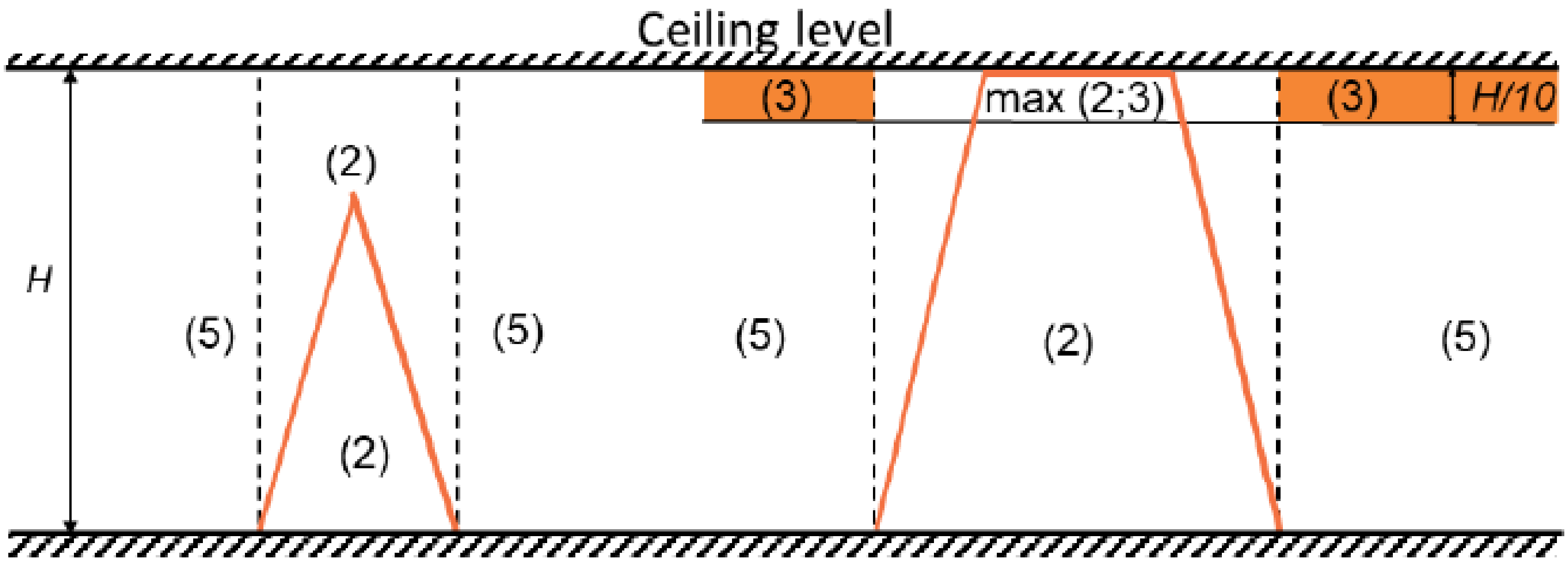

Figure C.6: Domains of application of clauses (2), (3) and (5)

Figure C.6: Domains of application of clauses (2, (3) and (5) (see next slide)

New content included in scope of EN 1991-1-2

(2) If the structural element is **engulfed into the localised fire and not situated at the ceiling level** ($z < 0,9\ H$, see Figure C.6)

(3) If the virtual solid flame is **impacting the ceiling and the structural element is situated at the ceiling level** ($z \geq 0,9\ H$, see Figure C.6)

(5) If both conditions (2) and (3) are **not fulfilled** (see Figure C.6)

How ease of use has been enhanced

- → Reduction of the NDPs from 10 to 7
- → Introduction for Table E.2 of a new note clarifying the applicability of “work fire brigade” and “off site fire brigade”:

The factor δ_{n5} of Table E.2 corresponding to “off-site fire brigade” translates the effect of a professional fire brigade: it may be taken as 0,78 or 0,84 if the brigade acts in maximum 20 minutes or 30 minutes after the fire alarm, respectively

- → In Table E.5 for fire load densities clarification of terms to help practitioners in making the proper choice:

- Densely loaded office (office including minimum 20% archive’s surface)

- Office

- Sparsely loaded office (open space office with limited combustible furniture's, paperless office without archives)

Overview of the Evolution of EN 1991-1-3: Eurocode 1 - Actions on structures –Part 1-3: General actions – Snow loads

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Agenda – Evolution of EN 1991-1-3: Snow loads

- → Key changes to EN 1991-1-3
- → New content included in the scope of EN 1991-1-3
- → How ease of use has been enhanced

Key changes to EN 1991-1-3

- Implementation of new models closer to the physics and based on state-of-the-art available experimental data for European climates, e.g. an updated model for the snow load on the roofs
- Consideration of snow load for additional types of roofs
- Implementation of updated and specific models for snow local effects

Key changes to EN 1991-1-3

As an example :

- The terms **“balanced”** and **“unbalanced”** are used in place of “**undrifted**” and “**drifted**”. The reason is because the “balanced” snow layer accounts for redistribution or erosion due to wind as well as melting effects and is not to be interpreted as snow deposited in absence of wind or melting, as the term “undrifted” could be. For the same reason the term “drifted” mostly addressing the effects of wind is now changed into “unbalanced”, as melting can have significant effects in the clearing of roof areas.

This terminology is consistent with ISO 4355:2013 and with ASCE/SEI 7-16.

Key changes to EN 1991-1-3

Some examples :

→ The **exposure coefficient** C_e is introduced in the definition of shape coefficients to account for the wind effects in the definition of both "balanced" and "unbalanced" snow distributions. This change has been introduced to correct:

- unrealistic reductions of unbalance distributions in windswept conditions (reducing C_e);
- unrealistic unbalanced distributions in sheltered conditions.

→ The new application of Ce now accounts for increase of snow load in locally sheltered areas of the roof.

Key changes to EN 1991-1-3

Some examples :

→ The exposure coefficient is defined by:

- orography conditions of the terrain surrounding the building, which are now linked to the "terrain category" defined in EN1991-1-4 for wind actions;
- for windswept locations, the orographic conditions are not enough to allow the adoption of a reduced C_e value and the value of the mean wind speed during the coldest month of the year is to be checked against a threshold value.
- The mean wind speed requirement is introduced to account for the effectiveness of wind to redistribute the snow.

Key changes to EN 1991-1-3

Some examples :

→ Snow shape coefficients (which can be considered as the major innovation in the standard), namely:

- For **flat roofs**, the influence of the roof dimensions is now taken into account, as well as the presence of rows of tilted (solar) panels (see next two slides)

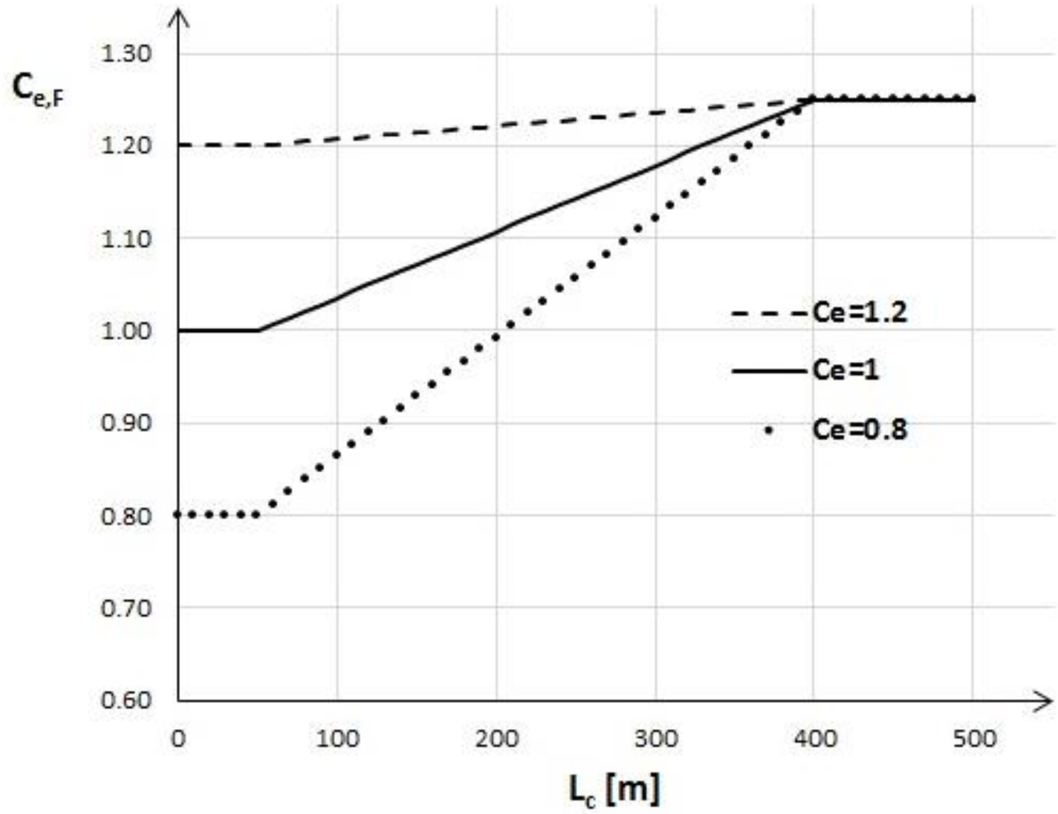
- For **pitched roofs (gabled)** a **new** snow load model is introduced

Key changes to EN 1991-1-3

Some examples :

→ **Exposure coefficient for flat roofs (new)**

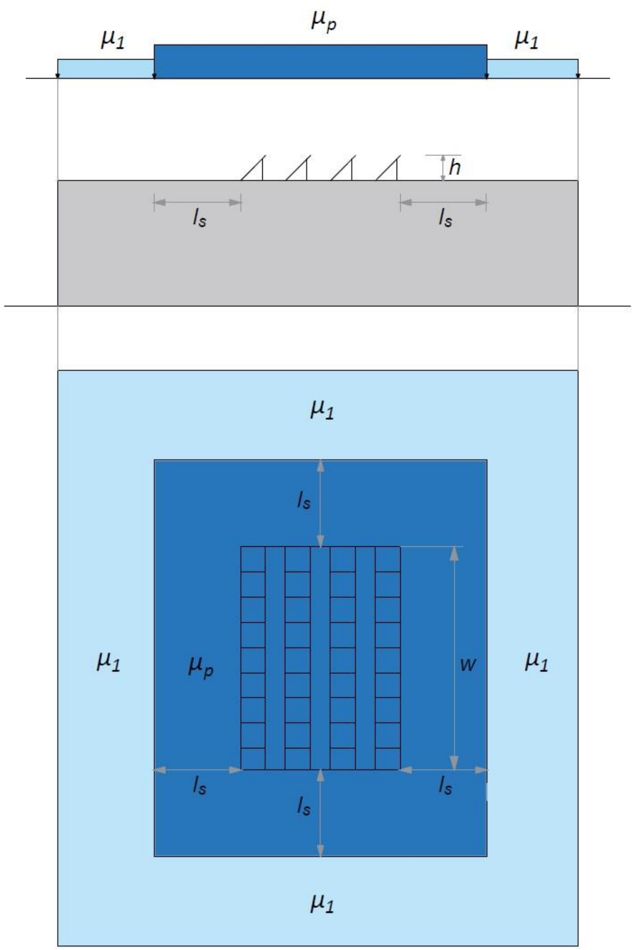
Wind exposure conditions	Ce
Windswept[a]	0,8
Normal[b]	1,0
Sheltered[c]	1,2



Key changes to EN 1991-1-3

Some examples :

→ **Snow load arrangement for flat roofs with tilted panels**



Key changes to EN 1991-1-3

Some examples :

- For **cylindrical roofs** the model is slightly changed to take into account the observations and the assumptions that wind, melting and sliding from a solar exposed part of a cylindrical roof can lead to the worst-case scenario of no snow on one side of the roof. In addition, the model is updated to account for variations in drifted snow load based on varying exposure coefficient.

- For **domes** a **new** snow load model is introduced, as a simplification of the relevant models of ISO 4355:2013 and with ASCE/SEI 7-16.

Key changes to EN 1991-1-3

Some examples :

- For **multi-span roofs** the model is revised to account for:

1. Realistic snow load depths in the valley (not exceeding the ridge of the roof)
2. The effect of sliding in the valley; this is revised by realistic consideration of snow sliding down into the bottom of the valley, and additional deposition of snow drifted by wind drifts into the valley.

The value adopted is based on a slightly conservative value for the gable roof with pitch angles of 30°. No reduction of snow deposition due to wind exposure in the valley is considered.

Key changes to EN 1991-1-3

Some examples :

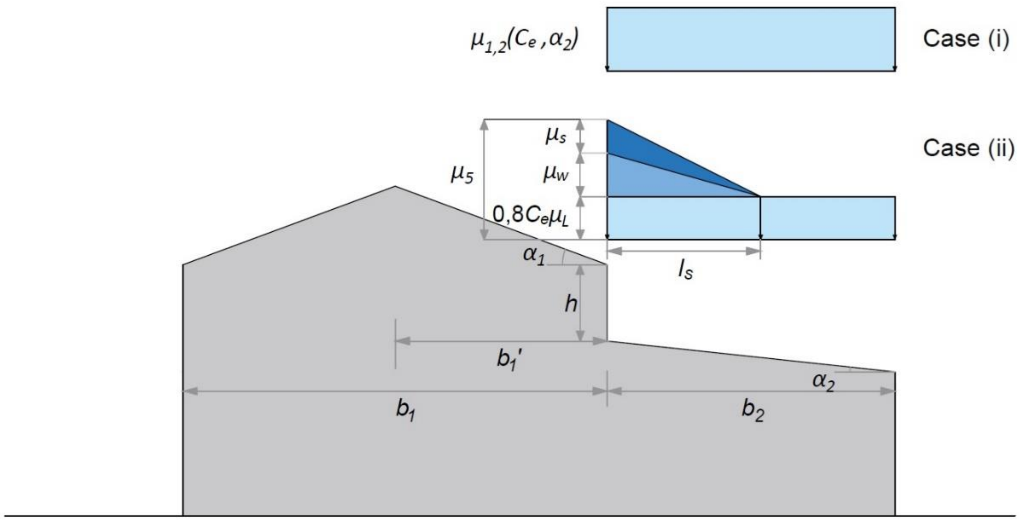
→ **Roof abutting and close to taller construction works**

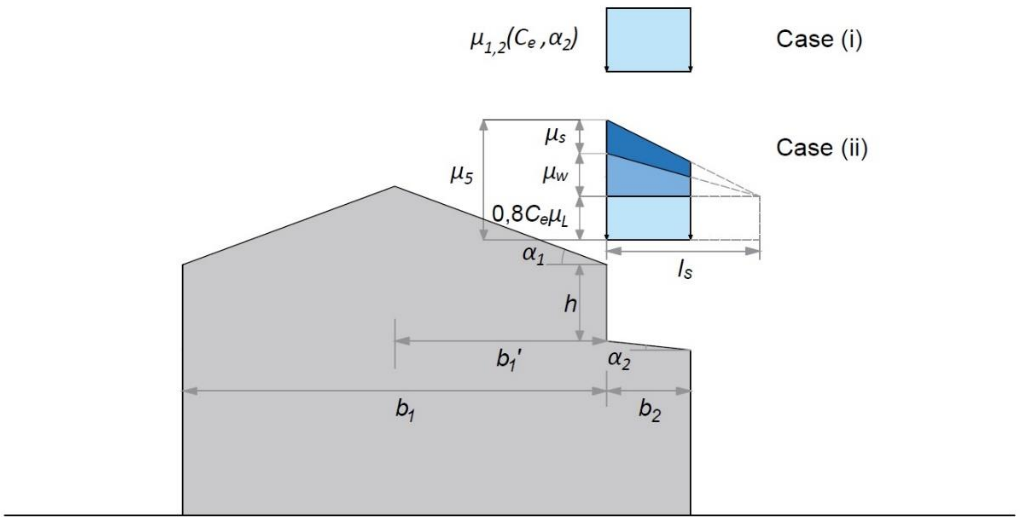
A **new** model for "unbalanced" snow load on the lower roof is introduced, in order to correct inconsistencies detected in the current standard. The new model accounts for three different contributions:

- The load pertaining to the balanced condition, on top of which the two other contributions are summed (μ_L)
- The sliding part from the upper roof (μ_s)
- The wind driven accumulated snow (μ_s), originating from the available snow for redistribution, present on both the upper and the lower roofs.

Key changes to EN 1991-1-3

Some examples :





Key changes to EN 1991-1-3

Some examples :

→ **Drifting at obstructions**

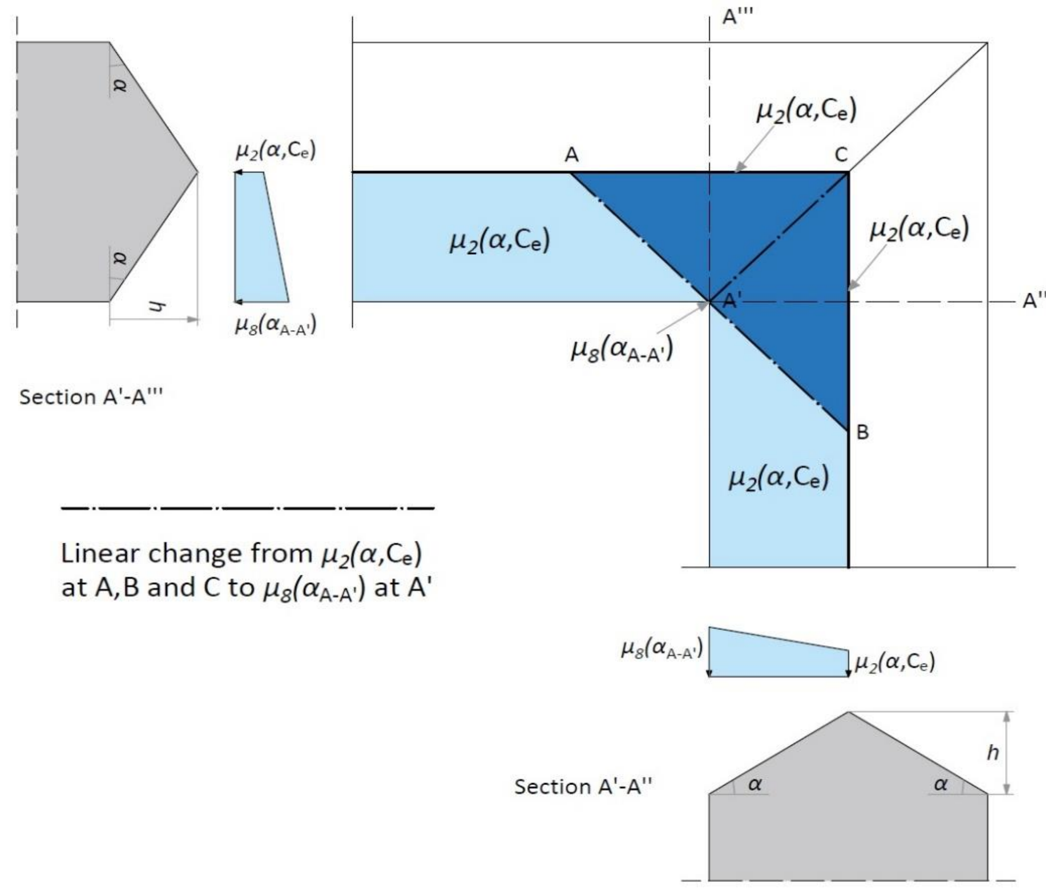
The section is an updated version of section 6.3 of the current standard (EN 1991-1-3:2003) with the following changes:

- Snow load shape coefficient and drift length of obstructions are made dependent on the exposure coefficient
- Introduction of an aspect ratio *w/h* < 2 between the width and the height of the obstruction
- Introduction of a new NDP for the limiting range of the load shape coefficient on NSB requests.
- A new clause (4) in section 7.5.2 “Flat roofs” delimits global effects from local effects of tilted panels.

Key changes to EN 1991-1-3

Some examples :

→ **Snow load shape coefficients for intersecting pitched roofs** **(new)**



Key changes to EN 1991-1-3

Some examples :

→ **Annex A (informative) on Ground snow load maps**

This Annex contains (mainly **new**) clauses on:

- Treatment of ground snow load measurements
- Zoning
- Climate change effect

It is essentially addressed to NSBs in view of providing a common background for the treatment of snow data and the elaboration of snow maps in a consistent way to help inconsistencies at borders to be reduced

New content included in scope of EN 1991-1-3

→ Already indicated in **red** in previous slides referring to key changes

How ease of use has been enhanced

Summary table of NDPs	
No. of essential NDPs retained	10
No. of other NDPs retained	1
No. of NDPs removed	19
No. of new NDPs (essential)	13
No. of new NDPs (others)	0

How ease of use has been enhanced

→ *Some examples :*

- The definition of terrain's orographic conditions, needed to select the appropriate exposure coefficient (Ce), is now linked to the "terrain category" as defined in prEN1991-1-4 on wind actions. Designers will therefore use the same classification of "terrain category" for both the evaluation of wind actions and snow loads

- The former Annex B on load cases for the "exceptional snow drifts" are included in the main text as persistent load cases. This allows for a significant simplification of the standard and of the design situations while, at the same time, the use of models appropriate for national climatic conditions is permitted

Overview of the Evolution of EN 1991-1-4: Eurocode 1 - Actions on structures –Part 1-4: General actions – Wind actions

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Agenda – Evolution of EN 1991-1-4: Wind actions

- → Key changes to EN 1991-1-4
- → New content included in the scope of EN 1991-1-4
- → How ease of use has been enhanced

Key changes to EN 1991-1-4

- Extension of the field of application of the standard for buildings between 200 m and 300 m high
- The two procedures defined in the current standard for determining the structural factor $c_s c_d$ have been unified, as well as the two approaches for determining the vortex excited cross wind amplitudes, in the informative Annexes F and H, respectively
- Treatment of the across-wind and torsional actions on susceptible buildings within the informative Annex G
- Inclusion of the effects of atmospheric icing in the informative Annex E
- Inclusion of wind actions on silos and tanks

New content included in scope of EN 1991-1-4

- New formulation for determining the mean velocity and turbulence intensity up to $z = 300\ m$
- Many values of aerodynamic coefficients have been added for types of structures not considered in the current standard, in order to cover most of the current designs. Considering their large amount, they have been transferred into 3 new normative Annexes C (for pressures on surfaces), D (for pressures across walls) and E (for forces on structures).
- Annex A (informative) gives a European wind map based on National Annexes to the current standard (to be replaced by a new version once the new National Annexes to the revised edition will be available)

New content included in scope of EN 1991-1-4

- A new Annex J (informative) on response of steel lattice towers and guyed masts has been added (transferred from EN 1993-3-1).
- Guidance is given in three new Annexes K, L and M, respectively:

  - on derivation of design parameters from wind tunnel tests and numerical simulations

  - on derivation of wind speeds from measurements at metrological stations, and

  - on probabilistic models for wind actions.

How ease of use has been enhanced

→ *Some examples :*

- Various guidance tables provided facilitating the navigation for the evaluation of wind actions and the related physical magnitudes (velocity, pressure, force etc.) and coefficients
- Tables of values of external pressure coefficients have been supplemented with curves illustrating their variation, in order to make interpolation easier for the users

Summary table of NDPs	
No. of essential NDPs retained	6
No. of other NDPs retained	35
No. of NDPs removed	29
No. of new NDPs (essential)	2
No. of new NDPs (others)	63

Overview of the Evolution of EN 1991-1-5: Eurocode 1 - Actions on structures –Part 1- 5: General actions – Thermal actions

2020-08-21

Issue 1
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Agenda – Evolution of EN 1991-1-5: Thermal actions

- Key changes to EN 1991-1-5
- New content included in the scope of EN 1991-1-5
- How ease of use has been enhanced

Key changes to EN 1991-1-5

- Removal of various inconsistencies detected so far
- Some definitions and rules of application clarified and improved
- Guidance provided on how to determine the temperature components and temperature differences of different structural members within a structure
- For buildings a new presentation of temperatures - merging of tables for inner and outer temperatures (see next slide)

Key changes to EN 1991-1-5

→ Indicative temperatures for structural members on buildings (NDP)

Area				$T_{N,max}$ (C°) (Summer)	$T_{N,min}$ (C°) (Winter)
Temperatures T_{in} of inner environment				$T_1 = 20$	$T_2 = 25$
Temperatures T_{out} for buildings above the ground level[a)]	North-East facing members	Bright light surfaces	$T_{max} + 0$		T_{min}
		Light coloured surfaces	$T_{max} + 2$		
		Dark surfaces	$T_{max} + 4$		
	South-West facing members	Bright light surfaces	$T_{max} + 18$		
		Light coloured surfaces	$T_{max} + 30$		
		Dark surfaces	$T_{max} + 42$		
Temperatures T_{out} for underground parts of buildings				6	– 4

[1)] For intermediate member orientation, the value may be determined by interpolating the angular direction.

Key changes to EN 1991-1-5

- For the three usual types of bridges (1-steel, 2-composite steel/concrete, 3-concrete) the maximum and minimum uniform bridge temperature component $T_{N,max}$ and $T_{N,min}$ are presented in the form of the following table (NDP) :

Bridge deck type	$T_{N,max}$	$T_{N,min}$
1	T_{max} + 16	T_{min} - 3
2	T_{max} + 4	T_{min} + 4
3	T_{max} + 2	T_{min} + 8

Key changes to EN 1991-1-5

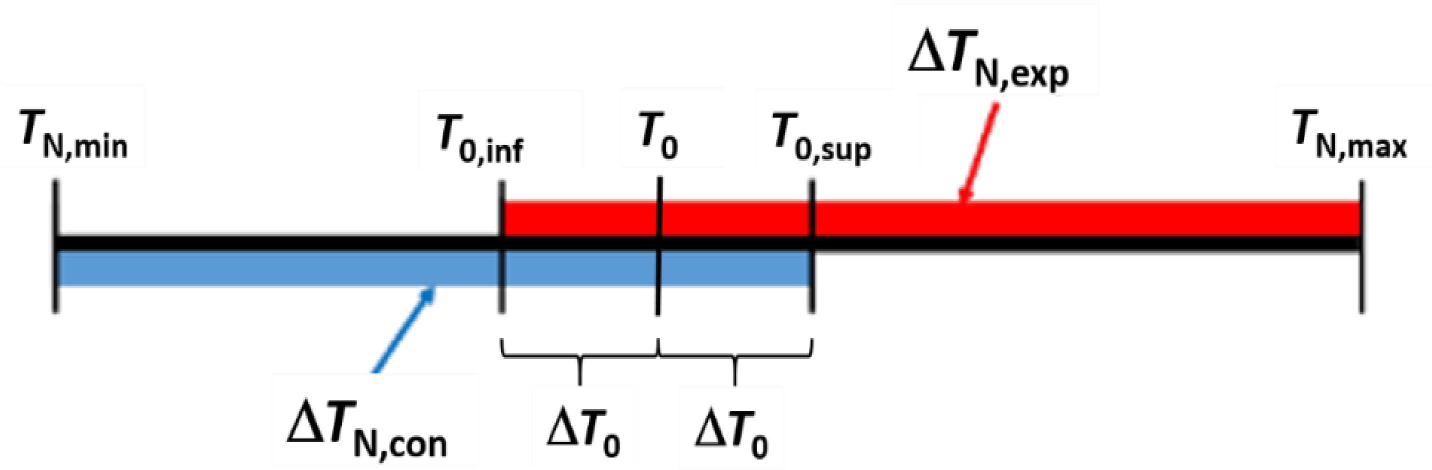
- For the evaluation of the vertical components of temperature differences with non-linear effects on bridge decks an improved presentation in the form of figures and tables has been provided, together with a couple of corrections of values

New content included in scope of EN 1991-1-5

- → Extension of the scope to include principles for the evaluation of thermal actions on structural members due to the paving of hot asphalt on bridge decks.
- → New approach for the consideration of uncertainties related to the initial bridge temperature T_0 of a structural member at the relevant stage of its restraint (completion) and its range ΔT_0 (see next slide); especially important for the design of bearings and joints
- → As a background document, some comparisons on shade air temperature differences across borders have been presented together with some references on recent literature concerning the establishment of thermal maps (or tabulated data) at European level

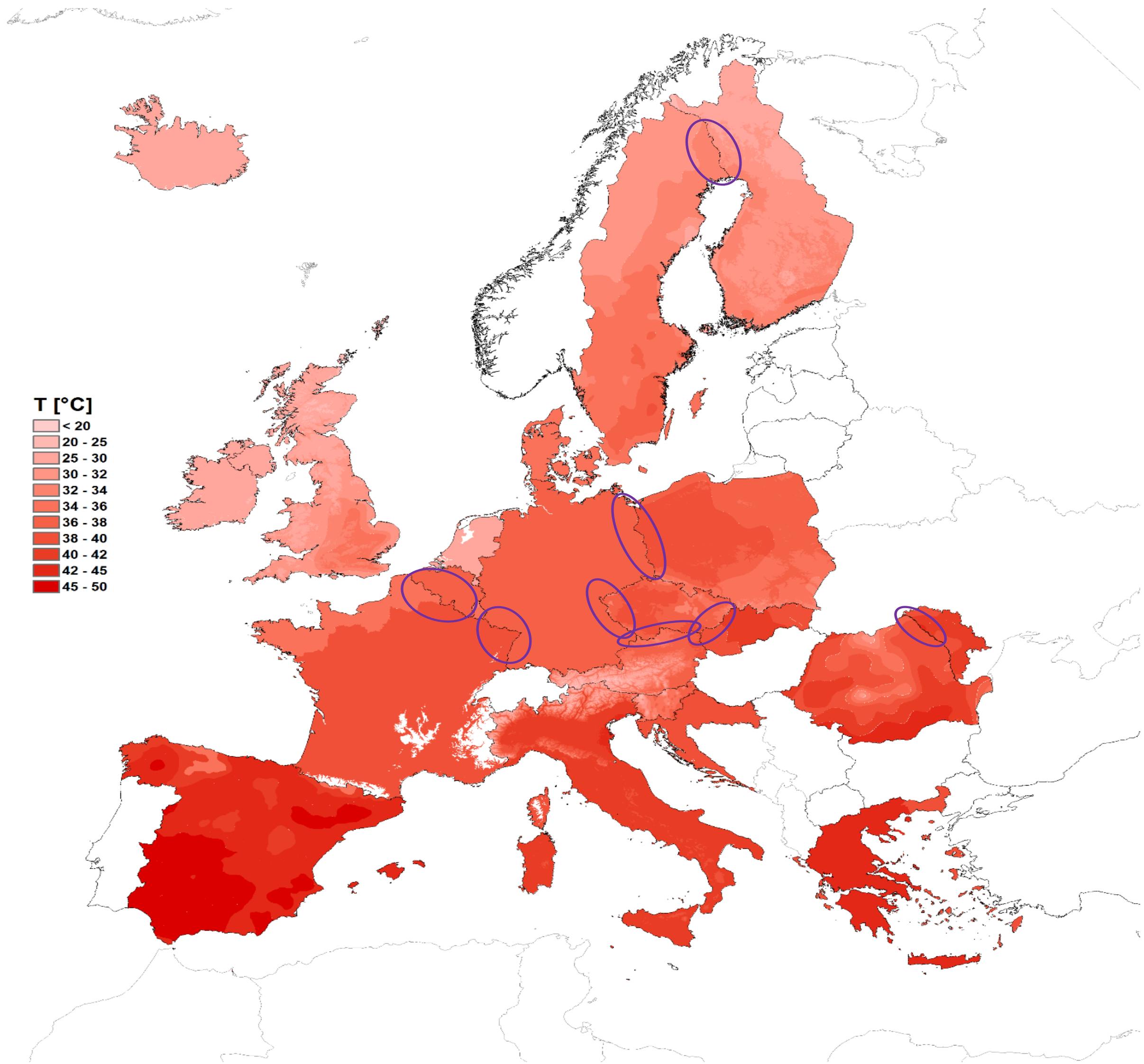
New content included in scope of EN 1991-1-5

→ Characteristic value of the maximum contraction ($\Delta T_{N,con}$) and expansion ($\Delta T_{N,exp}$) range of the uniform bridge temperature component



$$\Delta T_{\mathrm{N,con}} = T_{\mathrm{0,sup}} - T_{\mathrm{N.m}} \quad \text{and} \quad \Delta T_{\mathrm{N,exp}} = T_{\mathrm{N,max}} - T_{\mathrm{0.inf}}$$

New content included in scope of EN 1991-1-5



→ Eliminating inconsistencies across borders

How ease of use has been enhanced

→ Some examples :

- As already mentioned various editorial and document navigation improvements have been provided, mainly in the form of restructuring/updating tables and figures

- Clear and flexible formulation for the design of bearings and joins provided

- Former Annex C on coefficients of linear expansion removed as redundant

Summary table of NDPs	
No. of essential NDPs retained	13
No. of other NDPs retained	17
No. of NDPs removed	6
No. of new NDPs (essential)	4
No. of new NDPs (others)	2

Overview of the Evolution of EN 1991-1-8: Eurocode 1 - Actions on structures –Part 1-8: General actions - Actions from waves and currents on coastal structures

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Agenda – Evolution of EN 1991-1-8: Actions from waves and currents on coastal structures

- Key changes to EN 1991-1-8 (irrelevant)
- New content included in the scope of EN 1991-1-8
- How ease of use has been enhanced

Key changes to EN 1991-1-8 (as compared to ISO 21650:2007)

- There has not been so far an EN 1991-1-8, therefore this aspect could only make sense if comparison is made against ISO 21650:2007 upon which (as background) EN 1991-1-8 is based
- As compared with ISO 21650 the following key differences can be stated:

- EN 1991-1-8 is intended to be a standard referring to actions (only) while ISO 21650 covers actions and modelling (actions effects) and also touches in to the resistance aspects of the design.

- ISO 21650 is only briefly covering aspects of reliability, while partial factors and combinations of actions are missing. Achieving consistency with EN 1990 and the Eurocodes framework in general is hardly feasible in parallel with some design practices according to ISO 21650

Key changes to EN 1991-1-8 (as compared to ISO 21650:2007)

- A new serviceability limit state was introduced [**SLS-(LD)**] to cope with design state functions allowing for a **limited damage** in a major class of coastal structures
- The notion of structural resilience was introduced with a corresponding limit state and target values

New content included in scope of EN 1991-1-8

→ As stated previously EN 1991-1-8 is a new standard. Main topics:

- Basis of design (bridging wave and current actions in to the Eurocode design frame)
- Hydrodynamic conditions (environmental sea conditions)
- Wave and current actions on fixed cylindrical structures and suspended decks
- Wave and current actions on mound breakwaters
- Wave and current actions on vertical face breakwaters
- Wave and current actions on composite breakwaters
- Wave and current actions on coastal embankments
- Wave and current actions on floating structures
- Design assisted by physical model testing
- Reliability analysis of coastal structures

New content included in scope of EN 1991-1-8

- Annexes providing complementary information for the design of the various types of coastal structures subjected to wave and current actions including specific topics such as, for example, additional guidance related to physical modelling for coastal structures and reliability analysis of coastal structures

- A Normative Annex related to the basis of design of aspects (e.g. partial factors and combinations of actions) intended to become part of the Annexes of the revised EN 1990 as “A.6 – Application for coastal structures”

New content included in scope of EN 1991-1-8

→ As most significant items of the standard can be considered the following:

- A comprehensive definition of design **“Environmental sea conditions”** (stand alone) – *The basic actions, stage before influence and interaction with structures is accounted for (For some classes structures (i.e. breakwaters), this is defines «the action»)*

- The implementation of the **“Hydrodynamic Estimation Approach”” (HEA)**

- The implementation of **“Design Approaches” (DA)**

→ The purpose is that methods and requirement to the design can be outlined dependent on HEA-level, DA-Level, and Consequence Classes (CC).Target reliability levels are based on prEN1990:2020 (see next 3 slides)

New content included in scope of EN 1991-1-8

Table 4.6 - HEA level selection matrix

Consequence class	Hydrodynamic uncertainty [1]		
	LOW[2]	MEDIUM	HIGH[3]
CC0 Lowest[4]	1	1	1
CC1 Lower	1	1	2
CC2 Normal	1	2	2
CC3 Higher	2	2	3
CC4 Highest[4]	2	3	3

[1] Hydrodynamic uncertainty is defined by the level of understanding of environmental sea conditions at the site of interest and will depend on the relative complexity/ severity of physical processes (boundary condition generation and transformation to the site) and also the quality and quantity of available data (in the form of measurements, models, semi-empirical or empirical estimates).

[2] Examples of low hydrodynamic uncertainty may include tidal range < 1m, surge < 0,5m, fetch-limited seas (with fetch < 10 km), uniform currents with spring tide velocities < 1m/s, regular bathymetry or high quality time-series data of relevant sea condition parameters covering several decades at more than one location in the area of interest and high quality (recent) topo-bathymetric data.

[3] Examples of high hydrodynamic uncertainty may include tidal range > 3 m, surge > 1,0 m, ocean seas (swell and wind-waves), non-uniform currents (stratified) and/ or tide or surge current velocities > 1m/s, irregular bathymetry (e.g. reefs or sub-sea canyons) or limited quality and/ or duration of environmental sea condition parameters or low resolution or historic topo-bathymetric data.

[4] prEN 1990:2020 states that for consequence classes CC0 and CC4 ‘alternative provisions to those given in the Eurocodes may be used’.

New content included in scope of EN 1991-1-8

Table 4.7 – (NDP) HEA methodology guidance (typical minimum data/ approach)

HEA level	Boundary condition data	Pathway assessment	Other considerations
1	Locally or nationally determined parameter values from published sources (by others) possibly with limited probabilistic definition or reliability information attached.	Wind-wave[1] hindcast using empirical calculations taking into account fetch/ duration limitations. Extrapolation of sea-level or current values from published values for nearby sites.	Approach unlikely to be calibrated or validated.
2	Long-term[2] time-series data (or statistical distributions/ summaries thereof).	Numerical wave transformation[3] model representing (with reasonable accuracy) all key physical processes expected. Adjustment of (statistically estimated) sea-level or current values to account for site-specific physical processes either by empirical or numerical model.	Approach should be calibrated against measured, reported or published values.
3	Long-term[2] time-series data (or statistical distributions/ summaries thereof).	Coupled numerical wave/ sea-level/ current transformation[3] model representing (with reasonable accuracy) all key physical processes expected.	Approach should be calibrated against measured, reported or published values from relevant extreme events of sufficient magnitude and nature to be representative of physical processes expected during all design events.

1. This approach implies that the predominant wave energy system only is analysed, and can be expected to be wind-sea dominated.

2 'Long-term' is defined as proportionate to the design service life and probability of design events also considering the quality of data available (filtering/ removal of erroneous records). This should be measured data, or if not available, then calibrated and validated model data can be used, e.g. regional or global hindcast models. If insufficient duration of data is available, it may be extrapolated, e.g. by means of a Monte-Carlo analysis, subject to confirming the reliability of the extrapolated distributions.

3 This is based on the typical situation where boundary condition data is not available in close proximity to the structure location and must be transformed from a remote location.

New content included in scope of EN 1991-1-8

Table 4.8 – Minimum Design Approach (DA) level

HEA LEVEL	LOW-TO MEDIUM STRUCTURE DESIGN/RESPONSE UNCERTAINTY[1]	HIGH STRUCTURE DESIGN/RESPONSE UNCERTAINTY[1]
HEA-1	DA-0	DA-1 or DA-2[2]
HEA-2	DA-1 or DA-0[2]	DA-2 or DA-4[3]
HEA-3	DA-2 or DA-4[3]	DA-2 and DA-4[3]

[1] Where the term uncertainty is defined in NOTE 2 above.

[2] When no partial factor values are readily available.

[3] Where insufficient data is available to support a probabilistic approach, may refer to a part of the structure, e.g. breakwater roundhead or crown wall.

DA-0: Using a deterministic approach with return periods and appropriate sensitivity testing of key parameters, based on application of semi-empirical structure response formulae; global safety factors are applied.

DA-1: Using semi-probabilistic partial load and resistance factors.

DA-2: Using a fully probabilistic approach with allowable probabilities of failure or beta indexes

DA-3: Using a risk-informed method of socio-economic optimisation to determine the optimum probability of failure of the considered structure; this approach is not included here but is recommended by some National Standardisation Bodies.

DA-4: Using a design assisted by testing approach in combination with one or more of DA-0, DA-1, DA-2 (or DA-3).

New content included in scope of EN 1991-1-8

- Design approaches other than the default one (based on partial factors) were also addressed, namely one more conventional path and one based on fully probabilistic methods, both founded on the assessment/evaluation of the return periods of extreme events, which are widely used within the community of marine and coastal engineering. All design approaches are compatible with EN 1990 as regards target levels
- Structures that have only the purpose of flood risk management were not incorporated, notably dykes, as requested by NSBs, considered as a matter of relevant authority's competence at national level.

How ease of use has been enhanced

- Follow-up of CEN/CENELEC IR and adaptation of the document to the Eurocode framework. Although based on ISO 21650:2007
- Guidance provided throughout the document as appropriate (essentially in the Annexes) allowing for some flexibility
- Appropriate use of tables, diagrams/figures, flow charts etc. As an example, a decision scheme for calculating in-line forces on a vertical cylinder in waves (see an example in the next slide)

How ease of use has been enhanced

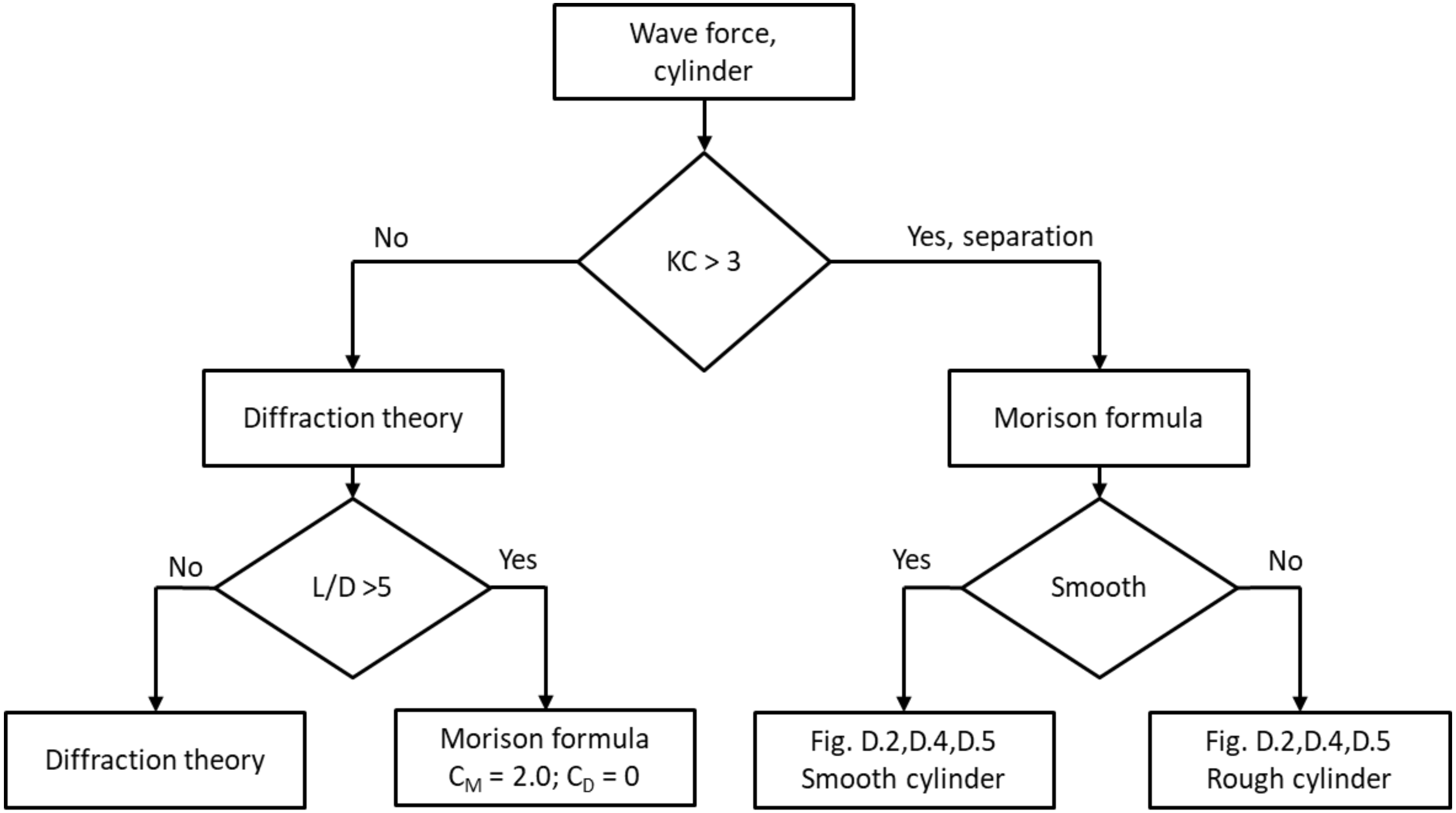


Figure D.1 - Decision scheme – how to calculate in-line forces on a vertical cylinder in waves

Overview of the Evolution of EN 1991-1-9: Eurocode 1 - Actions on structures –Part 1-9: General actions - Atmosphering icing

2020-08-21

Issue 1
Date: 21/09/2020

Agenda – Evolution of EN 1991-1-9: Atmospheric icing

- → Key changes to EN 1991-1-9 (irrelevant)
- → New content included in the scope of EN 1991-1-9
- → How ease of use has been enhanced

Key changes to EN 1991-1-9

- There has not been so far an EN 1991-1-9, therefore this aspect could only make sense if comparison is made against ISO 21494:2001 upon which (as background) EN 1991-1-9 is based

- As compared with ISO 21494 the following key differences can be stated:

  - EN 1991-1-9 more compact than ISO 12494 and consistent with EN 1990 and the Eurocode style

  - Most information on how to measure and model atmospheric icing removed and left for the National Annexes

  - Combination with wind actions considered

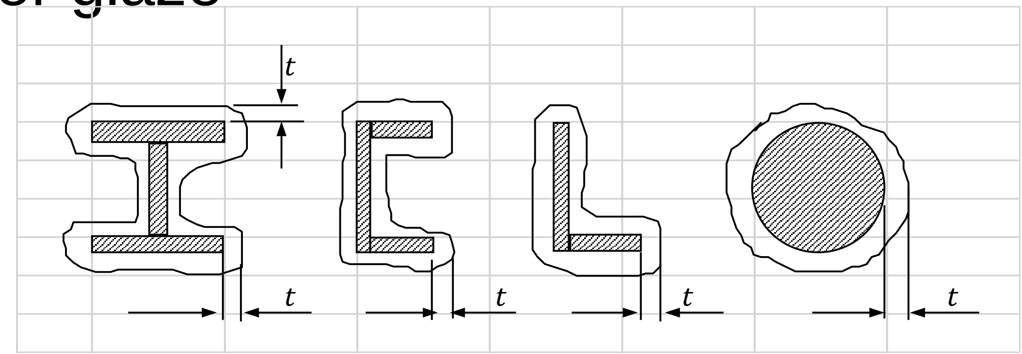
  - New height factor introduced for glaze ice.

New content included in scope of EN 1991-1-9

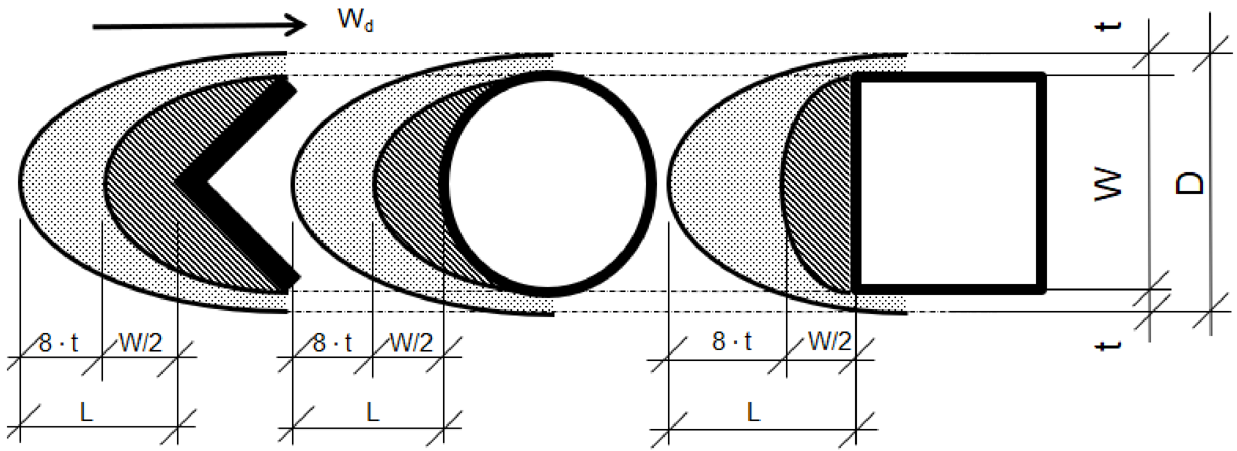
- As stated previously EN 1991-1-9 is a new standard. Main topics:
- Ice load is determined and classified according to ice classes (IC) for both glaze (ICG) and rime (ICR), because the characteristics for these differ. ICG should be determined for glaze deposits and ICR for rime deposits (see following slides)
- For the definition of ICs the characteristic value for 50 years return period of the ice accretion on the **reference collector** is used
- Allowance for relevant NDPs provided

New content included in scope of EN 1991-1-9

- → Ice accretion model for glaze



- → Ice accretion model for Rime for members up to 0,3 m maximum dimension



New content included in scope of EN 1991-1-9

→ Ice thicknesses for ICGs

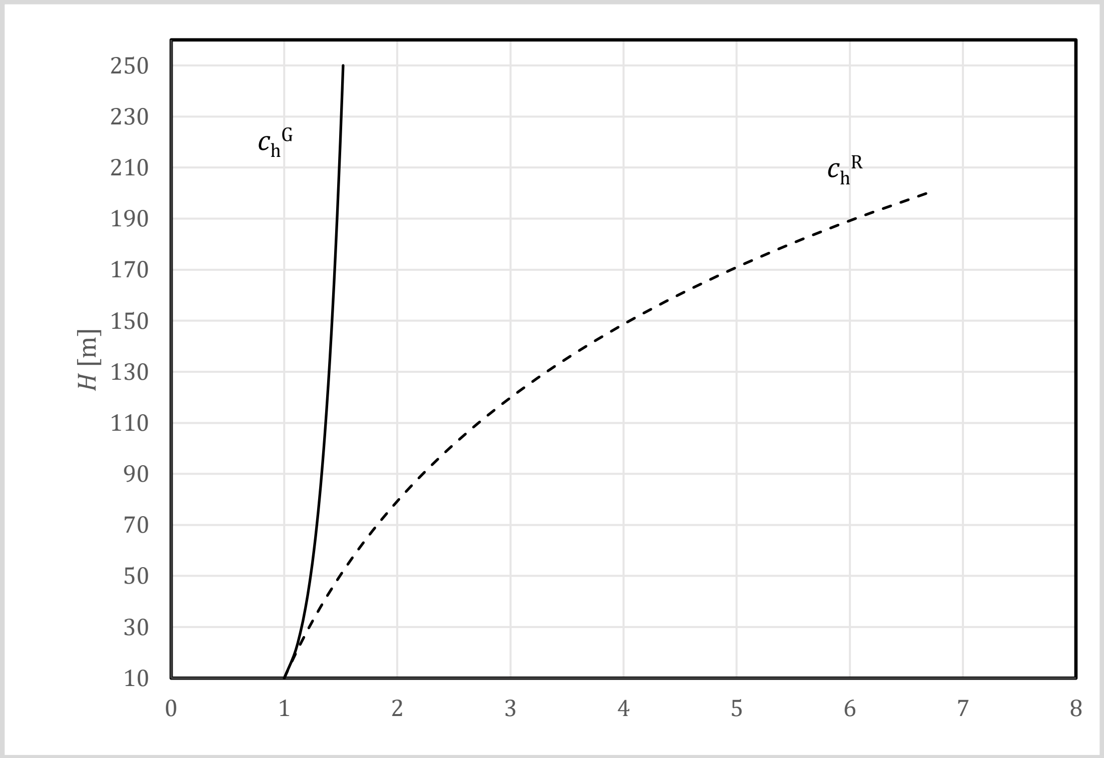
Ice classes ICG	G1	G2	G3	G4	G5	G6
Characteristic ice thickness *t* (mm)	10	20	30	40	50	*
* To be used for extreme ice accretions NOTE The numbers represent the upper bound for the corresponding ICGs.						

→ Ice masses for ICRs

Ice classes for rime	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
Characteristic Ice mass *m* (kg/m)	0,5	0,9	1,6	2,8	5,0	8,9	16,0	28,0	50,0	*
* To be used for extreme ice accretions NOTE The numbers represent the upper bound for the corresponding ICRs										

New content included in scope of EN 1991-1-9

→ Height factors for rime and glaze



New content included in scope of EN 1991-1-9

→ Wind on iced structures :

- Drag coefficients for rime and glaze
- Combination factors $\psi_{0,ice} = 0,5$, $\psi_{1,Ice} = 0,2$
- In addition, the wind action is reduced by the factor k

ICG	k	ICR	k
G 1	0,40	R 1	0,40
G 2	0,45	R 2	0,45
G 3	0,50	R 3	0,50
G 4	0,55	R 4	0,55
G 5	0,60	R 5	0,60
		R 6	0,70
		R 7	0,80
		R 8	0,90
		R 9	1,00
		R 10	1,00

How ease of use has been enhanced

- Follow-up of CEN/CENELEC IR and editorial improvements based on relevant clauses of ISO 21494:2001
- A concise flow chart provided as guidance on how to use the standard (informative Annex D)
- Reference on how ice acts on structures, as well as the types of icing and their data collection (informative Annexes B and C, respectively)

Overview of the Evolution of EN 1991-2: Eurocode 1 - Actions on structures – Part 2 Traffic loads on bridges and other civil engineering works

2020-08-21

Issue 1
Date: 21/09/2020

Agenda – Evolution of EN 1991-2: Traffic loads of bridges and other civil engineering works

- Key changes to EN 1991-2
- New content included in the scope of EN 1991-2
- How ease of use has been enhanced

Key changes to EN 1991-2

- **Extension of the scope and field of application (and associated change of title)** to include other civil engineering works (e.g. geotechnical works, but not buildings), see next 3 slides
- Some changes for geotechnical items especially new wording (more accurate/clear technical terms and definitions), mainly related to railway traffic loading
- Addressing the request of ERA (European Railway Agency) for the revision of some clauses in order to achieve consistency with TSI INF and relevant standards (e.g. EN 15528)

Key changes to EN 1991-2 - Some details :

→ Scope

(3) The load models and values given in EN 1991-2 are also applicable for the design of retaining walls adjacent to roads and railway lines and the design of earthworks subject to road or rail traffic actions. EN 1991-2 provides also applicability conditions for specific load models.

→ Terms

3.1.1.12

civil engineering works

they are comprising a structure, such as a bridge, road, railway, runway, utilities, or sewerage system, or the result of operations such as earthwork, geotechnical processes, but excluding a building and its associated site works

Key changes to EN 1991-2 - Some details :

→ Load model for geotechnical structures (road traffic)

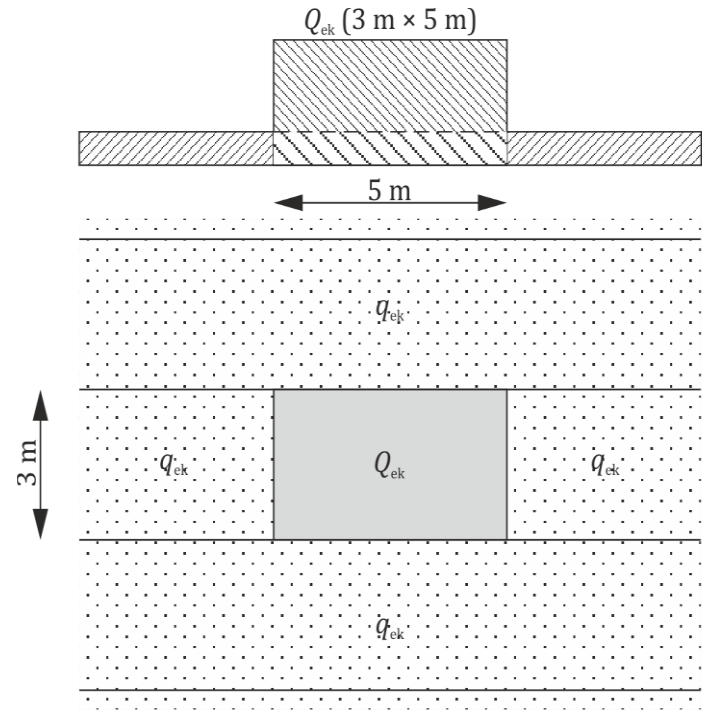


Figure 6.11 – Road traffic load model for geotechnical structures

Key changes to EN 1991-2 - Some details :

→ Static load models for geotechnical structures (railway traffic)

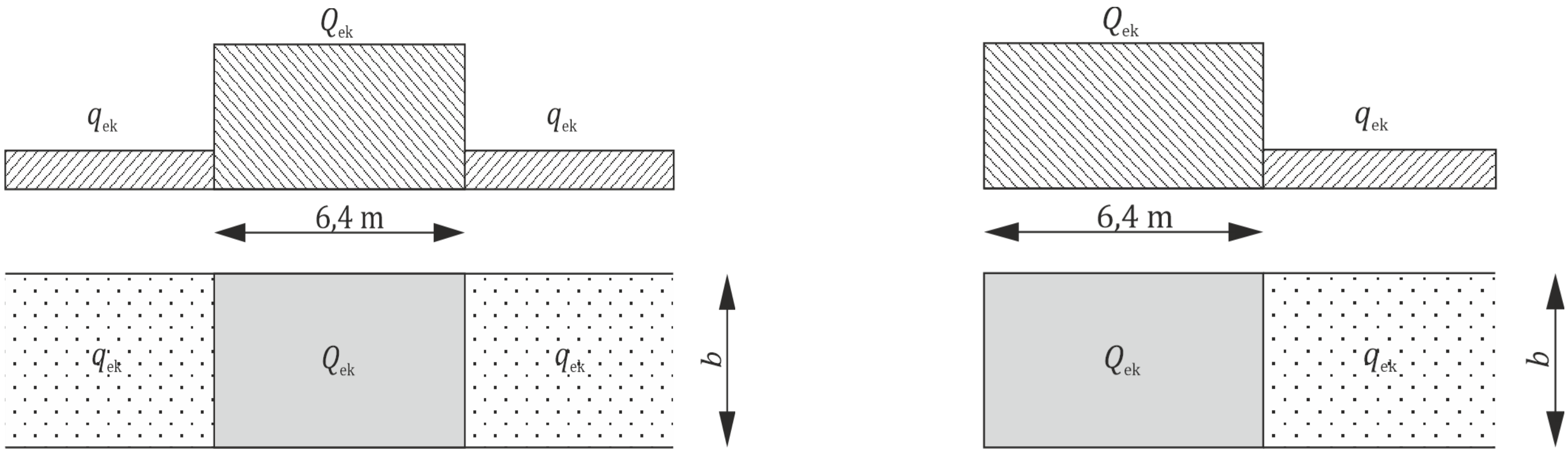


Figure 8.28 – Equivalent load arrangement for Load Model 71 for geotechnical structures

(a, left) Single concentrated patch load and uniformly distributed load on both sides

(b, right) Single concentrated patch load and uniformly distributed load on one side only

Key changes to EN 1991-2

- → Including some new methods and materials (e.g. for footbridges and timber structures)
- → Deleting old Annexes F and G
- → Providing additional special requirements and basic methods for pedestrian bridges including dynamic actions and pedestrian induced vibrations based on state-of-the-art literature (guidelines and/or largely/commonly accepted methods and results)
- → Changing Annex E (deletion of aggressiveness)
- → Adjustments in view of consistency with prEN 1990-Annex A.2 and other Eurocodes bridge parts (following HG-B proposals)

New content included in scope of EN 1991-2

- Creating an updated clause 7 and new Annex G for footbridges especially their dynamic behaviour, related to EN 1990 Annex H
- Including the new TR 17231 for Track-Bridge interaction
- Including the bases of design for noise barriers at railway lines (transfer from EN 16727-2-2)
- New subclause 8.10 (Static load models for geotechnical structures – characteristic values)

New content included in scope of EN 1991-2

→ New clause 7

7 Actions on footways, cycle ways and footbridges

7.1 Field of application

7.2 Representation of actions

7.2.1 Models of the loads

7.2.2 Application of the load models

7.3 Static models for vertical loads - characteristic values

7.3.1 General

7.3.2 Uniformly distributed load

7.3.3 Concentrated load

7.3.4 Service vehicle

New content included in scope of EN 1991-2

→ New clause 7 (cont'd)

7.4 Static model for horizontal forces – characteristic values (footbridges only)

7.5 Groups of traffic loads (footbridges only)

7.6 Collision and other actions for accidental design situations (footbridges only)

7.6.1 General

7.6.2 Collision forces from traffic under the footbridge

7.6.3 Accidental presence of vehicles on the footbridge

7.7 Dynamic models of pedestrian loads (footbridges only)

7.8 Actions on parapets

7.9 Load model for abutments and walls adjacent to bridges

New content included in scope of EN 1991-2

- **CEN/TR 17231:2018 Eurocode 1: Actions on Structures. Traffic Loads on Bridges. Track-Bridge Interaction**
- Essential content of this TR included in EN 1991-2 as clause **8.5.4 Combined response of structure and track to variable actions**
- Extended definition of expansion length (see next slide)
- Deletion of Annex G

New content included in scope of EN 1991-2

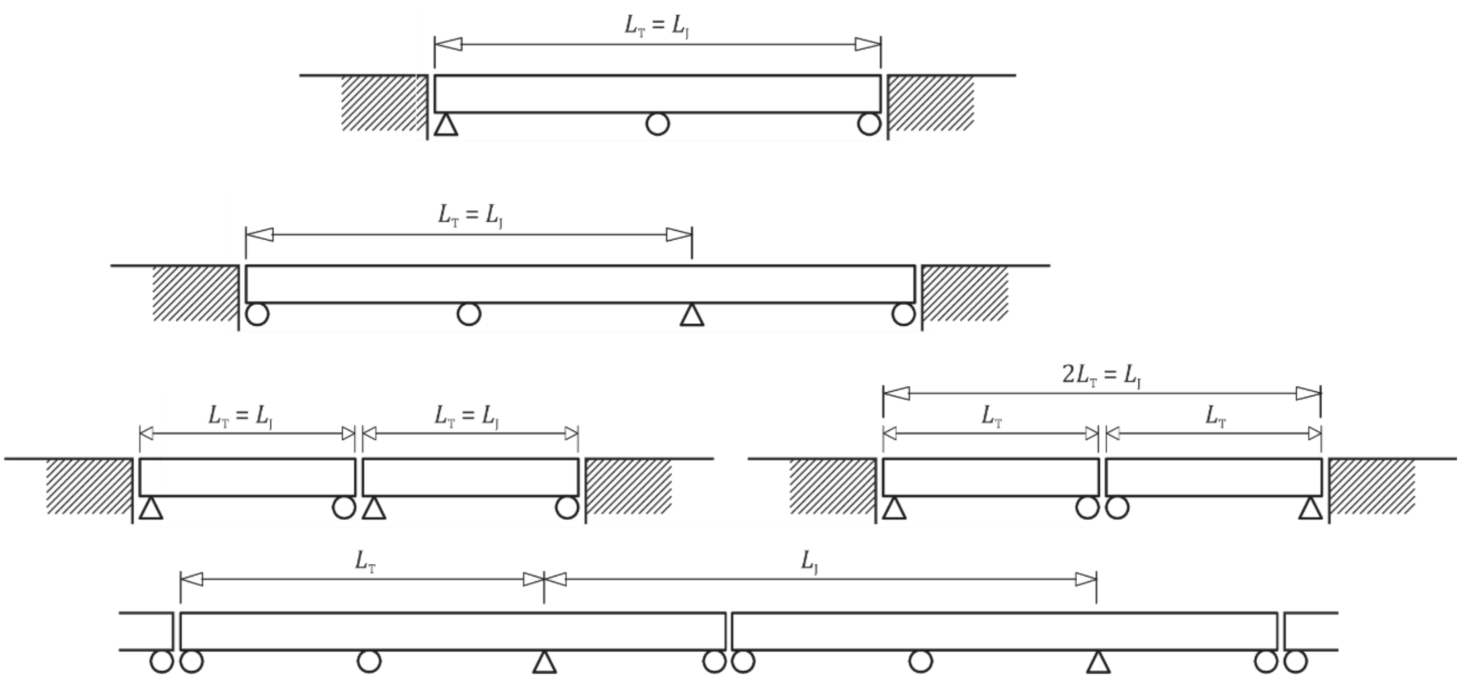


Figure 8.16 - Examples of expansion length L_T and L_J

New content included in scope of EN 1991-2

- Noise barriers
- **8.6.2 Simple vertical surfaces parallel to the track (*e.g.* noise barriers)** - Length factor (φ_L), height factor (φ_H) and dynamic factor (φ_{dyn})

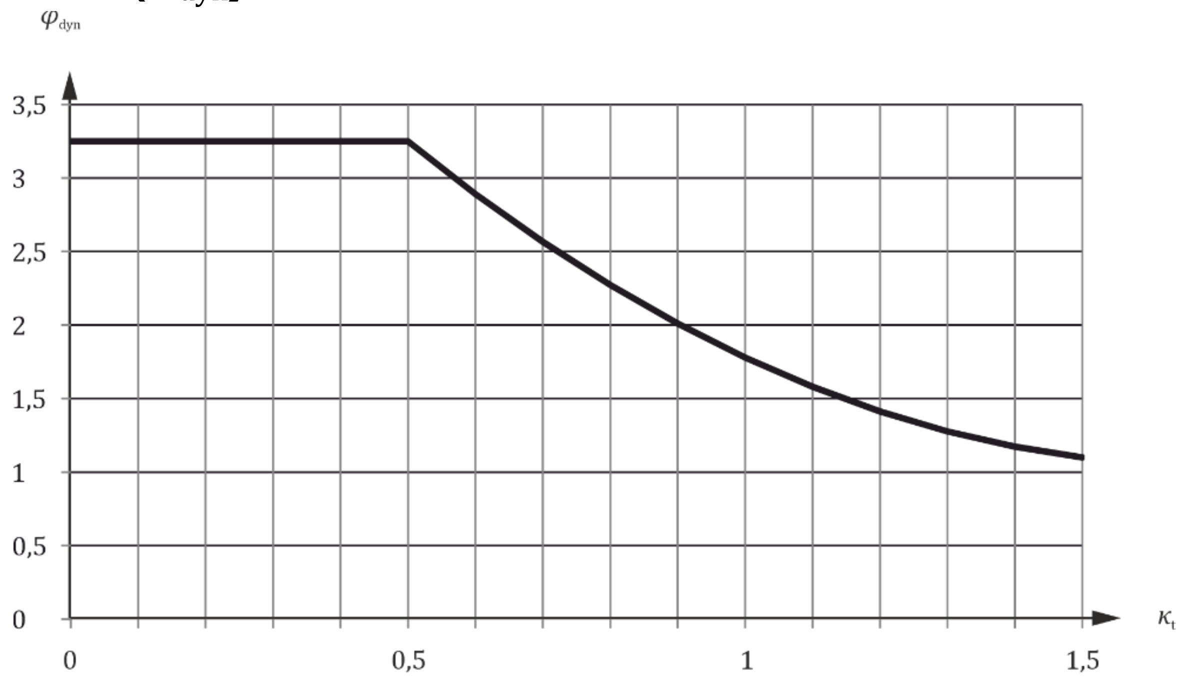


Figure 8.22 – Dynamic factor φ_{dyn}

8.10 Static load models for geotechnical structures – characteristic values (new subclause)

(1) For geotechnical structures, the load arrangement and characteristic values of vertical loads for Load Model 71 applied at a level 0,70 m below the running surface of the track may be taken as the more onerous arrangement (a) or (b) as shown in Figure 8.28.

NOTE 1 The more onerous load arrangement depends on the applicable ground conditions. Further guidance is provided in EN 1997.

NOTE 2 The width *b* in Figure 8.28 is 3 m unless the National Annex gives a different value for use in a country.

NOTE 3 Unless the National Annex gives a different value and application rules, the characteristic value of the concentrated load Q_{ek} is 1000 kN spread over rectangular surface area of 6,4 m × *b*.

NOTE 4 Unless the National Annex gives a different value and application rules for use in a country, the characteristic value of uniformly distributed load q_{ek} is 80 kN/m spread over a width of *b* applied on the remaining area of the carriageway.

New content included in scope of EN 1991-2

→ Subclause 8.10 (cont.)

(2) For geotechnical structures, the load arrangement and characteristic values of vertical loads for Load Model SW/2 applied at a level 0,70 m below the running surface of the track may be taken as shown in Figure 8.28 for the uniformly distributed loads set out in Figure 8.2. This load is distributed over a width *b*, as defined in NOTE 2 of (1).

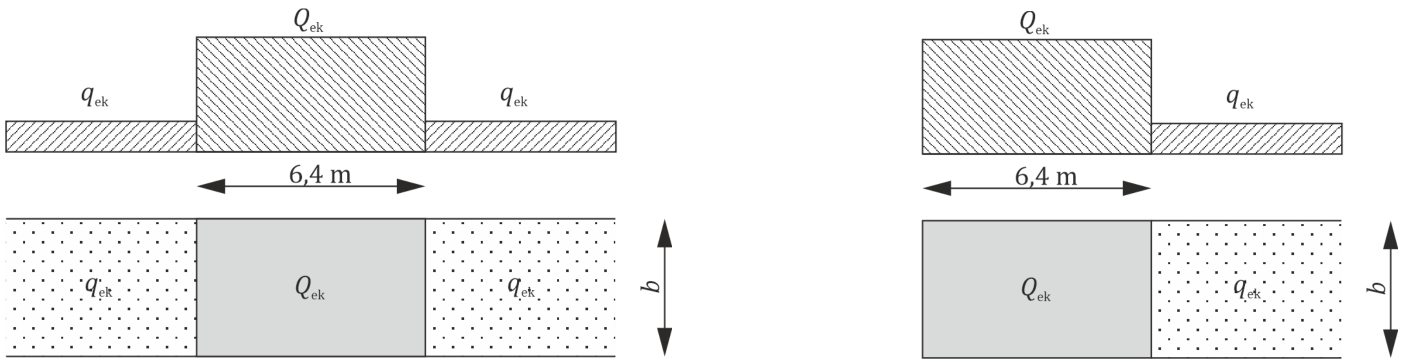


Figure 8.28 – Equivalent load arrangement for Load Model 71 for geotechnical structures
(a, left) Single concentrated patch load and uniformly distributed load on both sides
(b, right) Single concentrated patch load and uniformly distributed load on one side only

New content included in scope of EN 1991-2

→ Subclause 8.10 (cont.)

(3) The concentrated patch loads should be placed so that they give the most unfavourable effect on the structure.

(4) The characteristic values of loads given in Figure 8.28 shall be multiplied by the factor α specified in 8.3.2 to obtain the "classified vertical loads".

(5) No dynamic factor or enhancement should be applied to the above uniformly distributed load.

(6) For the design of local elements close to a track (e.g. ballast retention walls), a special calculation should be carried out taking into account the maximum local vertical, longitudinal and transverse loading on the element due to rail traffic actions.

(7) Where multiple tracks are loaded simultaneously, the load shall be applied in accordance with 8.3.2(10) or 8.3.3(8).

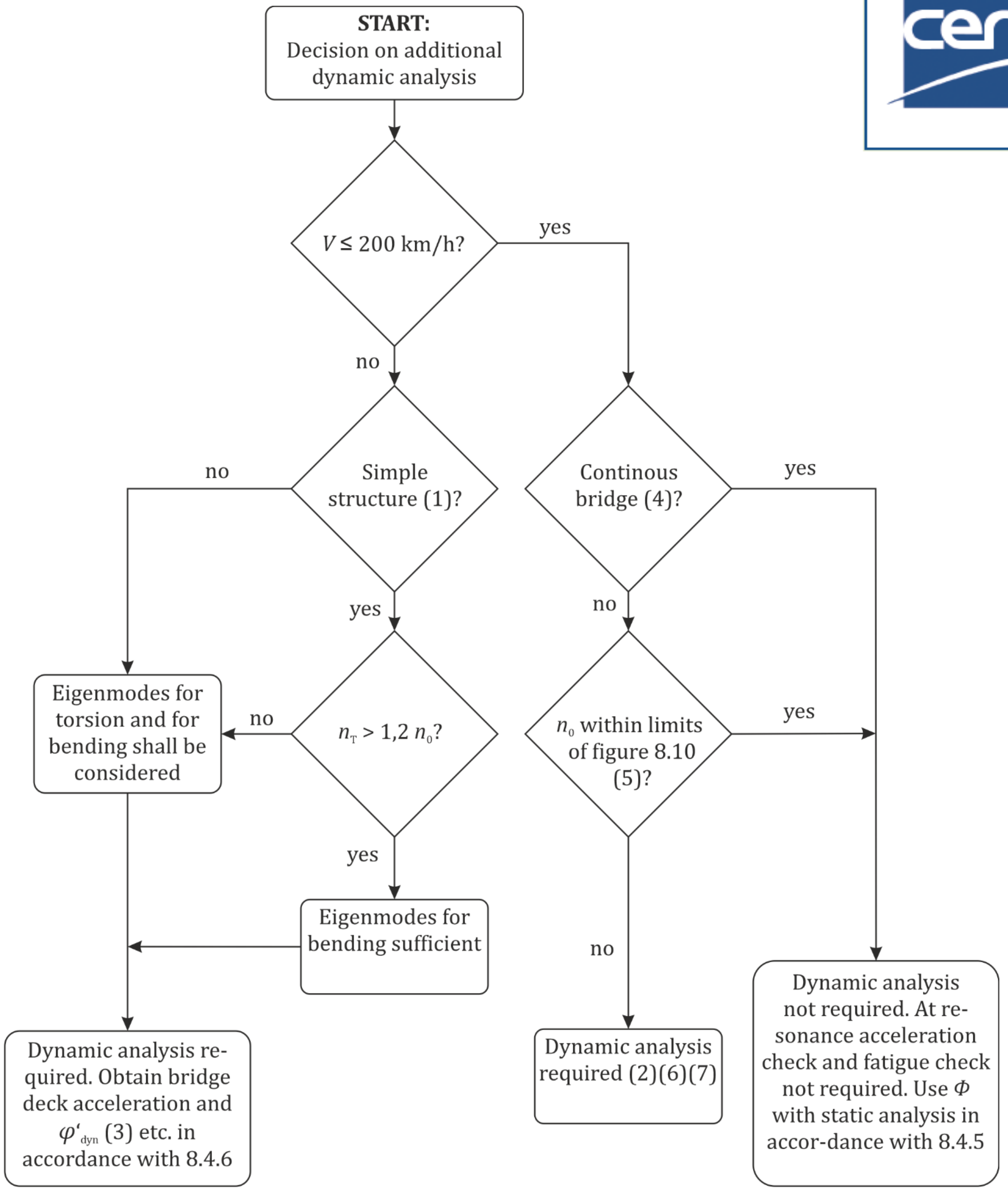
How ease of use has been enhanced

- Several proposals for an enhanced ease of use have been made.
- Certain overlapping design rules concerning accidental loads have been removed and referenced to EN 1991-1-7 only.
- Definition of requirements for dynamic analysis of railway bridges has been proposed including simplification and elimination of unused procedures (cl. 6.4 old) or complex unnecessary information (Annex E).
- Some items (e.g. references to load groups and serviceability limit state rules for railway bridges) have been cross-checked during the drafting of EN 1990 Annex A2.
- Annex F (old) is deleted.

How ease of use has been enhanced

Some examples

Figure 8.9 - Flow chart for determining whether a dynamic analysis is required (update of the old Fig. 6.9 and NDP)



Overview of the Evolution of EN 1991-4: Eurocode 1 - Actions on structures – Part 4: Silos and tanks

2020-08-21

Issue 1
Date: 21/09/2020

Agenda – Evolution of EN 1991-4: Silos and tanks

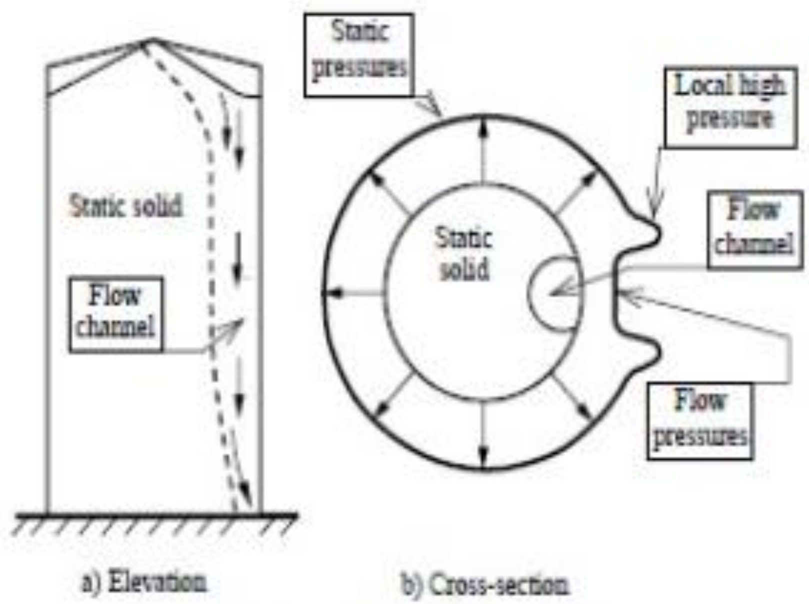
- Key changes to EN 1991-4
- New content included in the scope of EN 1991-4
- How ease of use has been enhanced

Key changes to EN 1991-4

- A clear differentiation between silos with very different requirements is provided by classifying according to action assessment, construction complexity, consequences of failure and stored bulk solid behaviour
- A user-friendly structure with simple routes throughout the document and easy access to loads in silos designed for symmetrical conditions
- A more rational basis for prescribing characteristic loads
- The revised standard is based in more physics and less empirical work
- Important steps towards harmonization with EN1990 Annex A4

Key changes to EN 1991-4

→ Discharge pressures on vertical walls subject to highly eccentric flow channels: The rules have basically been maintained, re-evaluated and calibrated and have now become applicable also for silos with steep hoppers (Clause 7)

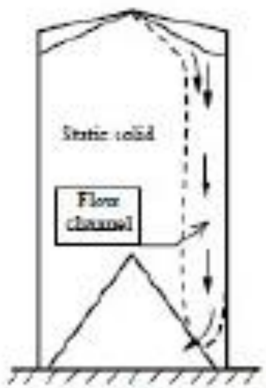


a) flow channel and pressure pattern

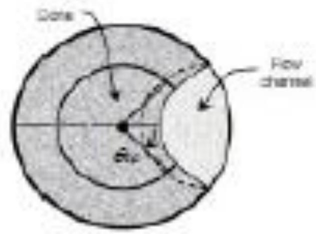
New content included in scope of EN 1991-4

- → Rules for stored solid – silo structure interaction have been introduced, based on the best data available for the material parameters, e.g. tangent modulus of a particulate solid
- → Pressures on the vertical walls of silos that have an internal inverted cone (see next slide): These new rules formulated match current practice, as they apply specifically to large concrete silos used for cement and cement raw meal
- → A new section has been introduced for rectangular silos with flexible walls

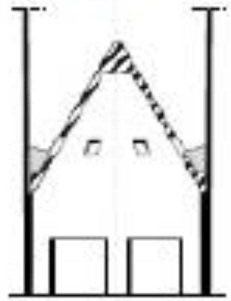
New content included in scope of EN 1991-4



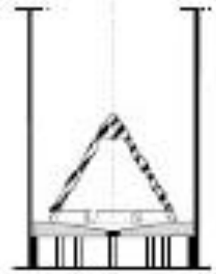
a) Flow channel outline



b) Plan view of cone



c) Cone supported on the walls
(spans the full silo diameter)



d) Cone supported on columns
(supported on the silo bottom plate)

New content included in scope of EN 1991-4

- A new section on pressures in unsymmetrical (oblique) conical hoppers has been introduced. It includes a rule for large eccentricity loads

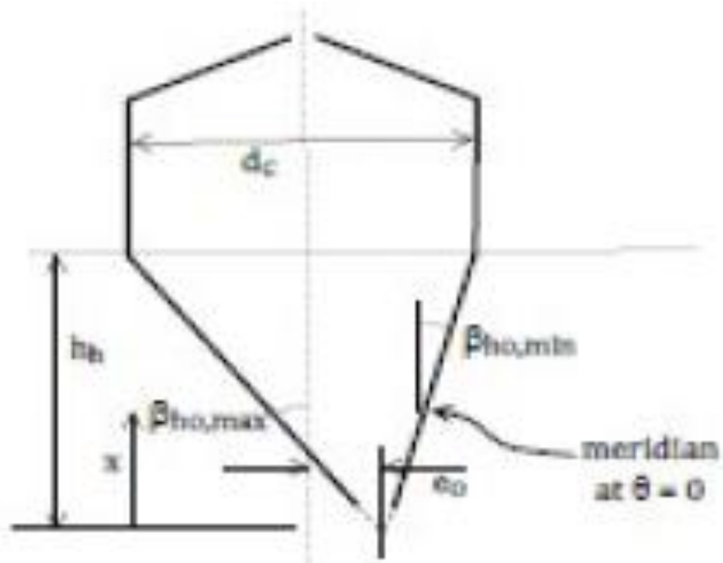


Figure 10.2 — Oblique hopper with pressure pattern

New content included in scope of EN 1991-4

- → Overpressure factors for silos under mixed flow: A new rule for mixed flow, with a theoretical basis, has been implemented and calibrated

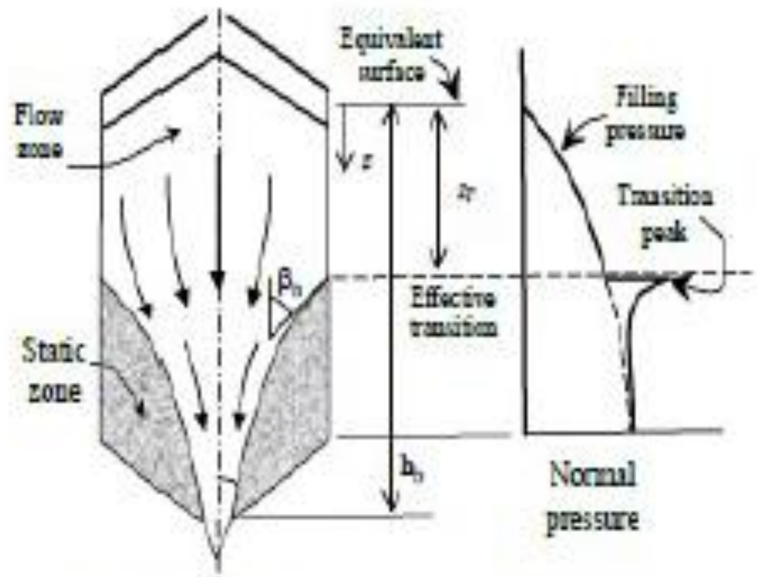


Figure 5.6 — Symmetrical discharge pressures design under mixed flow

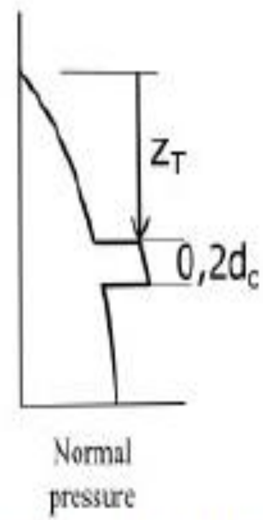


Figure 7.3 — The position of the band load under mixed flow discharge

How ease of use has been enhanced

Summary table of NDPs	
No. of essential NDPs retained	2
No. of other NDPs retained	0
No. of NDPs removed	5
No. of new NDPs (essential)	5
No. of new NDPs (others)	0

How ease of use has been enhanced

Some examples:

- The standard now has a structure which dissociates simple silo cases - the majority of silos with central outlet and inlet – which can be treated by “Fundamental Silo Load Cases” described in only 17 pages (Clauses 7 and 9, for vertical walls and hoppers, respectively)
- Furthermore, it is clearly described under which circumstances one or more of the “Special Silo Load Cases” need to be considered (Clauses 8 and 10, for vertical walls and hoppers, respectively, in 34 pages)
- An informative Annex provides Flow Charts to further assist the designer in navigating through the standard and applying it
- A significant number of new figures have been added to give greater clarity to the rules