EUROCODES

EN 1991

Actions on structures


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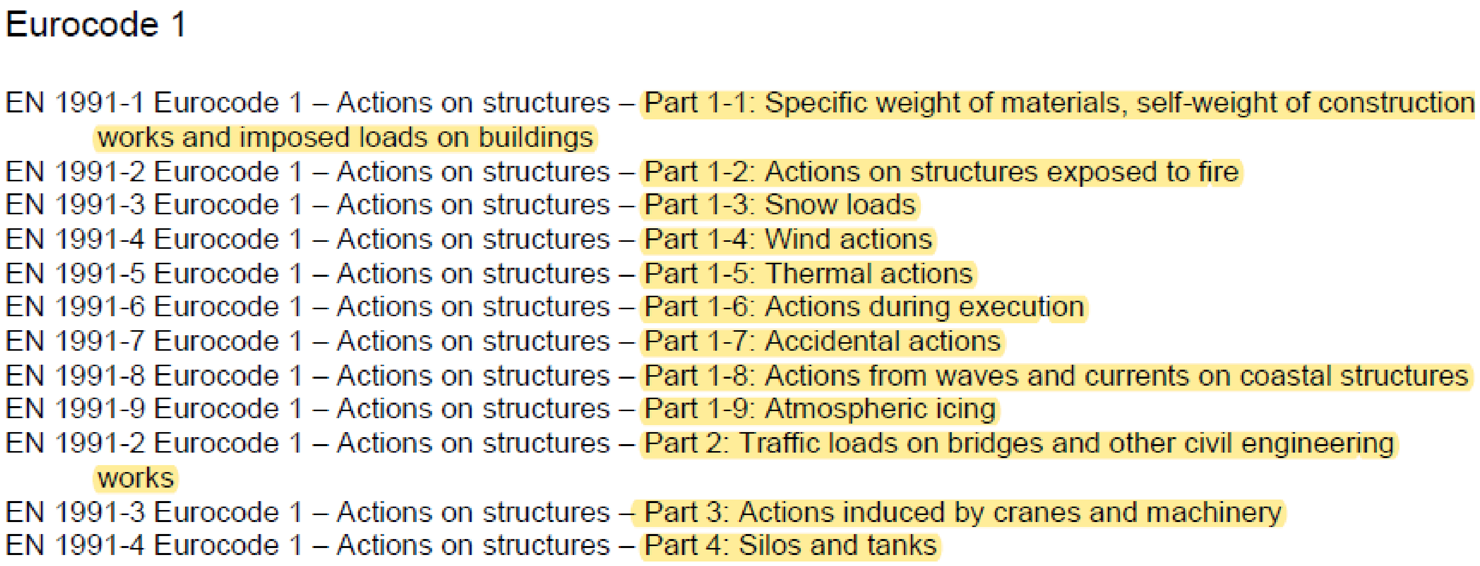
2. Specific overview of the evolution of EN 1991 parts:



Eurocode 1

EN 1991-1 Eurocode 1 – Actions on structures – Part 1-1: Specific weight of materials, self-weight of construction works and imposed loads on buildings
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Key changes to EN 1991

- Update of **titles**
- **Common structure** of the core content of practically all EN 1991 parts (design situations; classification of actions; representation of actions)
- Incorporation in EN 1991 of 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”
- Consistency with the relevant Annexes of EN 1990 enhanced

Key changes to EN 1991-1-1

- Clarification/update of some definitions (e.g. “tributary area”)
- Provision of a single table of imposed loads on buildings for all categories of use
- Idem for horizontal loads on partition walls and parapets
- Updates on partitions treated as imposed loads
- Updates on reduction factors:
  - Modified formula for the reduction factor $\alpha_A = 0.5 + \frac{10}{A} \leq 1,0$
  - Modified formula for the reduction factor $\alpha_n = \min\left\{0.7 + \frac{0.6}{n}\ ; 1\right\}$
- Former Annex B (Vehicle barriers and parapets for car parks) removed

New content included in the scope of EN 1991-1-1 and enhancement of the Ease of Use

- Additional sub-category G2 of garages for vehicles with gross weight > 160 kN
- Additional class of helicopter HC3 for 60 kN < Q < 120 kN for category K roof
- Three subcategories S1, S2, S3 for stairs and landings and
- Inclusion of previously separated tables for various imposed loads on buildings in a single table integrating all categories and subcategories (but foreseen as NDP)
- A single table provided for horizontal loads on partition walls and parapets
- Clarification of tributary areas
- Updates and clarification for the use of reduction factors
- Removal of the former Annex B

Key changes to EN 1991-1-2

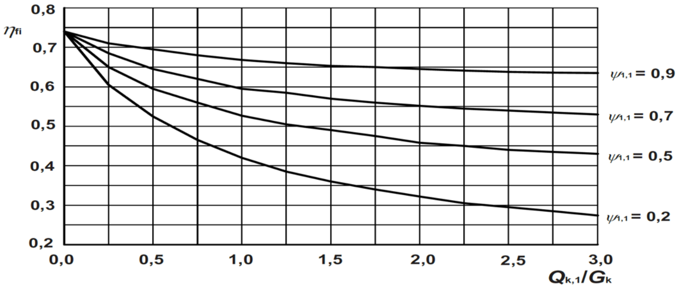
- Clarification/update of some definitions
- Scope clarified, in particular the non-coverage of:

  - 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 as simplified rules for the determination of the reduction factor η_{fi}

$$E_{fi,d,t} = E_{fi,d} = \eta_{fi} \cdot E_d \qquad (6.1)$$

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

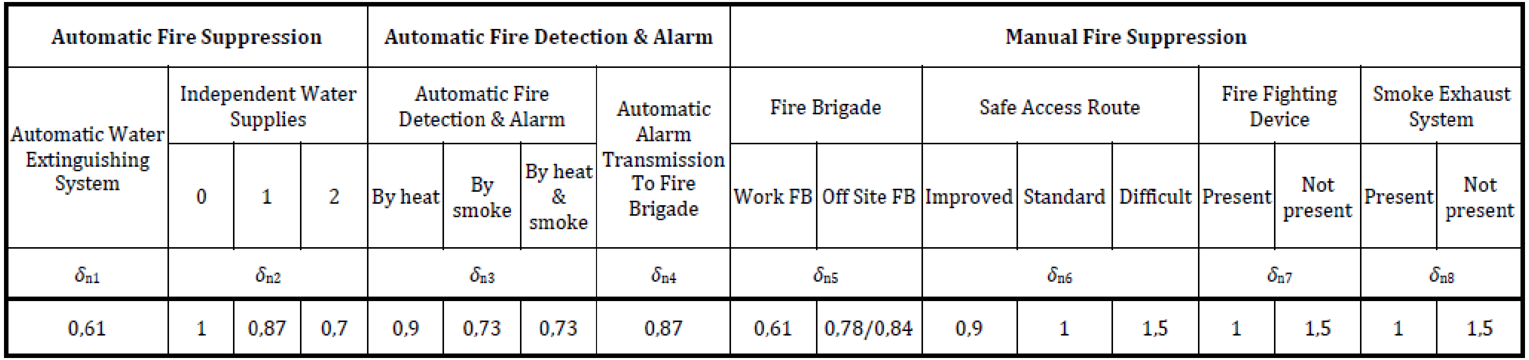


Key changes to EN 1991-1-2

- The **Annex E** on “**Fire load densities, Fire Growth Rates and Rate of Heat Releases**” has been revisited and led to the introduction of an updated and detailed factor taking into account the different active fire fighting measures (sprinkler, detection, automatic alarm transmission, firemen …) in the formula (E.1) for the evaluation of the design value of the fire load $q_{f,d}$:

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

Table E.2 — Factors δ_{ni}



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 Device		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

Key changes to EN 1991-1-2 (new content)

- The scope of **Annex C** on the thermal action of a **localised fire** represented by a virtual solid flame as exposed in this annex has been clarified and substantially extended.

- In **Annex G** a model has been introduced 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)

- A new **Annex H** (informative) on “**Thermal actions for structural fire loads of timber structures**” has been added, to be combined with the Annex A (informative) of EN 1995-1-2 on the “Design of timber structures exposed to physically based design fires”

- All Annexes remain informative

Key changes to EN 1991-1-3 and new content

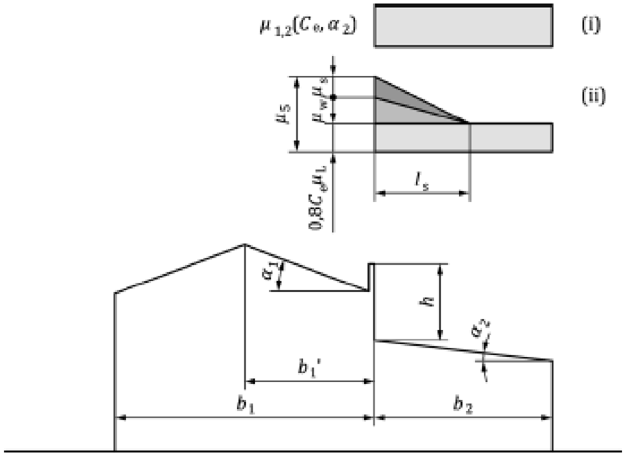
- Implementation of new models closer to the physics and based on state-of-the-art experimental data available for European climates, e.g. an updated model for the snow load on the roofs
- Consideration of snow load for additional types of roofs
- Implementation of updated and specific models for snow local effects
- As an example, the terms **“balanced”** and **“unbalanced”** are used in place of “undrifted” and “drifted”. (This terminology is also consistent with ISO 4355:2013 and with ASCE/SEI 7-16)
- The exposure coefficient **Ce** has been updated accordingly, in order to account for the increase of snow load in locally sheltered areas of the roof
- The snow coefficients have been revisited and a **new snow model** for **pitched (gabled) roofs** has been introduced
- 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

Key changes to EN 1991-1-3 and new content

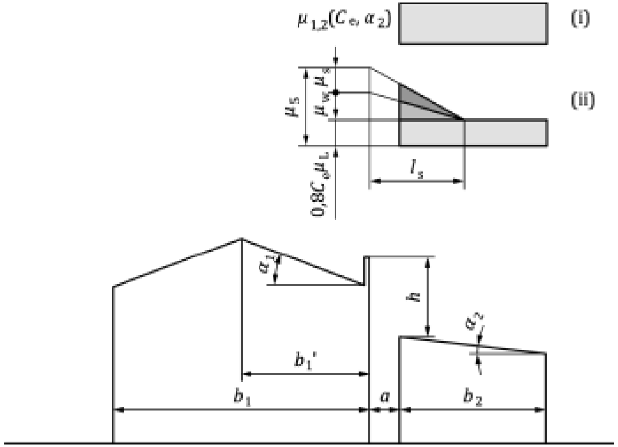
- For **cylindrical roofs** slightly updated model to account for variations in drifted snow load based on varying exposure coefficient.
- For **domes** a new snow load model is introduced, as a simplification of the relevant models of ISO 4355:2013 and with ASCE/SEI 7-16
- For **multi-span roofs** the model is revised to account for realistic snow load depths in the valley (not exceeding the ridge of the roof) and the effect of sliding in the valley
- Update to the snow load shape to account for the **drifting at obstructions** (snow load shape coefficient and drift length of obstructions are made dependent on the exposure coefficient)
- New snow load shape coefficients for **intersecting pitched roofs**

Key changes to EN 1991-1-3 and new content

- **For 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 (**μ_L**), the sliding part from the upper roof (**μ_s**) and the wind driven accumulated snow (**μ_w**)



a) This load arrangement applies where $a = 0$ and $b_2 \geq l_s$



b) This load arrangement applies where $0 < a < l_s$

Key changes to EN 1991-1-4 and new content

- **Extension of the field of application of the standard for buildings between 200 m and 300 m high**
- New formulation for determining the mean velocity and turbulence intensity up to $z = 300\,m$
- The two procedures defined in the current standard for determining the structural factor $c_\mathrm{s}c_\mathrm{d}$ 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 included in the informative Annex G
- Inclusion of the effects of atmospheric icing in the informative Annex E
- Inclusion of wind actions on silos and tanks

Key changes to EN 1991-1-4 and new content

- 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).
- A new Annex J (informative) on the 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 the derivation of design parameters from wind tunnel tests and numerical simulations
  - on the derivation of wind speeds from measurements at meteorological stations, and
  - on probabilistic models for wind actions.

Key changes to EN 1991-1-5

- 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
- 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
- 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

Key changes to EN 1991-1-5

Table 8.1 (NDP) — Maximum and minimum uniform bridge temperature $T_{N,\max}$ and $T_{N,\min}$

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

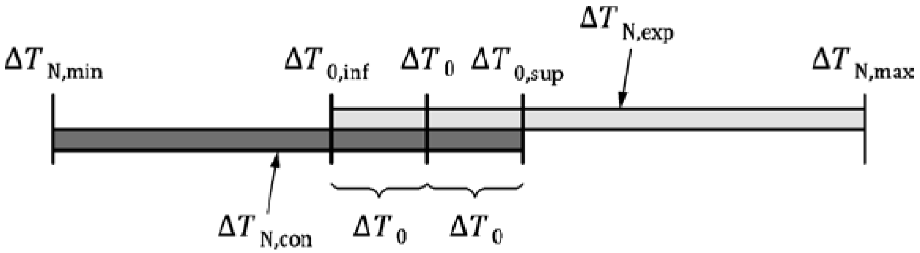


Figure 8.1 — Characteristic value of the maximum contraction ($\Delta T_{N,con}$) and expansion ($\Delta T_{N,exp}$) range of the uniform bridge temperature component

Key changes to EN 1991-1-6 and new content

- Update and clarification of the scope and the assumptions
- Proper delimitation vis-à-vis the use of product standards relevant for auxiliary structures and equipment (e.g. falsework, temporary works equipment, scaffolds)
- Design of auxiliary structures clarified
- Improved description of the design situations and limited update of the classification and representation of actions
- Update of the guidance for the determination of the characteristic values of the climatic actions (new Table 6.1, former Table 3.1)
- Additional considerations on actions during execution (imperfections, lateral stability, dynamically applied actions)
- Former Annex B (Actions on structures during alteration, reconstruction or demolition) removed

Key changes to EN 1991-1-6 and new content

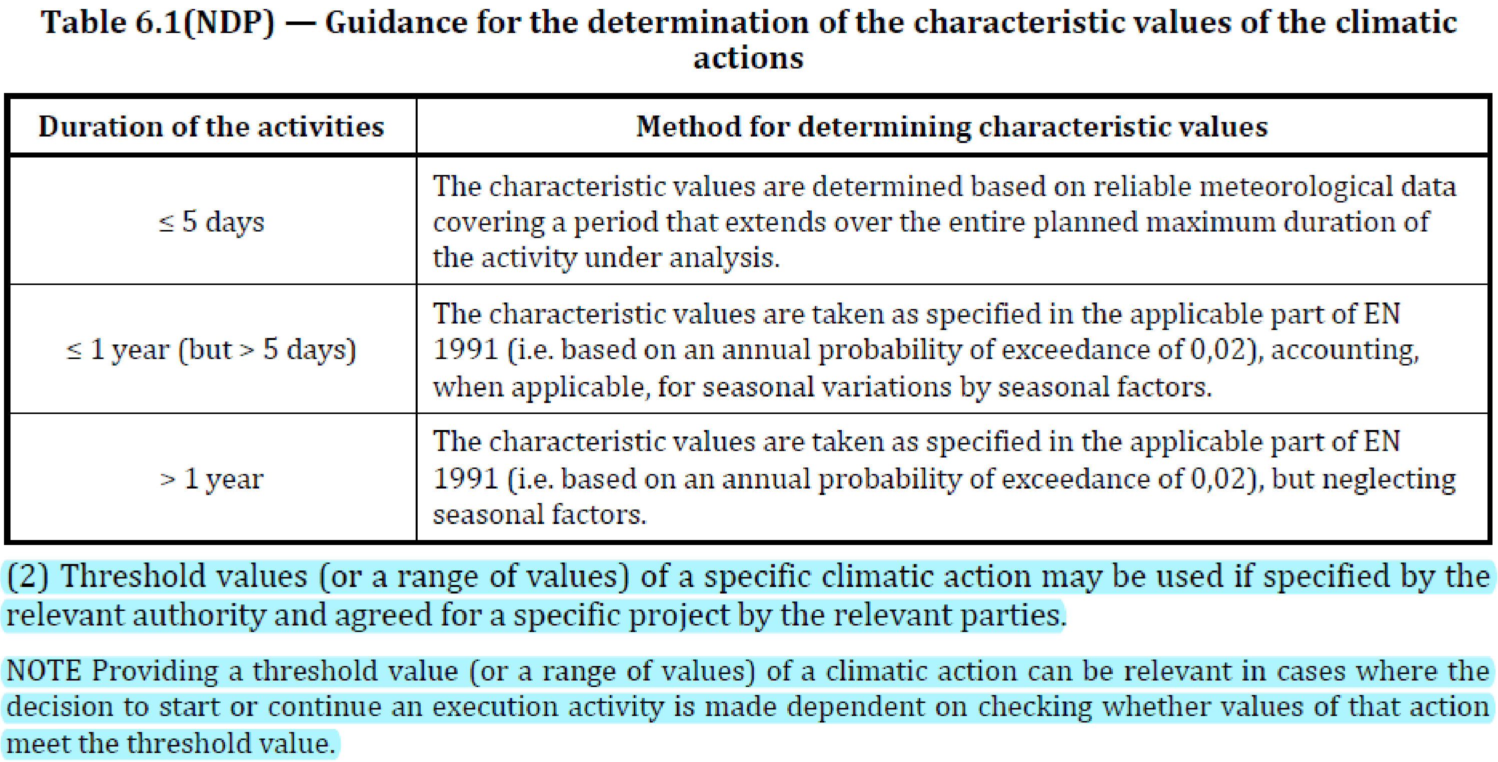


Table 6.1(NDP) — Guidance for the determination of the characteristic values of the climatic actions

Duration of the activities	Method for determining characteristic values
≤ 5 days	The characteristic values are determined based on reliable meteorological data covering a period that extends over the entire planned maximum duration of the activity under analysis.
≤ 1 year (but > 5 days)	The characteristic values are taken as specified in the applicable part of EN 1991 (i.e. based on an annual probability of exceedance of 0,02), accounting, when applicable, for seasonal variations by seasonal factors.
> 1 year	The characteristic values are taken as specified in the applicable part of EN 1991 (i.e. based on an annual probability of exceedance of 0,02), but neglecting seasonal factors.

(2) Threshold values (or a range of values) of a specific climatic action may be used if specified by the relevant authority and agreed for a specific project by the relevant parties.

NOTE Providing a threshold value (or a range of values) of a climatic action can be relevant in cases where the decision to start or continue an execution activity is made dependent on checking whether values of that action meet the threshold value.

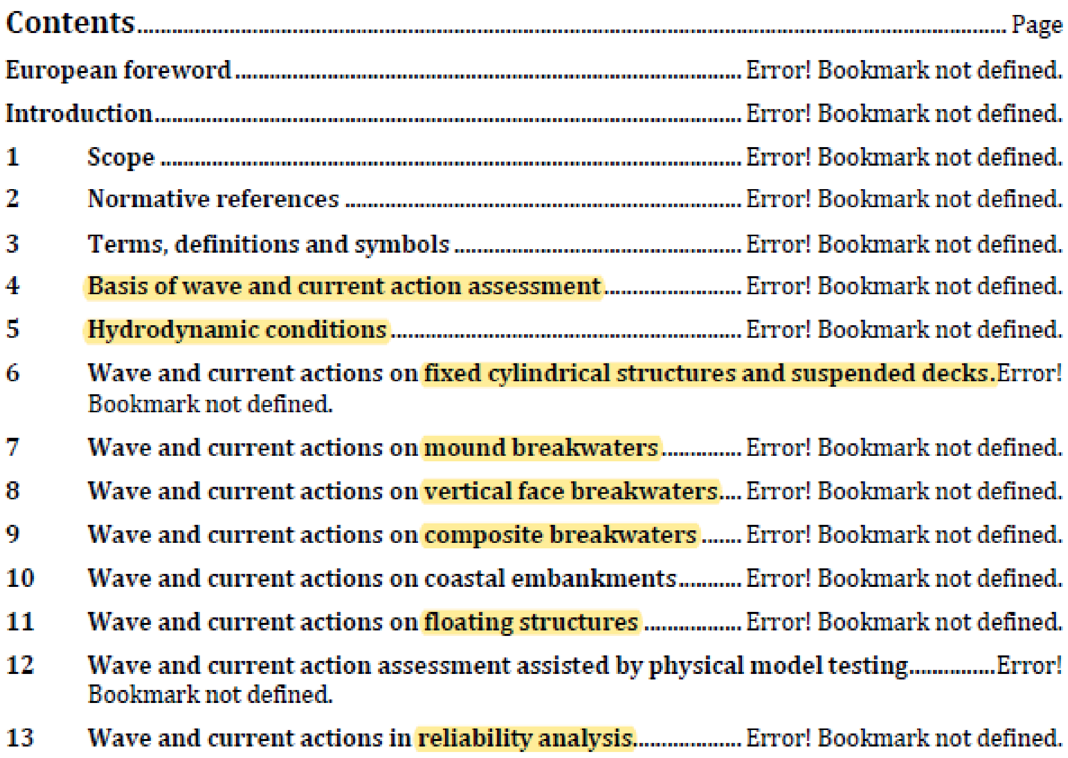
Key changes to EN 1991-1-7 and new content

- Limited changes as compared to the actual version
- Clarification and improvement of some clauses
- Improvement of the compatibility with EN 1990 (Annex E, in particular, related to strategies for accidental design situations)
- Rearrangement of the categorization of consequence classes
- Clarifications for the impact from river, canal and seagoing vessels
- Addition of ship impact formulas for non-ice-classed vessels
- Clarification about internal explosions
- Addition of a new Annex E on actions from debris

Content of EN 1991-1-8 (new standard)

- 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 some resistance aspects of the design.
  - ISO 21650 is only briefly covering aspects of reliability, while partial factors and combinations of actions are missing. Achieving full consistency with EN 1990 and the Eurocodes framework in general is hardly feasible in view of some design provisions of ISO 21650
  - For breakwaters, **severe displacement of armour units** and **severe overtopping ultimate limit states** are introduced
- Structures that have only the purpose of flood risk management were not incorporated, notably dykes, as requested by some NSBs

Content of EN 1991-1-8 (new standard)



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- **Annexes A to H** with additional guidance on the key topics of the main text

Content of EN 1991-1-8 (new standard)

- As most significant items of the standard can be considered the following:
  - A comprehensive definition of design **“Environmental sea conditions”** (essentially water level, wave conditions, currents). Detailed guidance is provided in Annex A
  - The implementation of the **“Hydrodynamic Estimate Approach””** **(HEA)**, which is defined as : “methodology to assess metocean parameters that relates to the consequence class of the structure and the local hydrodynamic conditions”
  - The implementation of **“Design Approaches” (DA)**

The purpose is that methods and requirements for the design can be outlined depending on the HEA-level, the DA-Level and the Consequence Classes (CC).

Content of EN 1991-1-8 (new standard)

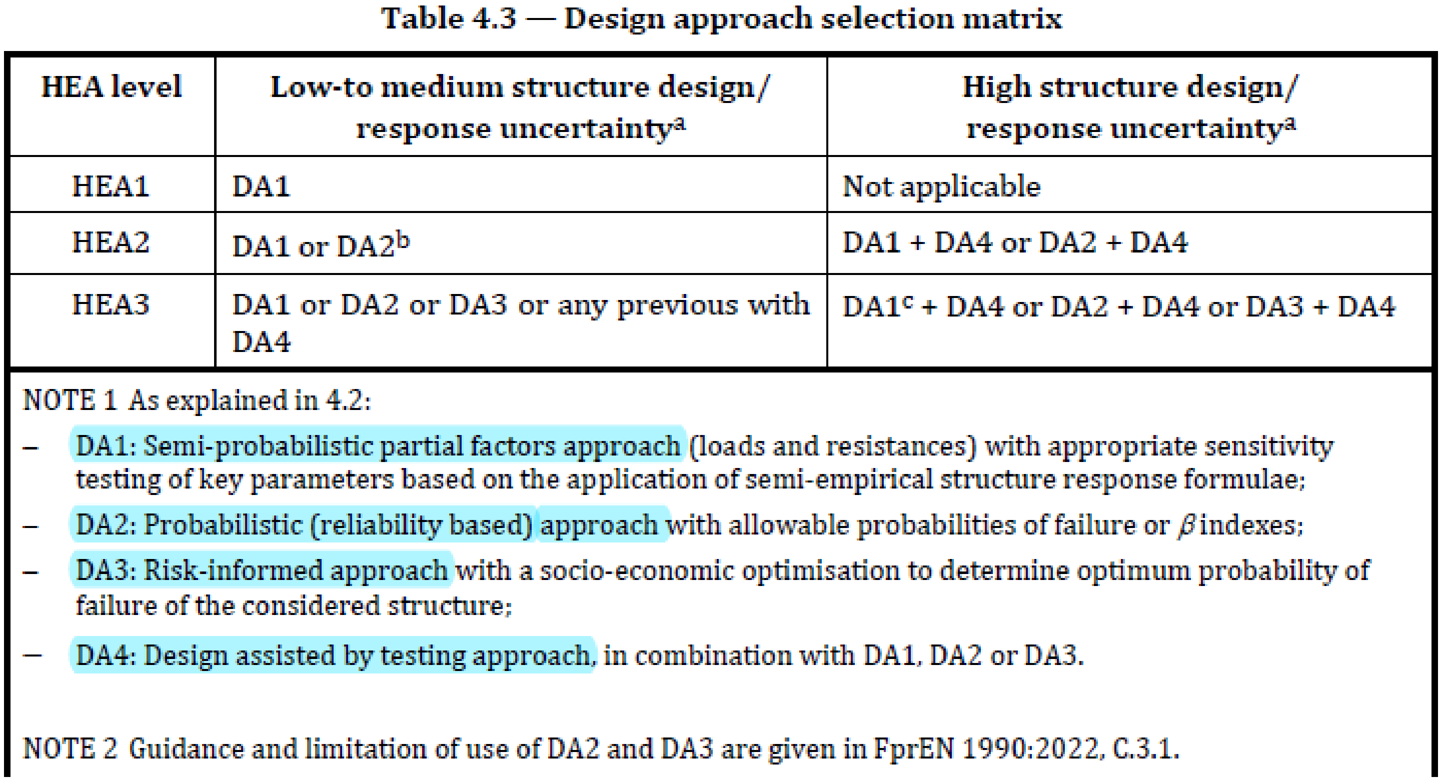


Table 4.3 — Design approach selection matrix

HEA level	Low-to medium structure design/ response uncertainty[a]	High structure design/ response uncertainty[a]
HEA1	DA1	Not applicable
HEA2	DA1 or DA2[b]	DA1 + DA4 or DA2 + DA4
HEA3	DA1 or DA2 or DA3 or any previous with DA4	DA1[c] + DA4 or DA2 + DA4 or DA3 + DA4

NOTE 1 As explained in 4.2:

- DA1: Semi-probabilistic partial factors approach (loads and resistances) with appropriate sensitivity testing of key parameters based on the application of semi-empirical structure response formulae;
- DA2: Probabilistic (reliability based) approach with allowable probabilities of failure or β indexes;
- DA3: Risk-informed approach with a socio-economic optimisation to determine optimum probability of failure of the considered structure;
- DA4: Design assisted by testing approach, in combination with DA1, DA2 or DA3.

NOTE 2 Guidance and limitation of use of DA2 and DA3 are given in FprEN 1990:2022, C.3.1.

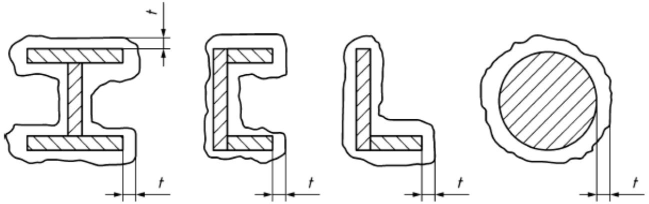
Content of EN 1991-1-9 (new standard)

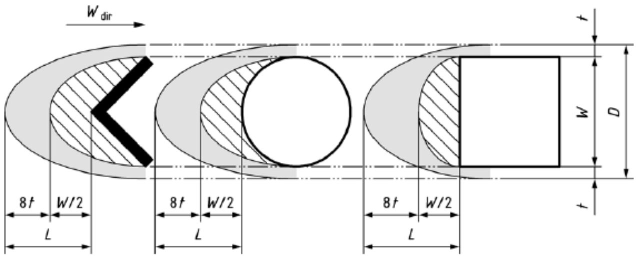
- There has not been so far an EN 1991-1-9, therefore this aspect could only make sense, if comparison is made against ISO 12494:2001 upon which (as background) EN 1991-1-9 is based
- Ice load is determined and classified according to **ice classes** (IC) for both **glaze** (ICG) and **rime** (ICR), because the characteristics for these differ. ICG should be determined for glaze deposits and ICR for rime deposits (see following slide)
- Combination with wind actions considered
- New height factor introduced for glaze ice
- Most information on how to measure and model atmospheric icing left open for the National Annexes
- In sum, EN 1991-1-9 is more compact than ISO 12494 and consistent with EN 1990 and the Eurocode style

Content of EN 1991-1-9 (new standard)

- Ice thickness for ICGs **(glaze)**

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 **(rime)**

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										

Key changes to EN 1991-2 and new content

- **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)
- 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, now European Union Agency for Railways) for the revision of some clauses in order to achieve consistency with TSI INF and relevant standards (e.g. EN 15528)
- Deleting former Annexes F and G
- Update of Annex E (on limits of validity of Load Model HSLM)
- Adjustments in view of consistency with EN 1990-Annex A.2 and other Eurocodes bridge parts (following HG-B proposals)

Key changes to EN 1991-2 and new content

- **New subclauses 6.9 and 8.10 (Static load models for geotechnical structures – characteristic values), for road and railway traffic, respectively**
- Update of clauses related to the final CEN/TR 17231 for Track-Bridge interaction
- Including the bases of design for noise barriers at railway lines (transfer from EN 16727-2-2)
- Including some new methods and materials (e.g. for footbridges and timber structures)
- Creating an updated clause 7 and a **new Annex G for footbridges** with additional special requirements related to EN 1990 Annex H, in particular on dynamic actions and pedestrian induced vibrations, based on state-of-the-art literature (guidelines and/or largely/commonly accepted methods and results); see next slide

Key changes to EN 1991-2 and new content

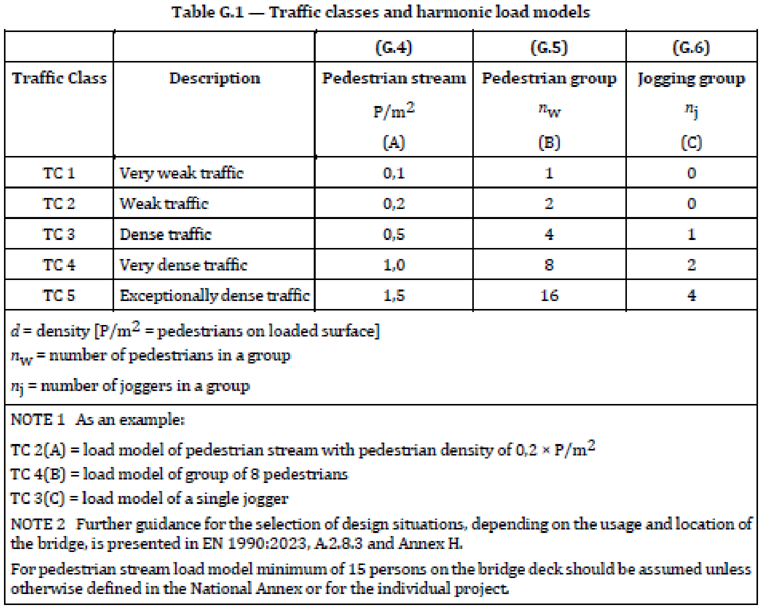


Table G.1 — Traffic classes and harmonic load models

		(G.4)	(G.5)	(G.6)
Traffic Class	Description	Pedestrian stream P/m^2 (A)	Pedestrian group n_w (B)	Jogging group n_j (C)
TC 1	Very weak traffic	0,1	1	0
TC 2	Weak traffic	0,2	2	0
TC 3	Dense traffic	0,5	4	1
TC 4	Very dense traffic	1,0	8	2
TC 5	Exceptionally dense traffic	1,5	16	4

d = density [P/m^2 = pedestrians on loaded surface]

n_w = number of pedestrians in a group

n_j = number of joggers in a group

NOTE 1 As an example:

TC 2(A) = load model of pedestrian stream with pedestrian density of 0,2 × P/m^2

TC 4(B) = load model of group of 8 pedestrians

TC 3(C) = load model of a single jogger

NOTE 2 Further guidance for the selection of design situations, depending on the usage and location of the bridge, is presented in EN 1990:2023, A.2.8.3 and Annex H.

For pedestrian stream load model minimum of 15 persons on the bridge deck should be assumed unless otherwise defined in the National Annex or for the individual project.

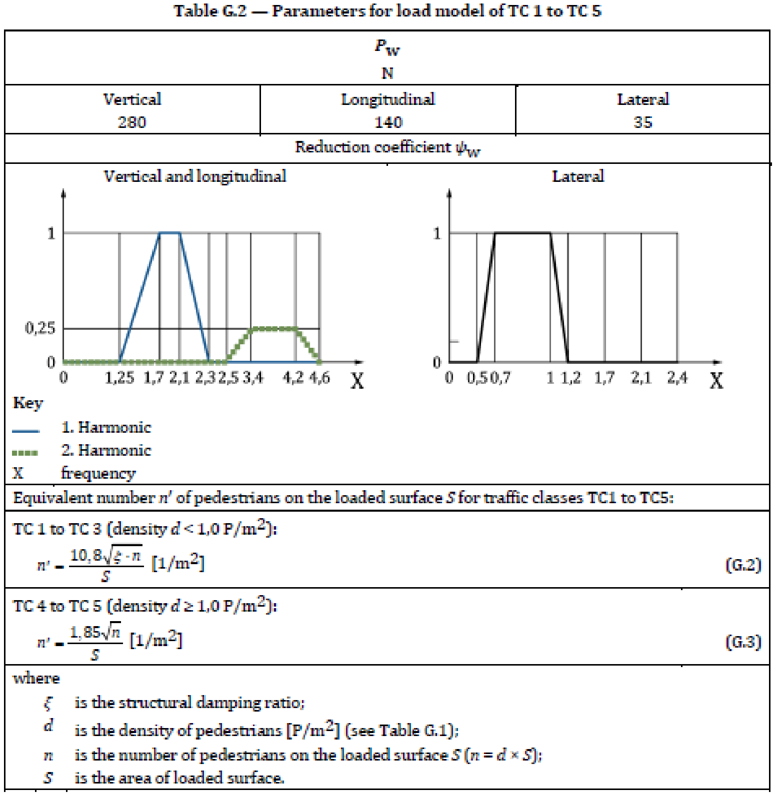


Table G.2 — Parameters for load model of TC 1 to TC 5

P_W N		
Vertical 280	Longitudinal 140	Lateral 35

Reduction coefficient ψ_W

Key

—	1. Harmonic
▪▪▪▪	2. Harmonic
X	frequency

Equivalent number n' of pedestrians on the loaded surface S for traffic classes TC1 to TC5:

TC 1 to TC 3 (density $d < 1{,}0$ P/m^2):

$$n' = \frac{10{,}8\sqrt{\xi \cdot n}}{S} \ [1/\mathrm{m}^2] \qquad \text{(G.2)}$$

TC 4 to TC 5 (density $d \geq 1{,}0$ P/m^2):

$$n' = \frac{1{,}85\sqrt{n}}{S} \ [1/\mathrm{m}^2] \qquad \text{(G.3)}$$

where

ξ is the structural damping ratio;

d is the density of pedestrians [P/m^2] (see Table G.1);

n is the number of pedestrians on the loaded surface S ($n = d \times S$);

S is the area of loaded surface.

Key changes to EN 1991-3 and new content

- Clarification in the scope that the content concerns the structures supporting **bridge, gantry and wall cranes travelling on fixed runways** and **fixed machines** that cause a harmonic dynamic loading on fixed supporting structures
- Setting some additional principles and requirements on actions transferred from cranes or machines at the interface with their supporting structures
- Update of the definitions, together with Annex A.5 of EN 1990, based on ISO 4306-1, especially on crane-related terms
- Improvement of the multiple crane operation
- Addition and clarification for the handling of in-service wind
- Removal of the former normative Annexes A (practically covered now by the Annex A.5 of EN 1990) and B (practically covered now by cl. 6.9 and new Annex A)

Key changes to EN 1991-3 and new content

- More user-friendly guidance on actions from cranes travelling on fixed runways for two important standard cases:
  - Main case of application: Use of the technical data file for cranes designed according to a relevant European crane product standard
  - Minor case of application for existing older cranes: User-friendly guidance on how to determine the crane-induced actions, if no technical data file is available (new Annex B)
- Improved and updated classification of typical bridge and gantry cranes for the fatigue design of their supporting structure that is now consistent with the relevant crane product standard EN 15011 (new Annex A)
- Addition of guidance on the calculation of actions from travelling wall cranes as this information has been missing up to now (new Annex C).

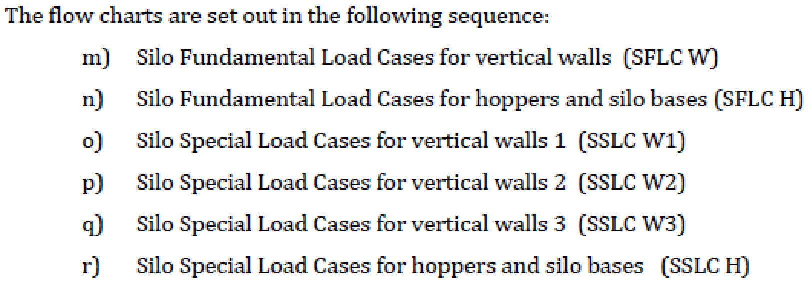
Key changes to EN 1991-4 and new content

- 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 behavior
- 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 consistency with EN1990 Annex A4
- A new section added on silos with inverted cone
- Additional rules have been added on rectangular silos with flexible walls
- New clauses have been added on **pressures in asymmetrical conical hoppers (mass flow)** and on **overpressure factors under mixed flow**, as well as on **thermal differential causing pressures** in different geometries

Key changes to EN 1991-4 and new content

- A clear distinction is made between:
    - symmetrical loads on vertical silos (**S**ilo **F**undamental **L**oad **C**ases - **SFLC**), in the case of symmetrical filling and discharge loads for silos of various slenderness and retaining silos, silo hoppers and bottoms (in Sections 7 and 9); and
    - (**S**ilo **S**pecial **L**oad **C**ases - **SSLC**), in the case of vertical walls, hoppers and silo bases with unsymmetrical pressures and high slenderness, large eccentricities of filling loads for squat or intermediate slender silos or pipe flow and several other special cases (in Sections 8 and 10)

- A **new Annex G with flow charts** to aid the use of the standard has been added



The flow charts are set out in the following sequence:

m) Silo Fundamental Load Cases for vertical walls (SFLC W)
n) Silo Fundamental Load Cases for hoppers and silo bases (SFLC H)
o) Silo Special Load Cases for vertical walls 1 (SSLC W1)
p) Silo Special Load Cases for vertical walls 2 (SSLC W2)
q) Silo Special Load Cases for vertical walls 3 (SSLC W3)
r) Silo Special Load Cases for hoppers and silo bases (SSLC H)

Key changes to EN 1991-4 and new content

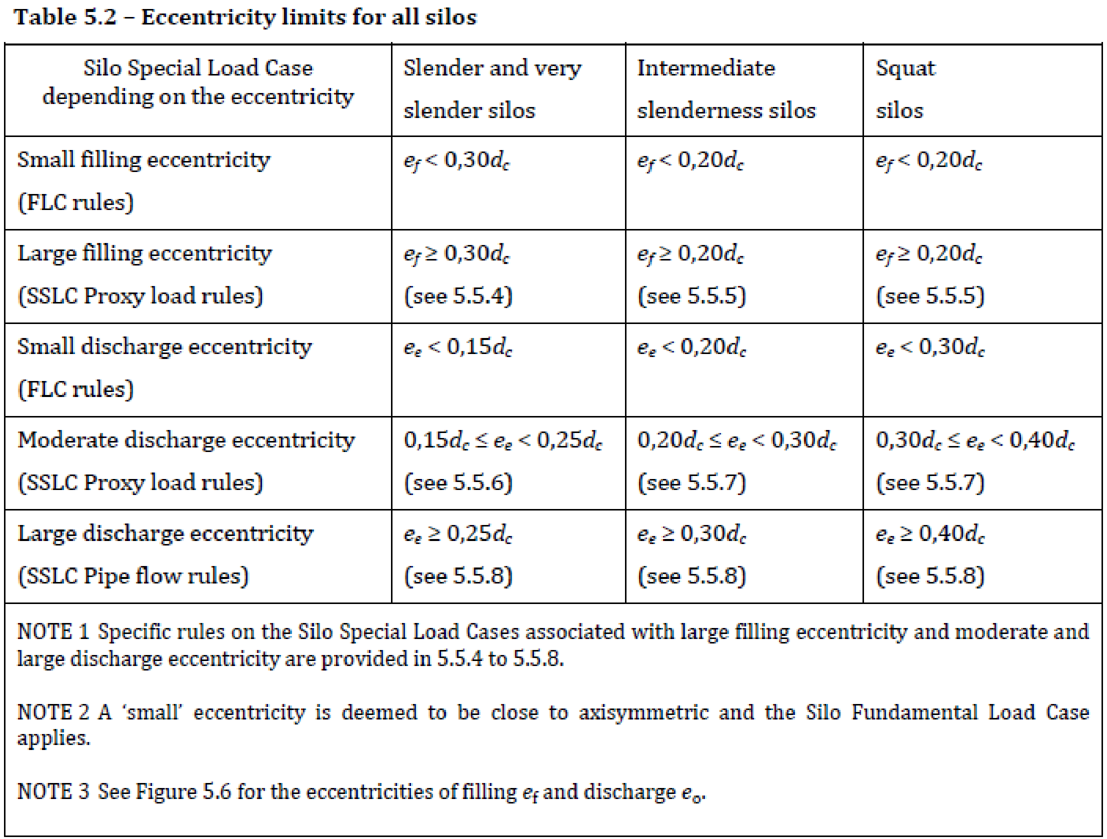


Table 5.2 – Eccentricity limits for all silos

Silo Special Load Case depending on the eccentricity	Slender and very slender silos	Intermediate slenderness silos	Squat silos
Small filling eccentricity (FLC rules)	$e_f < 0{,}30d_c$	$e_f < 0{,}20d_c$	$e_f < 0{,}20d_c$
Large filling eccentricity (SSLC Proxy load rules)	$e_f \geq 0{,}30d_c$ (see 5.5.4)	$e_f \geq 0{,}20d_c$ (see 5.5.5)	$e_f \geq 0{,}20d_c$ (see 5.5.5)
Small discharge eccentricity (FLC rules)	$e_e < 0{,}15d_c$	$e_e < 0{,}20d_c$	$e_e < 0{,}30d_c$
Moderate discharge eccentricity (SSLC Proxy load rules)	$0{,}15d_c \leq e_e < 0{,}25d_c$ (see 5.5.6)	$0{,}20d_c \leq e_e < 0{,}30d_c$ (see 5.5.7)	$0{,}30d_c \leq e_e < 0{,}40d_c$ (see 5.5.7)
Large discharge eccentricity (SSLC Pipe flow rules)	$e_e \geq 0{,}25d_c$ (see 5.5.8)	$e_e \geq 0{,}30d_c$ (see 5.5.8)	$e_e \geq 0{,}40d_c$ (see 5.5.8)

NOTE 1 Specific rules on the Silo Special Load Cases associated with large filling eccentricity and moderate and large discharge eccentricity are provided in 5.5.4 to 5.5.8.

NOTE 2 A 'small' eccentricity is deemed to be close to axisymmetric and the Silo Fundamental Load Case applies.

NOTE 3 See Figure 5.6 for the eccentricities of filling e_f and discharge e_o.

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