The Second Generation Eurocodes

Key changes and benefits through design examples

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EN 1991 “Eurocode 1: Actions on structures”

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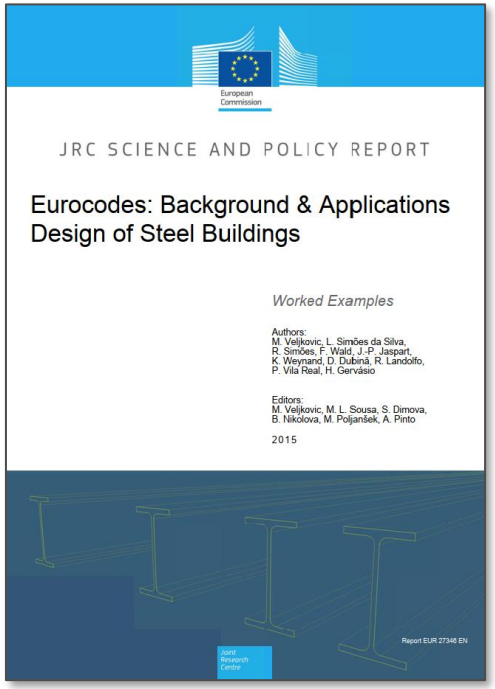
EN 1991

Actions on structures

Design example: agenda

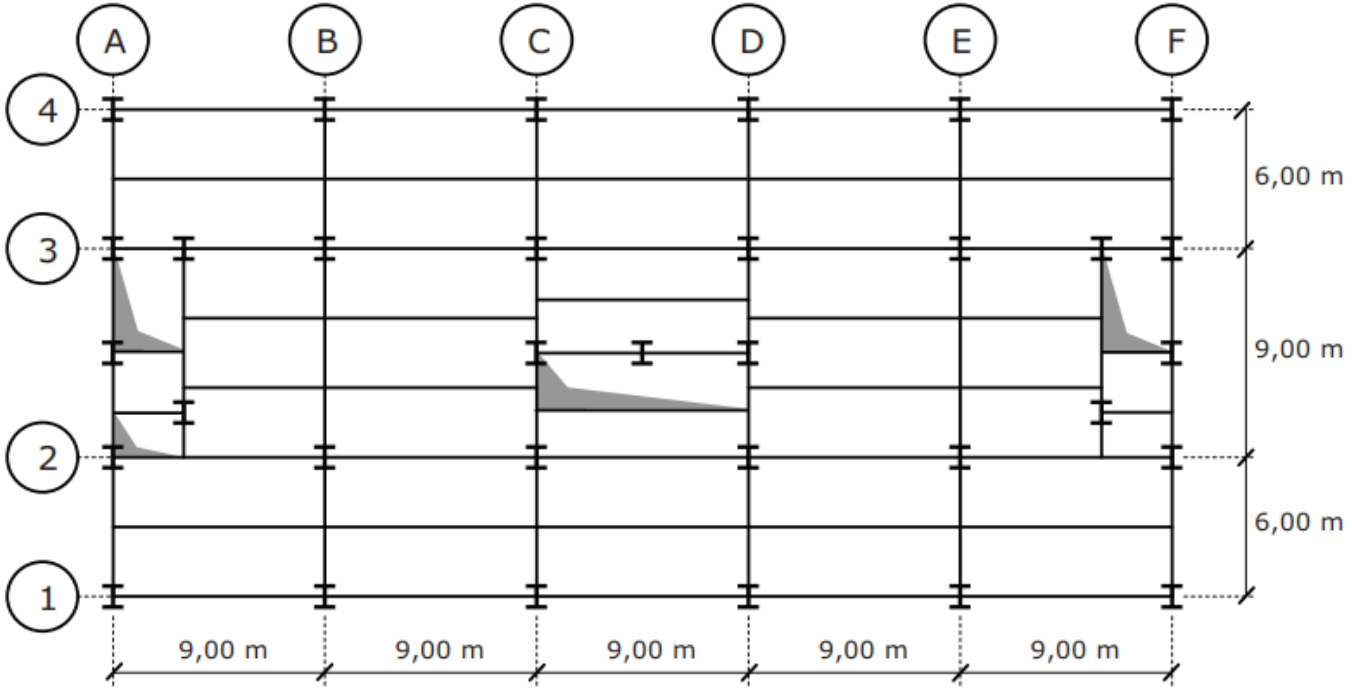
- Case study – building example
- Permanent actions
- Imposed loads
- Snow load
- Wind load

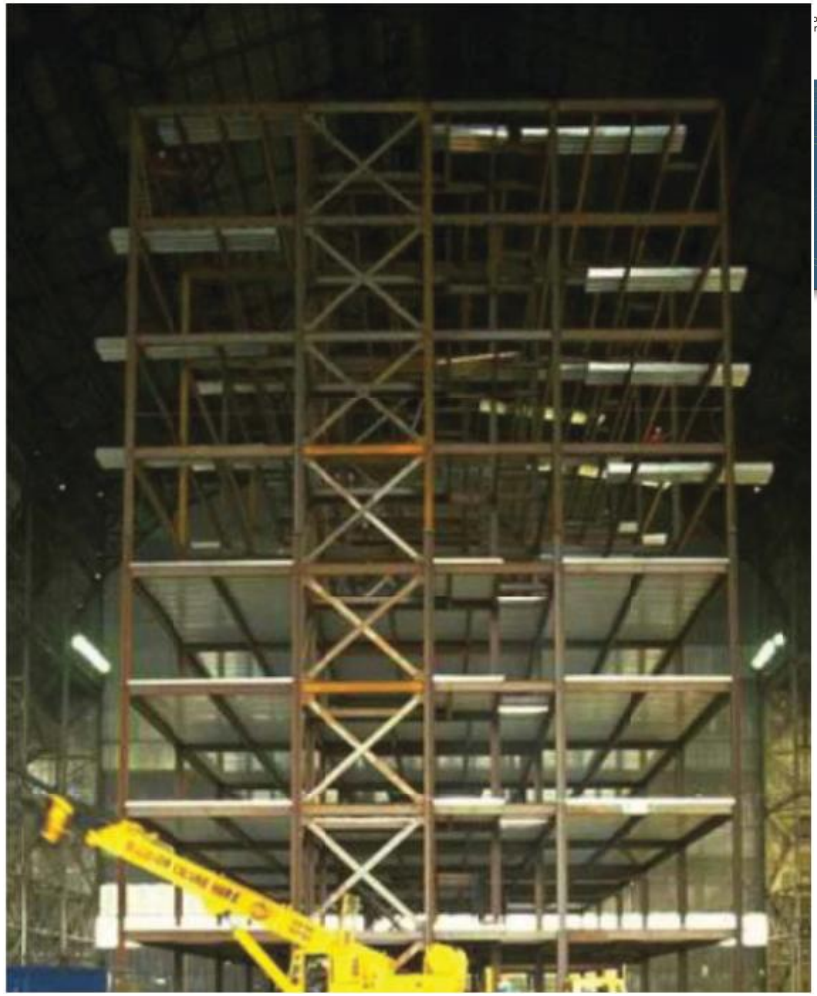
Case study – building example



Case study – building example

- 8 storeys
- 21m x 45m





Navigation

Benefit / change of second-generation Eurocode

Design example:

NDP

- $f_{s,cc}$ = 1,0

6 Snow load on the ground

6.1 Characteristic values

(3) The effects of climate change shall be taken into account.

NOTE 1 The effects of climate change are taken into account by multiplying the characteristic value of snow load on the ground (s_k) by a scaling factor, $f_{s,cc}$, greater than or equal to 1, unless the National Annex gives a different approach.

NOTE 2 When the scaling factor approach is used, minimum values for the scaling factor $f_{s,cc}$ can be set in the National Annex.

NOTE 3 For further guidance, see Clause A.5.

(4) Additional project-specific requirements to account for the effects of climate change should be as specified by the relevant authority or, where not specified, may be agreed for a specific project by the relevant parties.

Design example: agenda

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EN 1991-1-1

Content grouped into single clauses for self-weight and for imposed loads

Contents Page

Permanent actions: EN 1991-1-1

5 Self-weight of construction works

5.1 Design situations

(1) The self-weight of the structure or structural member shall be determined for each relevant design situation.

4 Specific weight of construction and stored materials

(1) Characteristic values of specific weight of construction and stored materials should be specified.

(2) Mean values should be used as characteristic values unless cases (3) and (4) occur.

NOTE Annex A gives mean values for specific weight and angles of repose for stored materials and products.

Permanent actions: EN 1991-1-1

Annex A ➡ Informative

- Lightweight concrete slabs: 12,5 kN/m^3
- Slab depth = 130mm
- Slab weight = 1.625 kN/m^2

Table A.1 — Construction materials – concrete and mortar

Materials	*Specific weight* γ [kN/m^3]
concrete (see EN 206) lightweight	
density class D1,0	8,0 to 10,0 [a] [b]
density class D1,2	10,0 to 12,0 [a] [b]
density class D1,4	12,0 to 14,0 [a] [b]
density class D1,6	14,0 to 16,0 [a] [b]
density class D1,8	16,0 to 18,0 [a] [b]
density class D2,0	18,0 to 20,0 [a] [b]
normal weight	24,0 [a] [b]
heavy weight	>26,0 [a] [b]
mortar	
cement mortar	19,0 to 23,0
gypsum mortar	12,0 to 18,0
lime-cement mortar	18,0 to 20,0
lime mortar	12,0 to 18,0

[a] Increase by 1kN/m^3 for normal percentage of reinforcing and pre-stressing steel

[b] Increase by 1kN/m^3 for unhardened concrete

Permanent actions: EN 1991-1-1

Annex A ➡ Informative

- Structural steel: 78,5 kN/m^3

- Assume IPE 400 beam section
- A = 84,46 cm^2
- Beam weight = 0,663 kN/m

Table A.4 — Construction materials – metals

Materials	*Specific weight* γ [kN/m^3]
metals	
aluminium	27,0
brass	83,0 to 85,0
bronze	83,0 to 85,0
copper	87,0 to 89,0
iron, cast	71,0 to 72,5
iron, wrought	76,0
lead	112,0 to 114,0
steel	77,0 to 78,5
zinc	71,0 to 72,0

Permanent actions: EN 1991-1-1

5 Self-weight of construction works

5.1 Design situations

(1) The self-weight of the structure or structural member shall be determined for each relevant design situation.

(2) Where elements other than structural are classified as permanent actions, the total self-weight (including both structural members and elements other than structural) should be treated as a single action when introducing relevant combinations of actions according to the single source principle.

NOTE 1 For the classification of self-weight of elements other than structural, see 5.2(2).

NOTE 2 For the single source principle, see EN 1990:2023, 6.1.1.

Make additions for flooring, finishes, coverings, etc. (elements other than structural)

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.

Terminology updated to provide consistency (see EN 1990)

Design example: agenda

- Case study – building example
- Permanent actions
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- Snow load
- Wind load

Imposed loads: EN 1991-1-1

6 Imposed loads on buildings

6.5 Characteristic values of imposed loads

6.5.2 Categories of use and characteristic values

(1) Imposed loads on buildings shall be divided into categories according to the specific use of the area under consideration.

NOTE The categories are those given in Table 6.1 (NDP) unless the National Annex provides sub-categories and/or additional categories.

(2) Imposed loads shall be designed by using characteristic values q_k (uniformly distributed load) and/or Q_k (concentrated load).

NOTE 1 q_k is intended for determination of general effects. Q_k is intended for local effects and not expected to be combined with q_k unless otherwise stated, see also 6.4.1(2) for local verifications.

NOTE 2 The values for q_k and Q_k are given in Table 6.1 (NDP) unless the National Annex gives different values.

Imposed loads: EN 1991-1-1

- Single combined table including categories and values for all categories
- Additional categories for garages, stairs, terraces, etc.

Category	Specific Use	Sub-categories with examples	q_k [kN/m²]	Q_k [kN]	Typical dimension of the area loaded by Q_k expressed in (m × m)
		C5: Areas susceptible to large crowds, e.g. in buildings for public events including corridors like concert halls, sports halls including stands, and railway platforms.	7,5	4,5	0,05 × 0,05
D	Shopping areas	**D1:** Areas in retail shops	4,0	4,0	0,05 × 0,05
		D2: Areas in department stores	5,0	7,0	0,05 × 0,05
E	Areas for archive, storage and industrial use[e]	**E1:** Areas susceptible to accumulation of goods, including access areas [f]	7,5	7,0	[a]
		E2: Industrial use [g,h,i,j]	[a]		
F	Garages and vehicle traffic areas (excluding ordinary roads and bridges)	Gross vehicle weight ≤ 30 kN: **F1** Traffic and parking areas for light vehicles (≤8 seats not including driver) e.g. garages; parking areas, parking halls	2,5	20	[a]
G		30 kN < Gross vehicle weight ≤ 160 kN: **G1** Traffic and parking areas for medium vehicles (on 2 axles) e.g. access routes, delivery zones, zones accessible to fire engines	5,0	90	0,2 × 0,2
		Gross vehicle weight > 160 kN: **G2** Traffic and parking areas for heavy vehicles [k]	[a]		
H [l]	Roofs not accessible except for normal maintenance and repair		0,4	1,0	0,05 × 0,05
I	Roofs accessible with occupancy according to categories A to G		See categories A to G		
K	Roofs accessible for special services, such as classes HC for helicopter landing areas		5,0	See Table 6.4	
S	Stairs and landings	**S1** Stairs and landings to areas belonging to category A1 and B1. [m]	See categories A1 and B1		0,05 × 0,05

Imposed loads: EN 1991-1-1

Table 6.1

Office floor loading:

- q_k: 3,0 kN/m^2
- Q_k: 3,0 kN

NDP

Table 6.1 — (NDP) Categories of use and values for q_k and Q_k

Category	Specific Use	Sub-categories with examples	q_k [kN/m^2]	Q_k [kN]	Typical dimension of the area loaded by Q_k expressed in (m × m)
A	Areas for domestic and residential activities	**A1** Rooms in residential buildings and houses, including corridors.	2,0	2,0	0,05 × 0,05
		A2 Bedrooms, wards, dormitories, private bathrooms and toilets in hospitals, hotels, hostels and other institutional residential occupancies.	2,0	2,0	0,05 × 0,05
B[a]	Public areas (not susceptible to crowding)	**B1** Office areas for general use including corridors other than archive / storage areas (see Category E)	3,0	3,0	0,05 × 0,05
		B2 Kitchens, communal bathrooms and toilets in hospitals, hotels, hostels and other institutional residential occupancies.	3,0	3,0	0,05 × 0,05

Imposed loads: EN 1991-1-1

Table 6.1

Roof loading:

- q_k: 0,4 kN/m^2
- Q_k: 1,0 kN

NDP

Table 6.1 — (NDP) Categories of use and values for q_k and Q_k

Category	Specific Use	Sub-categories with examples	q_k [kN/m^2]	Q_k [kN]	Typical dimension of the area loaded by Q_k expressed in (m × m)
H [l]	Roofs not accessible except for normal maintenance and repair		0,4	1,0	0,05 × 0,05
I	Roofs accessible with occupancy according to categories A to G		See categories A to G		
K	Roofs accessible for special services, such as classes HC for helicopter landing areas		5,0	See Table 6.4	
S	Stairs and landings	**S1** Stairs and landings to areas belonging to category A1 and B1. [m]	See categories A1 and B1		0,05 × 0,05
		S2 Stairs and landings for tribunes without fixed seats that are defined as escape ways. [m]	7,5	3,0	0,05 × 0,05
		S3 Stairs and landings not belonging to category S1 or S2. [m]	5,0	2,0	0,05 × 0,05

Imposed loads: EN 1991-1-1

Partitions

5.2 Classification

(1) The self-weight of structural members shall be classified as a permanent fixed action.

NOTE For the classification of actions, see EN 1990:2023, 6.1.1.

(2) The self-weight of elements other than structural should be classified as a permanent action, either fixed or free as relevant.

NOTE Elements other than structural are typically classified as permanent actions, but there can be cases where it is relevant to classify them as variable actions, see 6.5.3.1 for a simplified approach for the treatment of partitions as imposed loads.

Terminology updated to remove ambiguity about movable partitions

Imposed loads: EN 1991-1-1

Partitions

- Set partition weight $Q_{k,p} \leq 1$ kN/m
- NDP $q_{k,p} = 0{,}4$ kN/m^2
- Additive to floor load

6.5.3.1 Partitions treated as imposed loads

(1) The self-weight of partitions may be taken into account by introducing a uniformly distributed load $q_{k,p}$ as defined in (2) and (3) provided that the following conditions are verified:

— the relevant floor allows a sufficient distribution of a line load orthogonal to the intended orientation of the partition, and

— the self-weight of the partition is $Q_{k,p} \leq 3{,}0$ kN/m wall length.

NOTE Partitions are elements other than structural; as such, according to 5.2(2), they are expected to be classified as permanent actions, typically free for their spatial variation. The simplified approach provided in (1) only applies when the conditions defined above are verified. See (4) for heavier partitions.

(2) The uniformly distributed load $q_{k,p}$ defined in (1) should be added to the imposed loads of floors obtained from 6.5.2(2).

(3) The value of this uniformly distributed load $q_{k,p}$ for partitions with a self-weight $Q_{k,p} \leq 3{,}0$ kN/m wall length should be based on the self-weight of the partitions.

NOTE In such a case, $q_{k,p}$ is derived from Formula (6.1) unless the National Annex gives a different value.

$$q_{k,p} = \max\{0{,}35 \text{ kN/m}^2; (0{,}4/\text{m})\, Q_{k,p}\} \qquad (6.1)$$

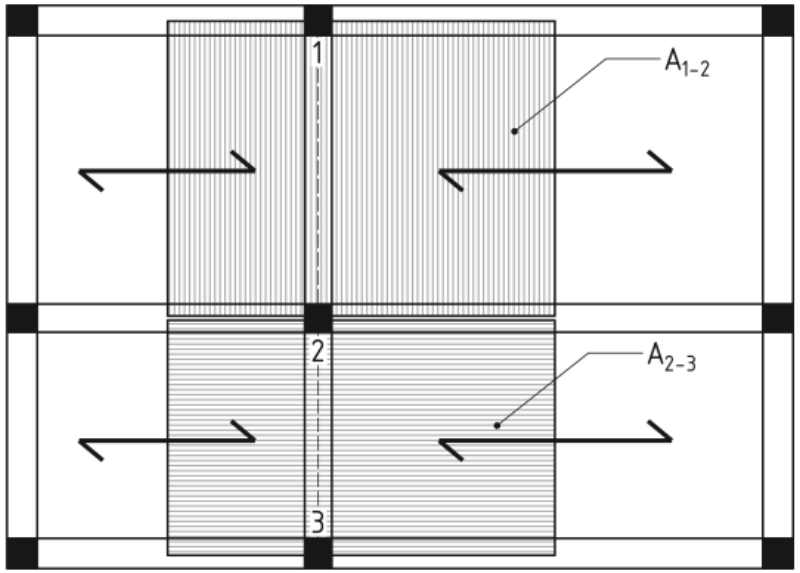
Imposed loads: EN 1991-1-1

Reduction factors

3.1.10
tributary area
area whose loading is assumed to contribute to the loading on the structural member supporting that area

Note 1 to entry: The tributary area can change depending on the support conditions. An example of tributary areas for a beam supporting two single span one-way decks is given in Figure 3.1. An example of tributary areas for columns is given in Figure 3.2, which takes account of the continuity effects of the slab.

Note 2 to entry: On each floor, the sum of tributary areas equals the total area of the slab.



Terminology updated to remove ambiguity about loaded area / tributary area

esign examples

Imposed loads: EN 1991-1-1

Formula simplified: all countries using the factor used the same value for ψ_0

Reduction factor: floors

- A = 54 m²
- NDP α_a = 0,69 (for beam C1-2)

6.5.3.2 Reduction factors

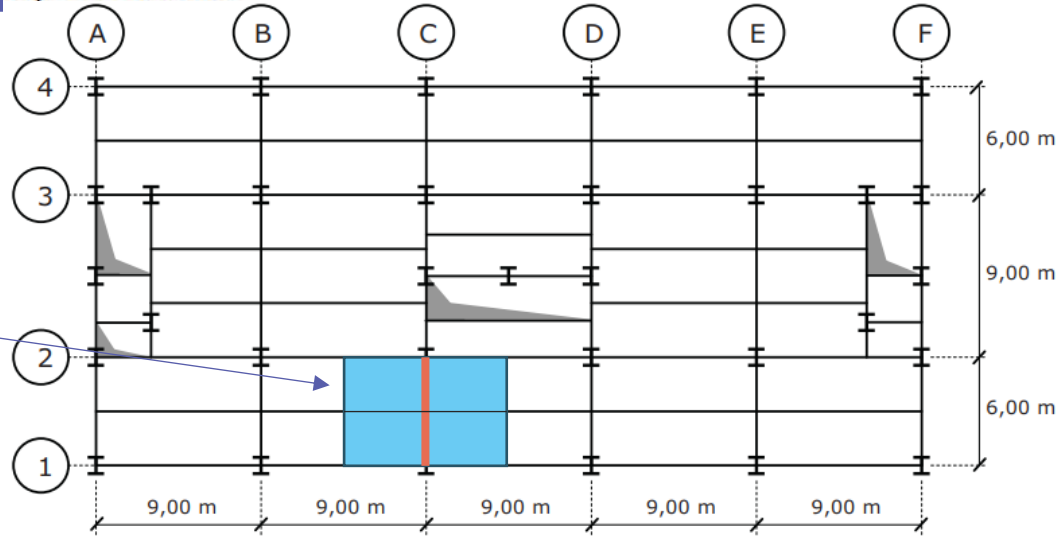
(4) In accordance with 6.4.1(3) a reduction factor α_A may be applied to the q_k values for imposed loads for floors, beams and accessible roofs.

NOTE 1 The value for the reduction factor α_A for categories A, B, C, D and category I (accessible roofs) is determined from Formula (6.2) unless the National Annex gives an alternative method and/or specific rules for the use of the reduction factor α_A, including its application for partitions and for specific categories C and D, where the reduction factor could be inappropriate to use.

$$\alpha_A = 0{,}5 + \frac{10}{A} \leq 1{,}0 \qquad (6.2)$$

with the restriction for categories C and D: $\alpha_A \geq 0{,}6$

where A is the tributary area expressed in m².



Tributary area A for beam C1-2 = 9,0 x 6,0 = 54 m²

Imposed loads: EN 1991-1-1

Formula simplified: all countries using the factor used the same value for ψ_0

Reduction factor: columns

6.5.3.2 Reduction factors

(5) In accordance with 6.4.2(3) and provided that the area is classified according to Table 6.1 (NDP) into the categories A to D and T, for columns and walls the imposed loads on the floors supported by the column or wall under consideration may be multiplied by the reduction factor α_n.

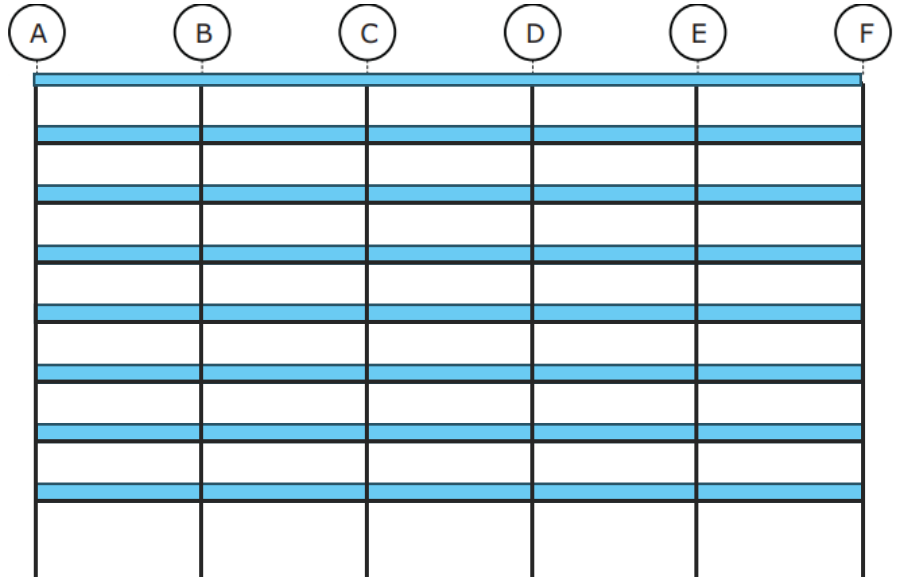
NOTE The values for α_n can be calculated from Formula (6.3) unless the National Annex gives an alternative method.

$$\alpha_n = 0,7 + \frac{0,6}{n} \leq 1,0 \qquad (6.3)$$

where α_n is calculated for each floor considering the number of floors n above the column or wall under consideration.

NDP

q_k	n	α_n	$q_k\ \alpha_n$	Cumulative
0,4	0	1.000	0.40	0.4
3,4	1	1.000	3.40	3.8
3,4	2	1.000	3.40	7.2
3,4	3	0.900	3.06	10.3
3,4	4	0.850	2.89	13.2
3,4	5	0.820	2.79	15.9
3,4	6	0.800	2.72	18.7
3,4	7	0.786	2.67	21.3



Imposed loads: EN 1991-1-1

Application of loads

Clarification on simplified load arrangement

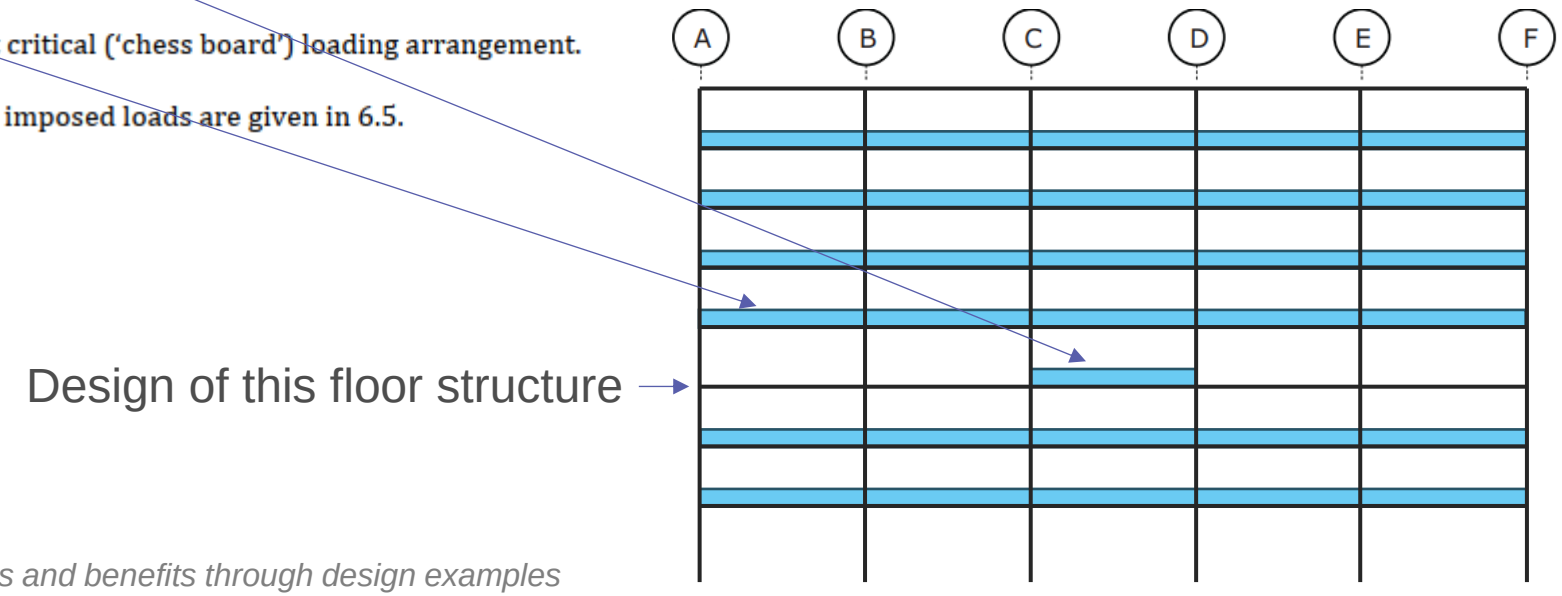
6.4 Load arrangements

6.4.1 Floors, beams and roofs

(1) For the design of a floor structure within one storey or a roof, the imposed load shall be taken into account as a free action applied at the most unfavourable part of the influence area of the action effects considered. For the other storeys, imposed loads may be assumed to be distributed uniformly (fixed actions) on the whole storey area.

NOTE 1 This is a simplified rule compared to the most critical ('chess board') loading arrangement.

NOTE 2 Characteristic values of uniformly distributed imposed loads are given in 6.5.



Design example: agenda

- Case study – building example
- Permanent actions
- Imposed loads
- Snow load
- Wind load

Snow load: EN 1991-1-3

Terminology updated to align with other international standards

3.1.5
balanced snow load arrangement on the roof
load arrangement which describes the uniformly distributed snow load on the roof, affected by the shape of the roof and its exposure to wind

3.1.6
unbalanced snow load arrangement on the roof
load arrangement which describes the snow load distribution resulting from snow having been moved from one location to another location on a roof or off the roof, depending on the exposure of the roof to wind and the effects of sliding

Note 1 to entry: Unbalanced load arrangements given in this document assume that wind can have any direction.

Snow load: EN 1991-1-3

Fundamental design situation used for unbalanced snow load

Accidental design situation used for exceptional snow loads

4 Design situations

4.1 General

(1) The snow loads shall be determined for each relevant design situation identified in accordance with EN 1990:2023, 5.2.

(2) Further to the fundamental (persistent and transient) design situation (see 4.2 and 4.3), accidental design situation should be considered where exceptional conditions apply (see 4.3).

4.2 Normal conditions

(1) For locations where exceptional snow falls (see 5.1(3)) are unlikely to occur, the fundamental (persistent and transient) design situation should be used for both the balanced and the unbalanced snow load arrangements determined as specified in 7.1.

(2) For local effects (see Clause 8), the fundamental (persistent and transient) design situation should be used.

4.3 Exceptional conditions

(1) For locations where exceptional snow loads on the ground (see 5.1(3)) are likely to occur the following apply:

Snow load: EN 1991-1-3

Design example:

NDP • s_k = 0,5 kN/m^2 (from national snow map)

6 Snow load on the ground

6.1 Characteristic values

(1) The characteristic value of snow load on the ground (s_k) should be determined in accordance with EN 1990:2023, 6.1.2.3(2) and the definition for characteristic snow load on the ground given in 3.1.1.

NOTE 1 Characteristic values of snow load on the ground at sites for altitudes up to 1 500 m can be set by the National Annex.

NOTE 2 Rules for the treatment of snow loads for altitudes above 1 500 m can be set by the National Annex.

Snow load: EN 1991-1-3

Climate change provisions included

Design example:

NDP • $f_{s,cc} = 1,0$

6 Snow load on the ground

6.1 Characteristic values

(3) The effects of climate change shall be taken into account.

NOTE 1 The effects of climate change are taken into account by multiplying the characteristic value of snow load on the ground (s_k) by a scaling factor, $f_{s,cc}$, greater than or equal to 1, unless the National Annex gives a different approach.

NOTE 2 When the scaling factor approach is used, minimum values for the scaling factor $f_{s,cc}$ can be set in the National Annex.

NOTE 3 For further guidance, see Clause A.5.

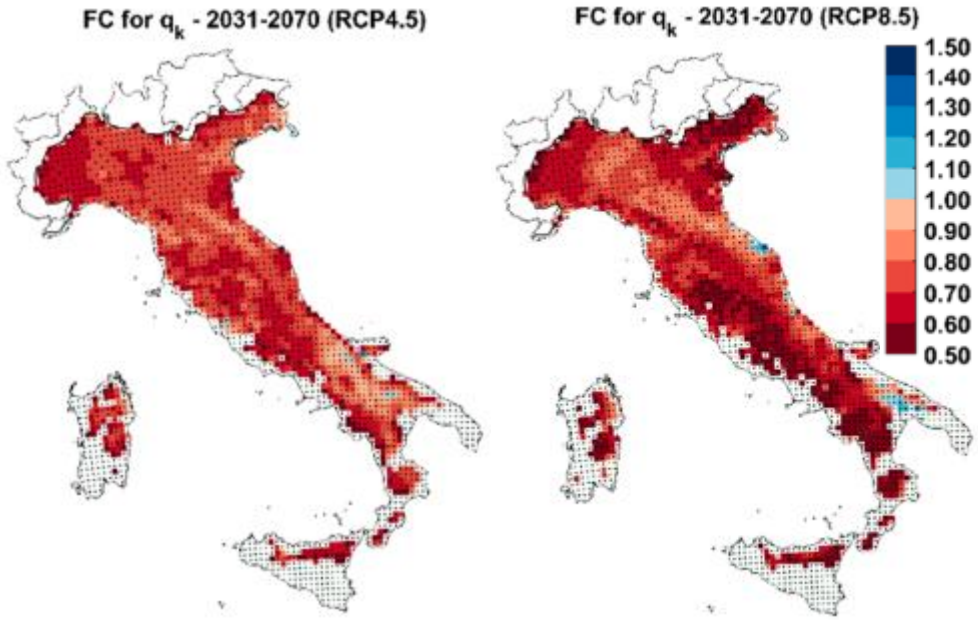
(4) Additional project-specific requirements to account for the effects of climate change should be as specified by the relevant authority or, where not specified, may be agreed for a specific project by the relevant parties.

Snow load: EN 1991-1-3

Climate change provisions included

Design example:

NDP • $f_{s,cc}$ = 1,0



6 Snow load on the ground

6.1 Characteristic values

(3) The effects of climate change shall be taken into account.

NOTE 1 The effects of climate change are taken into account by multiplying the characteristic value of snow load on the ground (s_k) by a scaling factor, $f_{s,cc}$, greater than or equal to 1, unless the National Annex gives a different approach.

NOTE 2 When the scaling factor approach is used, minimum values for the scaling factor $f_{s,cc}$ can be set in the National Annex.

NOTE 3 For further guidance, see Clause A.5.

(4) Additional project-specific requirements to account for the effects of climate change should be as specified by the relevant authority or, where not specified, may be agreed for a specific project by the relevant parties.

Example factor of change maps*
(dependent on climate change scenario)

* Croce, Formichi and Landi, *Climate Change: Impacts on Climatic Actions and Structural Reliability*, Applied Sciences, 2019, doi:10.3390/app9245416

Snow load: EN 1991-1-3

7.2 Determination of snow load

(1) Snow loads on roofs shall be determined:

a) for the fundamental (persistent and transient) design situations by using Formula (7.1) (normal conditions, see 4.2):

$$s = \mu_i \, C_t \, s_k \qquad (7.1)$$

where, further to the symbols defined in Clause 6:

μ_i is the snow load shape coefficient (see 7.5), function of the wind exposure of the site (through the exposure coefficient C_e, see 7.3) and of the geometry of the roof;

C_t is the thermal coefficient (see 7.4).

Snow load: EN 1991-1-3

Terrain categories linked to EN 1991-1-4

Design example:

- NDP • C_e = 1,0

7.3 Exposure coefficient

(2) The exposure coefficient C_e may be determined considering the wind exposure conditions of the roof.

NOTE 1 The wind exposure conditions, and the corresponding values of C_e are given in Table 7.1 (NDP) unless the National Annex gives different wind exposure conditions and/or values.

Table 7.1 (NDP) — Values of C_e for different wind exposure conditions

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

[a] *Windswept*: flat unobstructed areas exposed on all sides without, or little shelter afforded by terrain, higher construction works or trees, e.g. as terrain category 0, I and II defined in EN 1991-1-4. The wind velocity (at the height of 10 m above flat open country terrain, 10-min mean) in windswept sites averaged over the coldest month of the year is assumed to be higher than 4,5 m/s. For lower mean wind velocity *Normal* conditions apply.

[b] *Normal:* areas where there is no significant removal of snow by wind on construction work, because of terrain, other construction works or trees, e.g. as terrain category III defined in EN 1991-1-4.

[c] *Sheltered:* areas in which the construction work being considered is considerably lower than the surrounding terrain or surrounded by high trees and/or surrounded by higher construction works.

Snow load: EN 1991-1-3

Design example:

NDP • C_t = 1,0

Cases added where thermal coefficient may be higher or lower than unity

7.4 Thermal coefficient

(1) The thermal coefficient C_t should be specified.

NOTE For cases other than those described in (2) and (3), the value of C_t is 1,0 unless the National Annex gives a different value.

(2) For locations where the heat transfer through the roof and the duration of the snow load is long enough to melt significant parts of the snow cover, the thermal coefficient C_t may be reduced for roofs with high thermal transmittance (>1 W/m²K, e.g. greenhouses and some glass covered roofs).

(3) For buildings where the internal temperature is intentionally kept below 0 °C (e.g. freezer buildings, ice skating arenas), C_t should be increased above 1,0, unless the thermal insulation prevents increases in the roof snow load.

Snow load: EN 1991-1-3

Design example:

- L = 45 m
- W = 21 m
- L_c = 32,2 m
- For $L_c \leq 50$ m, $C_{e,F} = C_e = 1,0$
- $\mu_1 = 0,8$
- $s = \mu_1 C_t s_k = 0,8 \times 1,0 \times 0,5 = 0,4$ kN/m^2

7.5 Snow load shape coefficients

7.5.2 Flat roofs

(1) The balanced load arrangement should be used for flat roofs with a snow load shape coefficient μ_1 as given by Formula (7.3).

$$\mu_1 = 0,8\, C_{e,F} \tag{7.3}$$

(2) The exposure coefficient for flat roofs $C_{e,F}$ should be as given by Formula (7.4) and illustrated in Figure 7.1.

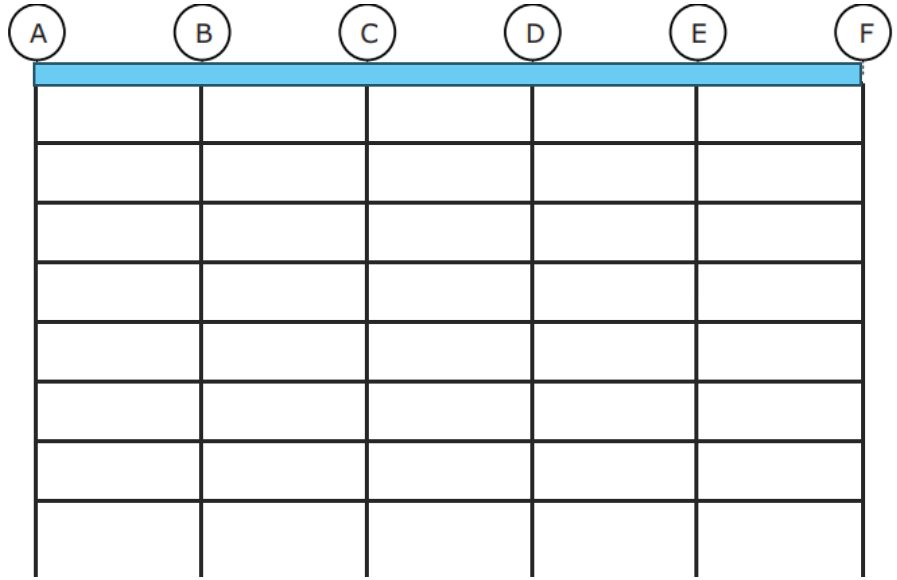
$$C_{e,F} = \begin{cases} C_e \text{ for } L_c \leq 50\,\text{m} \\ C_e + (1,25 - C_e)\dfrac{(L_c - 50)}{350} \text{ for } 50\,\text{m} < L_c < 400\,\text{m} \\ 1,25 \text{ for } L_c \geq 400\,\text{m} \end{cases} \tag{7.4}$$

where

L_c is the effective roof length (in m) equal to $2W - W^2/L$;

W is the length (in m) of the shorter side of the roof;

L is the length (in m) of the longer side of the roof.



Snow load: EN 1991-1-3

Cases added e.g. covering photovoltaic solar panels

Design example:

- Panel size = 1,5 m x 2,0 m
- Tilt angle = 10 °
- h = 1,5 sin(10 °) = 0,26 m
- NDP s_k / γ = 0,5 / 2,0 = 0,25 m
- μ_P = 0,26 / 0,25 = 1,04 limit to 1,0
- $s = \mu_P C_t s_k$ = 1,0 x 1,0 x 0,5 = 0,5 kN/m²

7.5.2.2 Flat roofs with tilted panels

(1) For flat roofs with parallel rows of tilted panels (e.g. solar or photovoltaic panels) the unbalanced load arrangement should be used according to Figure 7.2, μ_p being given by Formula (7.5):

$$\mu_p = \frac{\gamma h}{s_k} \quad with \quad \mu_1 \le \mu_p \le 1 \qquad (7.5)$$

where

μ_p is upper limit for the snow load shape coefficient for flat roofs with tilted panels;

h is the panel height, as shown in Figure 7.2;

γ is the snow weight density.

NOTE γ is taken as 2 kN/m³ unless the National Annex gives a different value (see also information in Annex C).

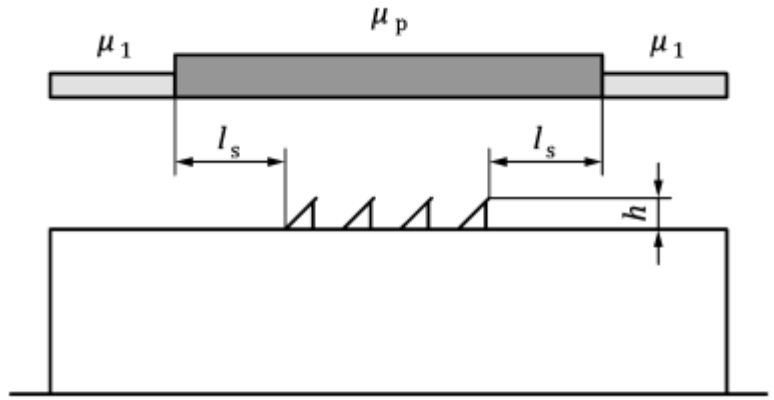


Figure 7.2 — Snow load arrangement for flat roofs with tilted panels

Snow load: EN 1991-1-3

Local effects brought into main text

Design example:

- Parapet height h_p = 1,1 m
- $b = L$ = 45 m
- l_s = 4 x 1,1 / 1,0 = 4,4 m
- μ_7 = 0,8 / 1,0 x 2 x 45 / 4,4 = 16,4
- Check limit = 0,8 / 1,0 x 1,1 / 0,25 = 3,5 governs
- μ_7 = 3,5

8 Local Effects

8.3 Drifting at parapets

(1) The snow load shape coefficient for the drifted snow at parapets with aspect ratio $w/h_p \geq 2{,}0$, should be taken from Formula (8.3):

$$\mu_7 = \frac{0{,}8}{C_e}\frac{2b}{l_s} \text{ with } \mu_7 \leq \min\left\{\frac{0{,}8\,\gamma h_p}{C_e\,s_k}, \mu_{7\max}\right\} \quad (8.3)$$

where

γ is the snow weight density, specified in 7.5.2.2(1);

h_p is the height of the parapet;

w is the width of the parapet (measured perpendicularly to the elevation in Figure 8.2);

b is the horizontal dimension of the roof.

NOTE The value of $\mu_{7\max}$ is 4,0 unless the National Annex gives different values.

(3) The drift length l_s in Figure 8.2 should be determined from Formula (8.4):

$$l_s = \frac{4h_p}{C_e} \text{ with } 5\,\text{m} \leq l_s \leq 15\,\text{m} \quad (8.4)$$

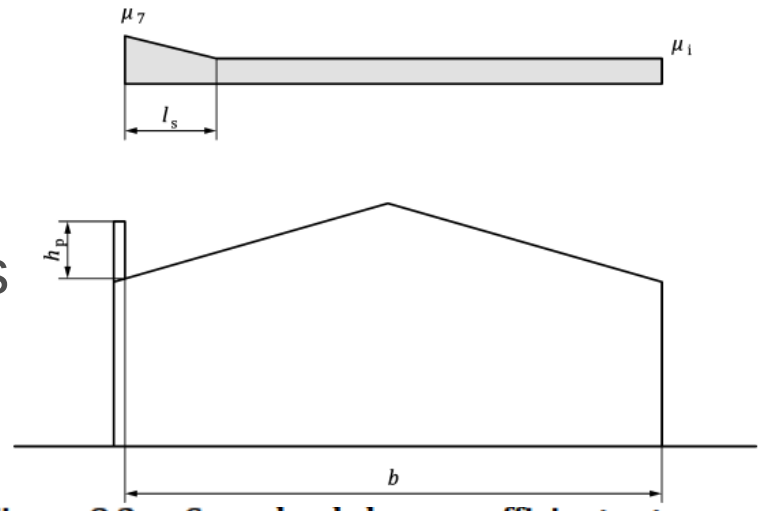


Figure 8.2 — Snow load shape coefficients at parapets

Design example: agenda

- Case study – building example
- Permanent actions
- Imposed loads
- Snow load
- Wind load

Wind load: EN 1991-1-4

Navigation: overview of main provisions

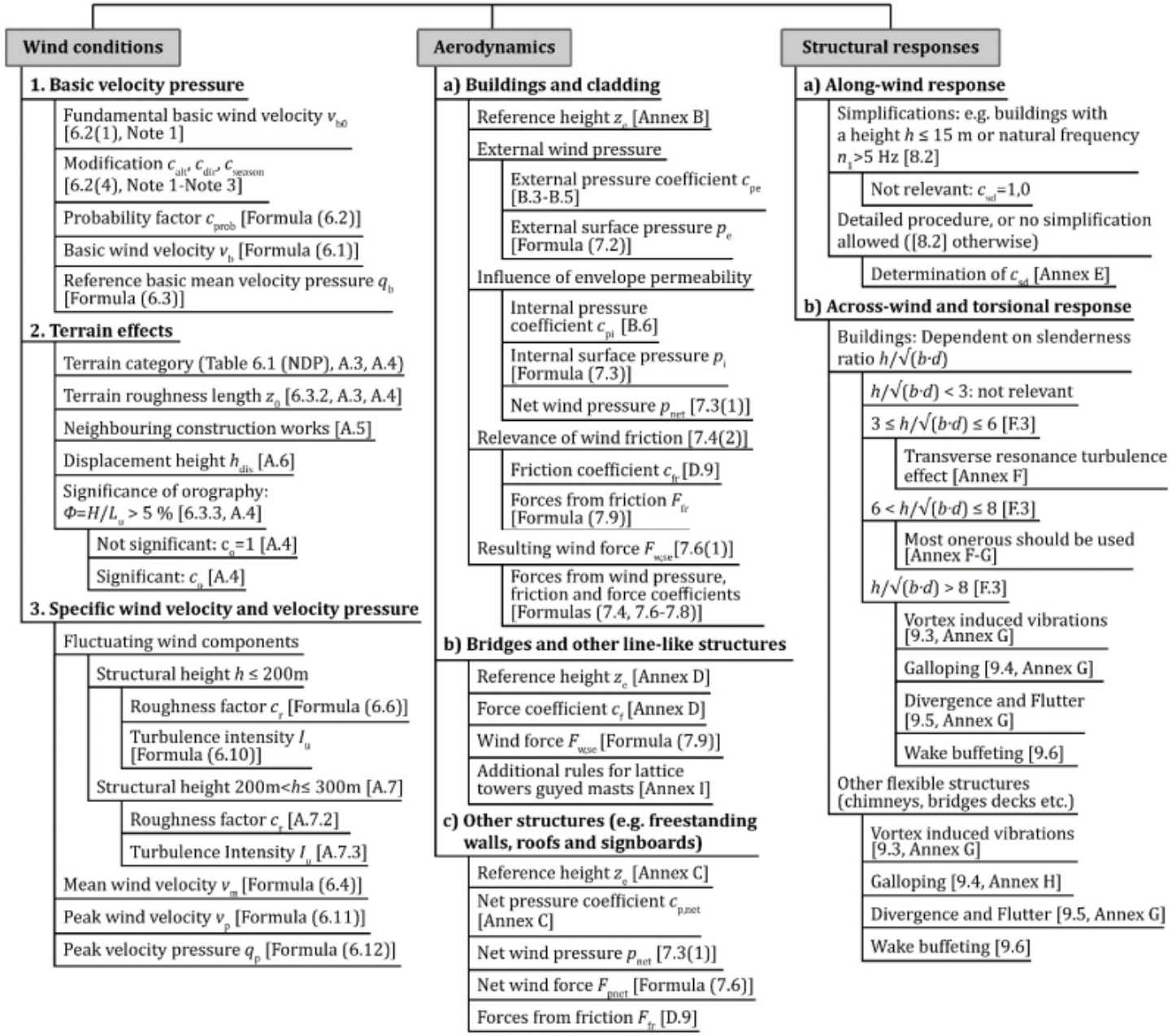


Figure 5.1 — Overview of the general design process and classification regarding the relevance of methods for individual design situations

Wind load: EN 1991-1-4

Figure 5.1

- Aspects illustrated in this example

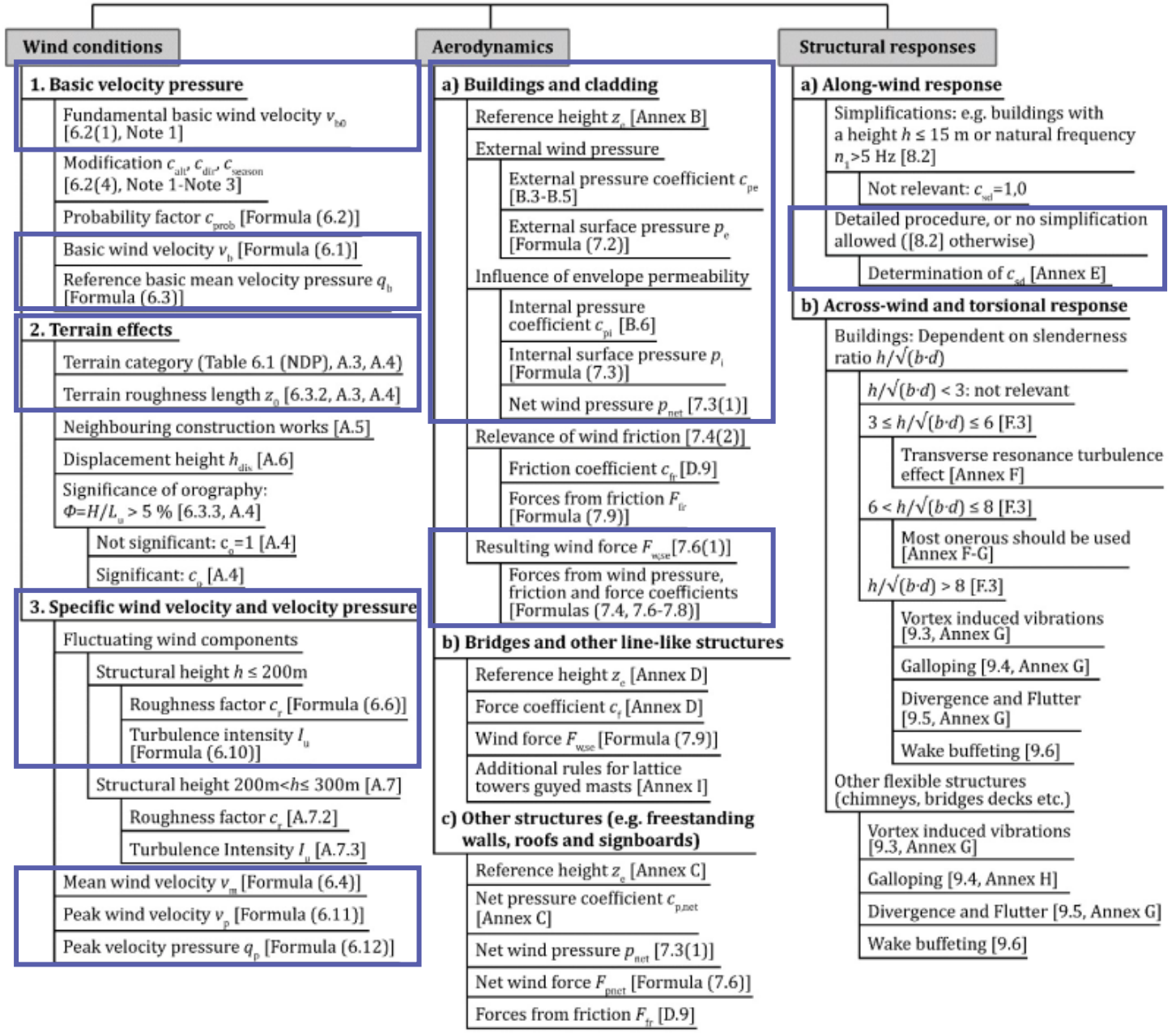


Figure 5.1 — Overview of the general design process and classification regarding the relevance of methods for individual design situations

Wind load: EN 1991-1-4

Design example:

- v_{b0} = 30 m/s (from national wind map)

6 Wind velocity and velocity pressure

6.2 Basic values

(1) The basic wind velocity should be calculated from the fundamental basic wind velocity v_{b0}.

NOTE 1 The National Annex can set values of the fundamental basic wind velocity and provide guidance to analyse regional data.

NOTE 2 For guidance on derivation of values of the fundamental basic wind velocity, v_{b0}, using measurements of wind velocities, see Annex K.

Wind load: EN 1991-1-4

Climate change provisions included

Design example:

- NDP • $f_{w,cc}$ = 1,0

6 Wind velocity and velocity pressure

6.2 Basic values

(2) The effects of climate change shall be taken into account.

NOTE 1 The effects of climate change are taken into account by multiplying the fundamental basic wind velocity v_{b0} by a scaling factor, $f_{w,cc}$, greater than or equal to 1, unless the National Annex gives a different approach.

NOTE 2 When the scaling factor approach is used, minimum values for the scaling factor $f_{w,cc}$ can be set in the National Annex.

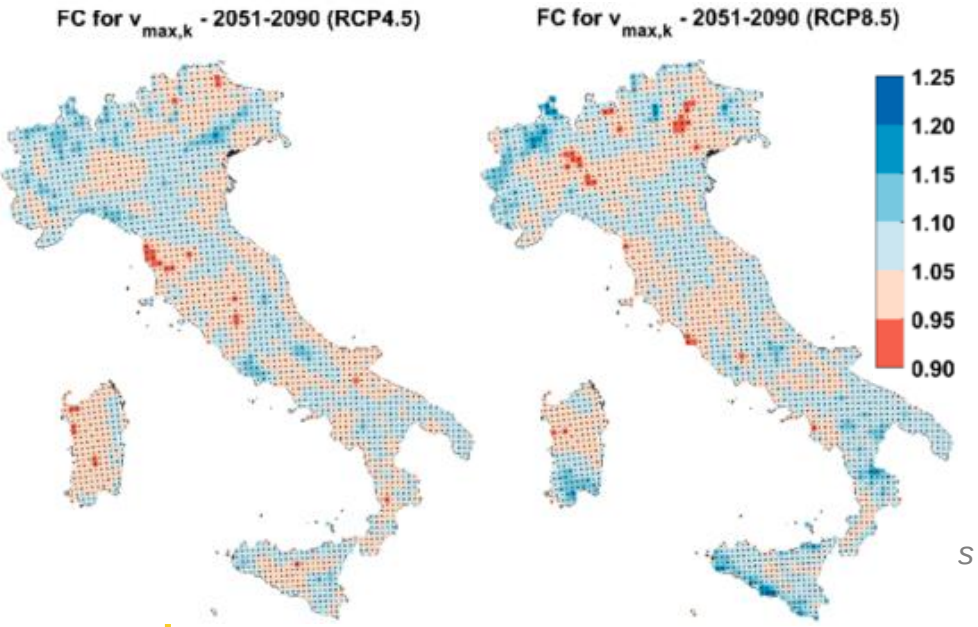
(3) Additional project-specific requirements to account for the effects of climate change should be as specified by the relevant authority or, where not specified, may be agreed for a specific project by the relevant parties.

Wind load: EN 1991-1-4

Climate change provisions included

Design example:

- NDP • $f_{w,cc}$ = 1,0



6 Wind velocity and velocity pressure

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NOTE 2 When the scaling factor approach is used, minimum values for the scaling factor $f_{w,cc}$ can be set in the National Annex.

(3) Additional project-specific requirements to account for the effects of climate change should be as specified by the relevant authority or, where not specified, may be agreed for a specific project by the relevant parties.

Example factor of change maps*
(dependent on climate change scenario)

* Croce, Formichi and Landi, *Climate Change: Impacts on Climatic Actions and Structural Reliability*, Applied Sciences, 2019, doi:10.3390/app9245416

Wind load: EN 1991-1-4

Calculation of mean velocity pressure

6.3 Mean wind velocity and pressure

6.3.1 Variation with height

(1) The mean wind velocity $v_m(z)$ at a height z above the terrain depends on the terrain roughness and orography and on the basic wind velocity, v_b, and should be determined using Formula (6.4):

$$v_m(z) = c_r(z) \cdot c_o(z) \cdot v_b \qquad (6.4)$$

Wind load: EN 1991-1-4

Key values provided in table form

Calculation of terrain roughness

NDP

Table 6.1 (NDP) — Terrain categories and terrain parameters

Terrain category		z_0 [m]	z_{min} [m]	k_r
0	Sea or coastal area exposed to the open sea	0,003	1	0,16
I	Lakes or flat and horizontal area with negligible vegetation and without obstacles	0,01	1	0,17
II	Area with low vegetation such as grass and isolated obstacles (trees, buildings) with separations of at least 20 obstacle heights	0,05	2	0,19
III	Area with regular cover of vegetation or buildings or with isolated obstacles with separations of maximum 20 obstacle heights (such as villages, suburban terrain, permanent forest)	0,3	5	0,22
IV	Area in which at least 15 % of the surface is covered with buildings and civil engineering works or forest, and their average height exceeds 15 m	1,0	10	0,23
NOTE The terrain categories can be illustrated as in Figure A.1.				

Wind load: EN 1991-1-4

Calculation of terrain roughness

6.3.2 Terrain roughness

(1) The roughness factor, $c_r(z)$, should account for the variability of the mean wind velocity at the site of the structure due to:

— the height above ground level

— the terrain roughness upwind of the structure in the wind direction considered

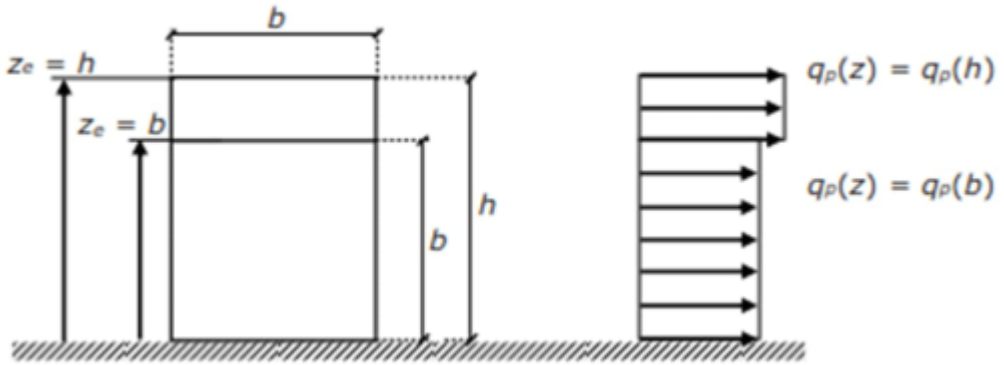
$$c_r(z) = k_r \cdot \ln\left(\frac{z}{z_o}\right) \quad \text{for} \quad z_{min} \le z \le z_{max} \qquad (6.6)$$

$$c_r(z) = c_r(z_{min}) \quad \text{for} \quad z \le z_{min}$$

Design example:

$$c_r(z = 33) = 0{,}19 \cdot \ln\left(\frac{33}{0{,}05}\right) = 1{,}23, \text{ and:}$$

$$c_r(z = 21) = 0{,}19 \cdot \ln\left(\frac{21}{0{,}05}\right) = 1{,}15$$



Wind load: EN 1991-1-4

Calculation of mean velocity pressure

6.3 Mean wind velocity and pressure

6.3.1 Variation with height

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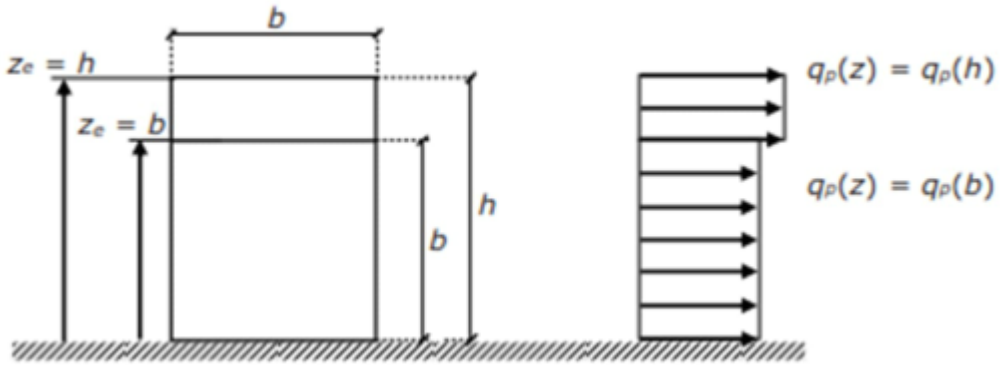
$$v_m(z) = c_r(z) \cdot c_o(z) \cdot v_b \qquad (6.4)$$

Design example:

$$v_m(z = 33) = 1{,}23 \cdot 1{,}0 \cdot 30 = 36{,}9 \text{ m/s}$$

$$v_m(z = 21) = 1{,}15 \cdot 1{,}0 \cdot 30 = 34{,}5 \text{ m/s}$$



Wind load: EN 1991-1-4

Calculation of turbulence intensity

6.4 Wind turbulence

(2) The turbulence intensity in the direction of the wind $I_u(z)$ should be calculated.

NOTE The turbulence intensity $I_u(z)$ is calculated using Formula (6.10), unless the National Annex gives a different method.

$$I_u(z) = \frac{\sigma_u}{v_m(z)} = \frac{k_I}{c_o(z) \cdot \ln\left(\frac{z}{z_o}\right)} \quad \text{for} \quad z_{min} \le z \le z_{max} \qquad (6.10)$$

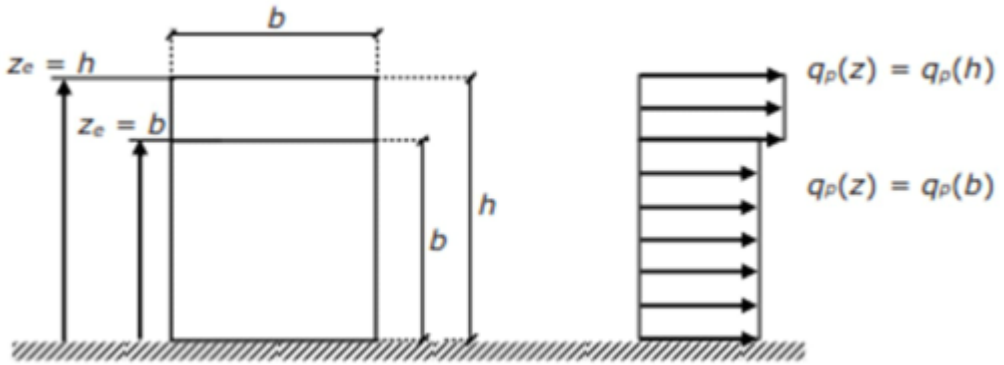
$$I_u(z) = I_u(z_{min}) \quad \text{for} \quad z < z_{min}$$

Design example:

$$I_u(z = 33) = \frac{1{,}0}{1{,}0 \cdot \ln\left(\frac{33}{0{,}05}\right)} = 0{,}15$$

NDP

$$I_u(z = 21) = \frac{1{,}0}{1{,}0 \cdot \ln\left(\frac{21}{0{,}05}\right)} = 0{,}17$$



Wind load: EN 1991-1-4

Calculation of peak velocity pressure

6.5 Peak wind velocity and peak velocity pressure

(1) The peak wind velocity $v_p(z)$ at height z, which includes mean and short-term fluctuations, should be determined by using the Formula (6.11).

$$v_p(z) = v_m(z) \cdot \left(1 + g_u \cdot I_u(z)\right) \tag{6.11}$$

(2) The peak velocity pressure $q_p(z)$ at height z, should be determined.

NOTE The peak velocity pressure $q_p(z)$ should be determined using the Formula (6.12), unless a different method is given in the National Annex.

$$q_p(z) = \frac{1}{2} \cdot \rho \cdot v_p^2(z) = c_e(z) \cdot q_b \tag{6.12}$$

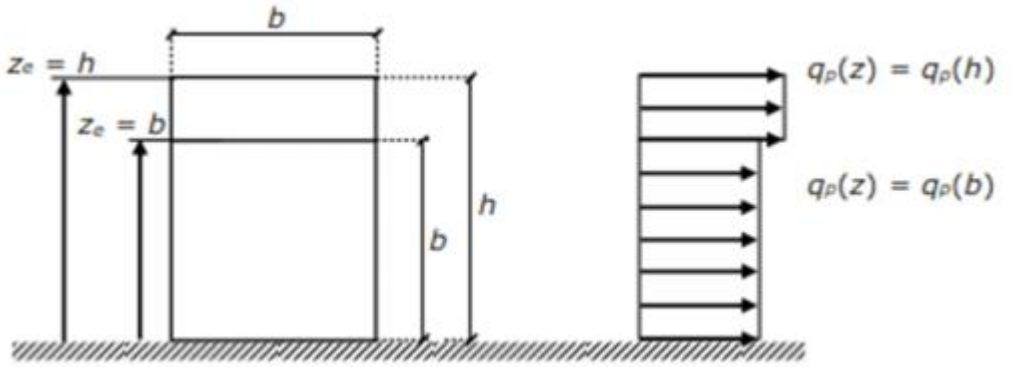
Design example:

$$v_p(z = 33) = 36{,}9 \cdot (1 + 2{,}9 \cdot 0{,}15) = 52{,}9\ \mathrm{m/s}$$

$$q_p(z = 33) = \frac{1}{2} \cdot 1.25 \cdot 52{,}9^2 = 1{,}75\mathrm{kN/m^2}$$

$$v_p(z = 21) = 34{,}5 \cdot (1 + 2{,}9 \cdot 0{,}17) = 51{,}5\ \mathrm{m/s}$$

$$q_p(z = 21) = \frac{1}{2} \cdot 1.25 \cdot 51{,}5^2 = 1{,}66\mathrm{kN/m^2}$$



Wind load: EN 1991-1-4

Main text contains general procedures

Structure-specific coefficients in Annexes

Use of pressure coefficients

7 Wind actions

7.1 Overview of calculation

(1) Sets of resultant wind actions, F_w, for use with EN 1990 shall be determined to envelope the wind actions on structures or structural parts in all directions.

(2) Contributions to the wind actions F_w should be calculated from external and internal wind pressures acting simultaneously on surfaces (see Annex B and Annex C) or from use of force coefficients (see Annex D).

NOTE 1 A summary of calculation procedures with reference to relevant clauses and annexes is given in Figure 5.1.

NOTE 2 External pressure coefficients are provided for local surfaces (c_{pe1} and c_{pe10}) and, also, to cover larger areas relevant to overall structural loading (c_{peg}) in Clause B.3, Clause B.4 and Clause B.5. Use of c_{pe1}, c_{pe10} and c_{peg} is described in 7.2.

NOTE 3 Internal pressures depend on average contributions from external sources depending on leakage. Guidance on internal pressure coefficients, c_{pi}, is provided in Clause B.6. Use of c_{pi} is described in 7.2.

Wind load: EN 1991-1-4

Use of pressure coefficients

7.2 Wind pressure and resultant wind forces on surfaces

(1) The wind pressure acting on an external surface, the external surface pressure p_e, should be obtained from Formula (7.2).

$$p_e = q_p(z_e) \cdot c_{pe} \qquad (7.2)$$

where

$q_p(z_e)$ is the peak velocity pressure defined in 6.5 at the reference height, z_e, for the external surface pressure given in Annex B;

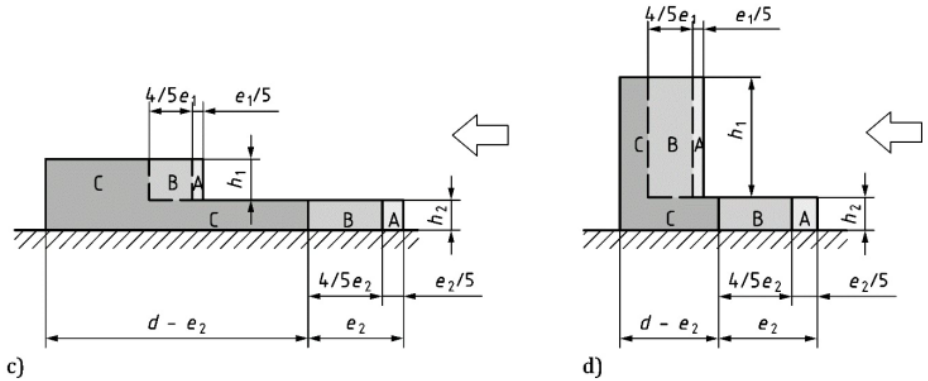
c_{pe} is the external pressure coefficient, given in Annex B.

Wind load: EN 1991-1-4

Structure-specific coefficients in Annexes

Use of pressure coefficients

B.4.3 Buildings with non-uniform height



Key

⇨ wind direction

Figure B.21 — Buildings with a rectangular plan and non-uniform height

Wind load: EN 1991-1-4

Reference height

B.3 Pressure coefficients for rectangular plan buildings

B.3.2 Vertical walls

(3) For buildings where $h \leq b$, the reference height z_e for zone D, see Figure B.6 (windward wall) should be taken as equal to the building height h, see Figure B.3 a).

(4) For buildings where $h > b$, two zones should be specified for the evaluation of the reference height z_e for zone D:

— For the lower part of the building, up to height $z = b$, the reference height $z_e = b$.

— For the upper part of the building, i.e. for z between b and h, the reference height z_e is selected by applying one of the two following criteria (Figure B.3 b) and c)).

a) The reference height is constant and equal to h.

NOTE 1 This simplifies the action scenario but gives larger forces.

b) The building is divided into strips of arbitrary height, each with a corresponding constant reference height, equal to the maximum height of the strip. For cladding design, the vertical extension of the upper zone is less than b.

NOTE 2 This is a more complex loading pattern but gives lower forces.

Wind load: EN 1991-1-4

Simple option for simple cases

More complex option where refinement gives economy

Reference height

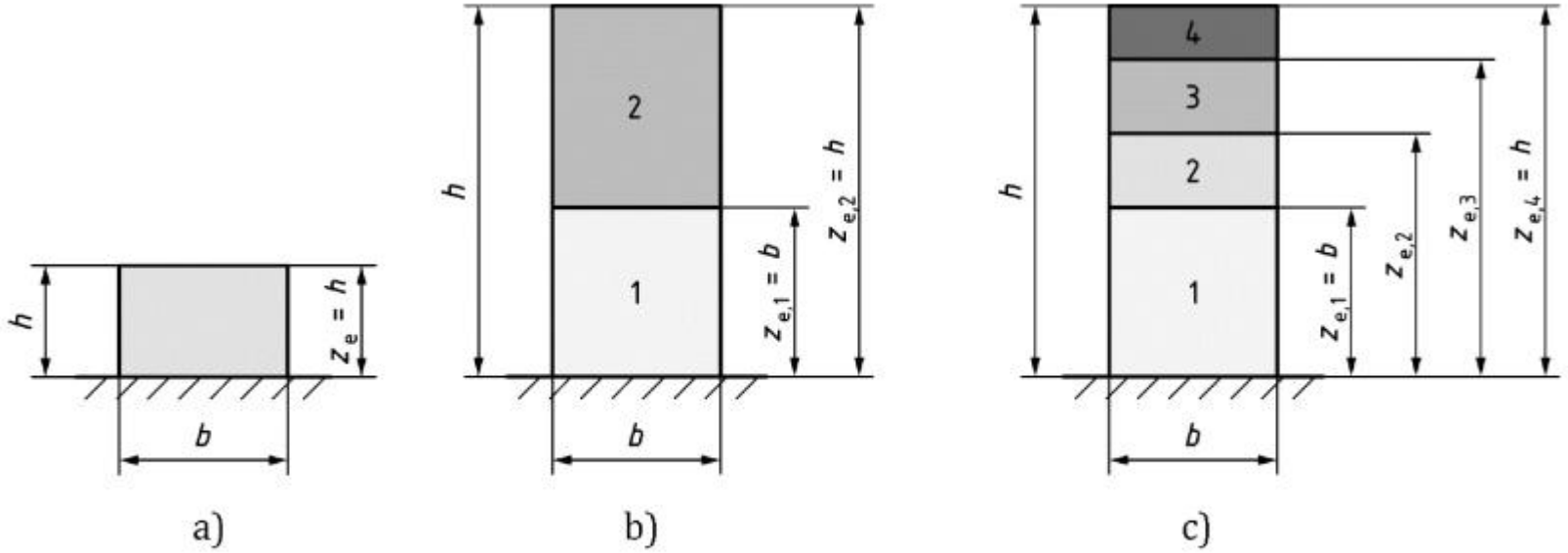
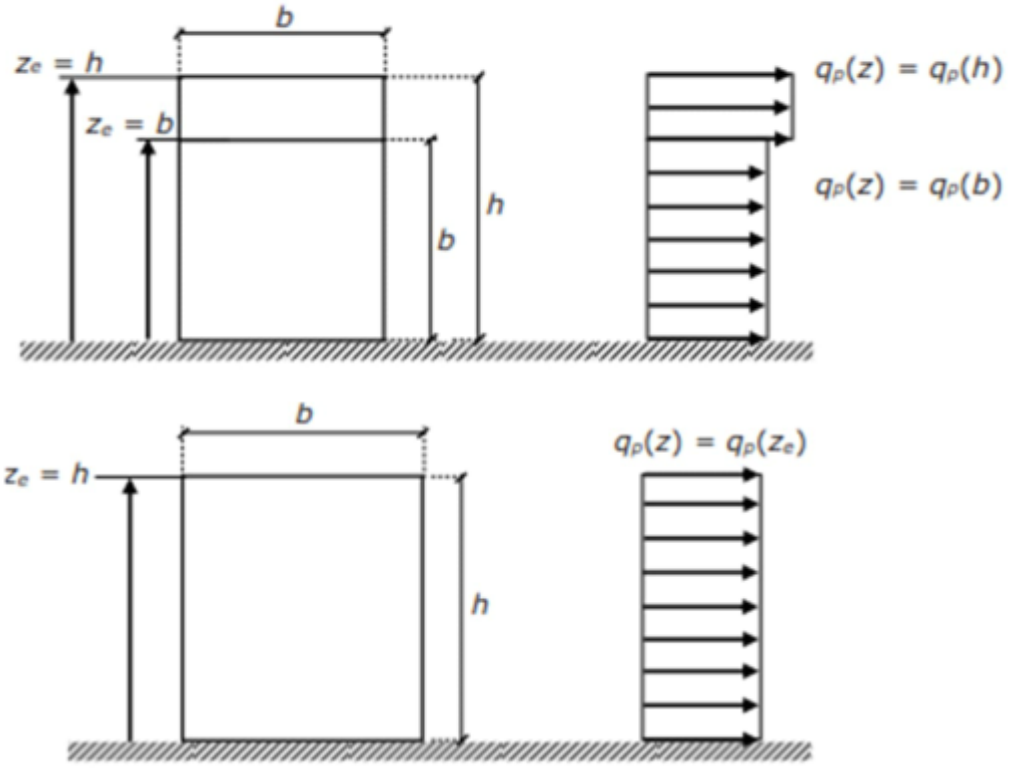


Figure B.3 — Reference height for zone D (windward wall) of buildings

Wind load:
EN 1991-1-4

Reference height: design example



$\theta = 0°$

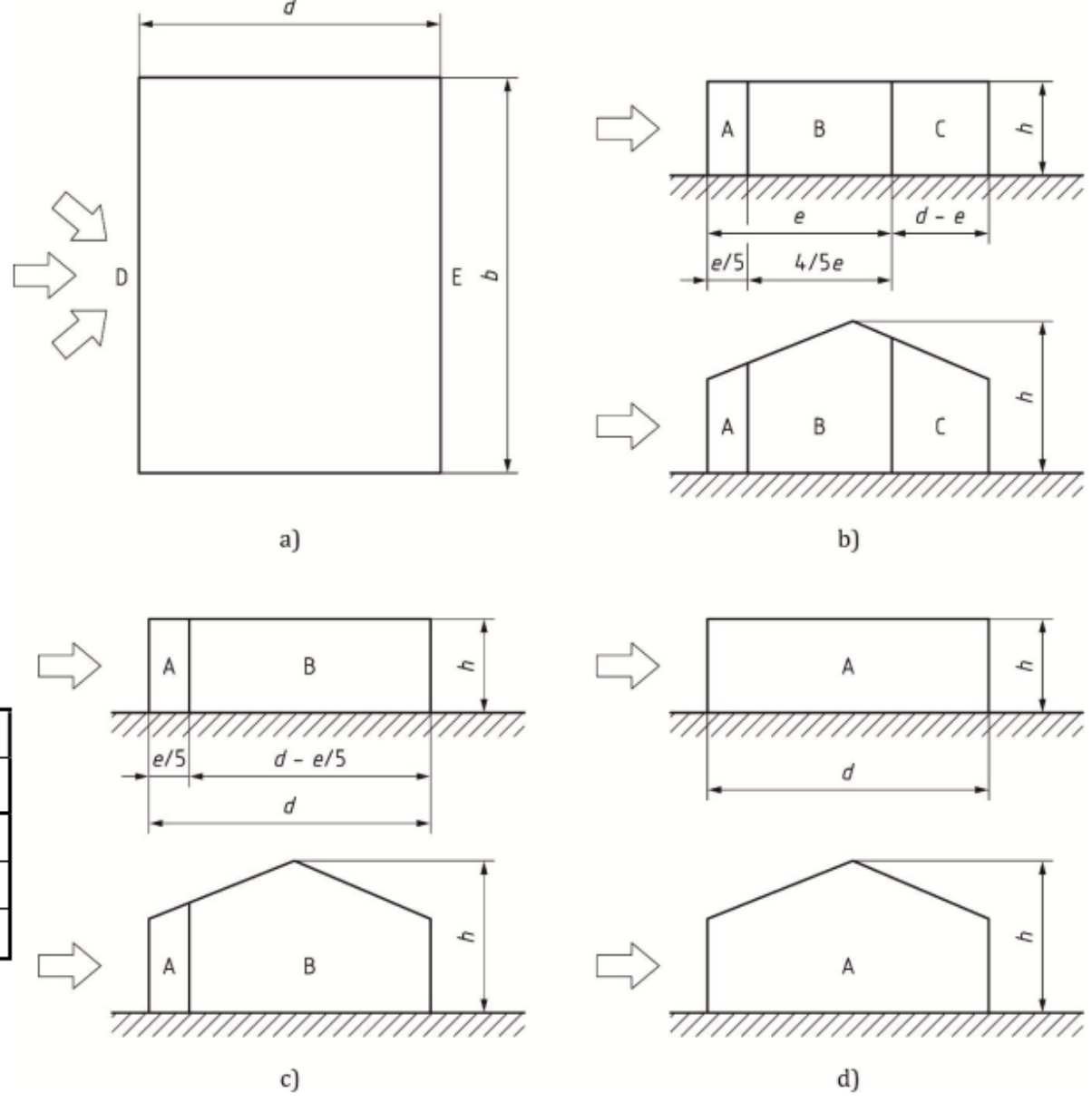
$\theta = 90°$

Wind load: EN 1991-1-4

External pressure coefficients

Table B.2 —External local pressure coefficients for vertical walls of rectangular plan buildings

h/d	Zone A		Zone B		Zone C		Zone D		Zone E	
	c_{pe10}	c_{pe1}	c_{pe10}	c_{pe1}	c_{pe10}	c_{pe1}	c_{pe10}	c_{pe1}	c_{pe10}	c_{pe1}
5	−1,2	−1,4	−0,8	−1,1	−0,5		+0,8	+1,0	−0,7	
1	−1,2	−1,4	−0,8	−1,1	−0,5		+0,8	+1,0	−0,5	
≤ 0,25	−1,2	−1,4	−0,8	−1,1	−0,5		+0,7	+1,0	−0,3	



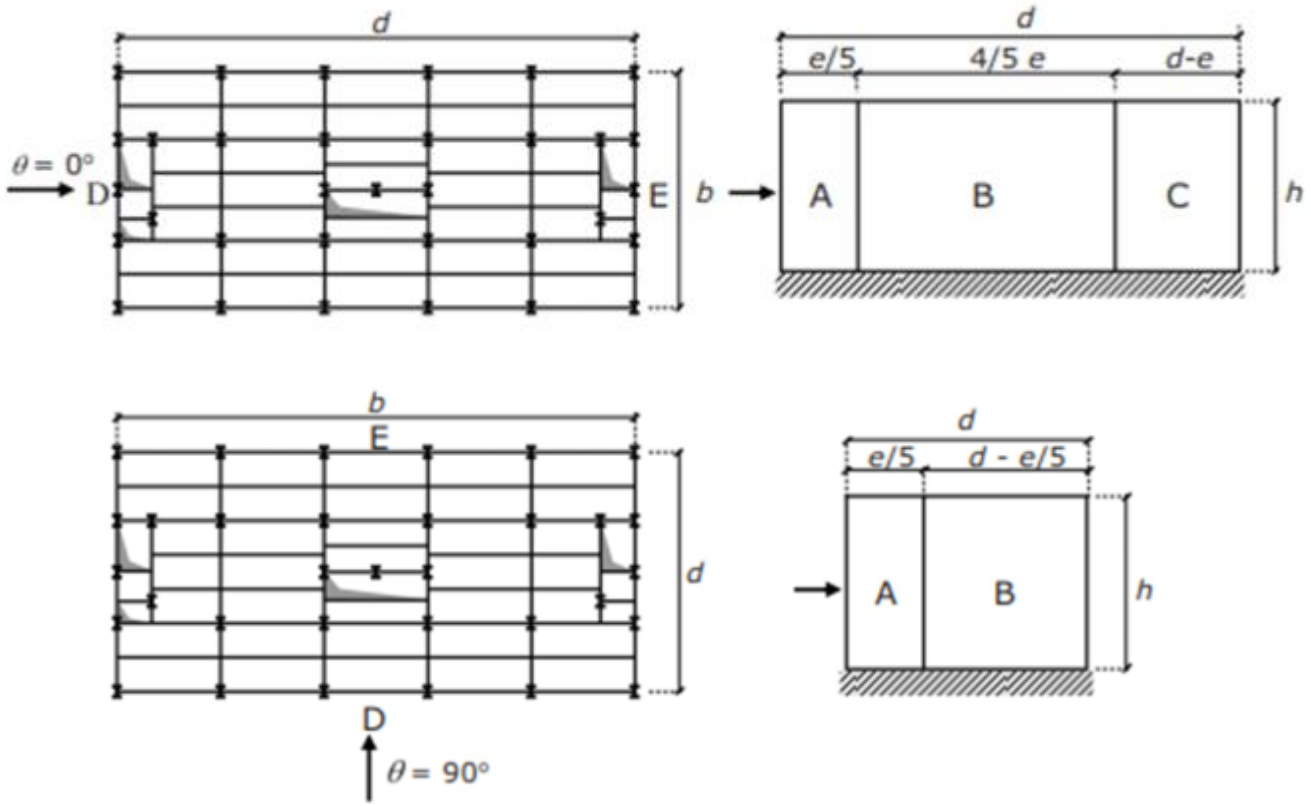
Key

a)	plan	d)	elevation for $e \geq 5d$
b)	elevation for $e < d$	e	$\min(b;2h)$
c)	elevation for $e \geq d$	⇨	wind direction

Figure B.6 — Zoning (plan dimensions) for the external pressure coefficients on vertical walls

Wind load: EN 1991-1-4

External pressure coefficients: design example

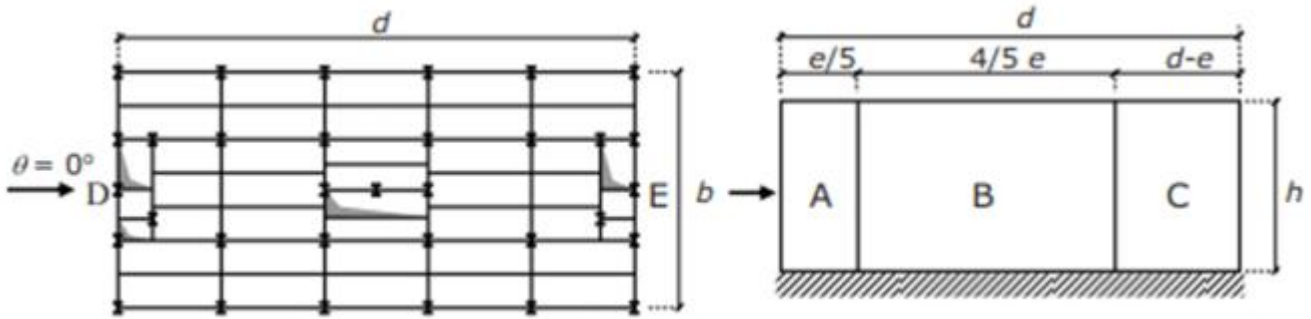


$\theta = 0°$

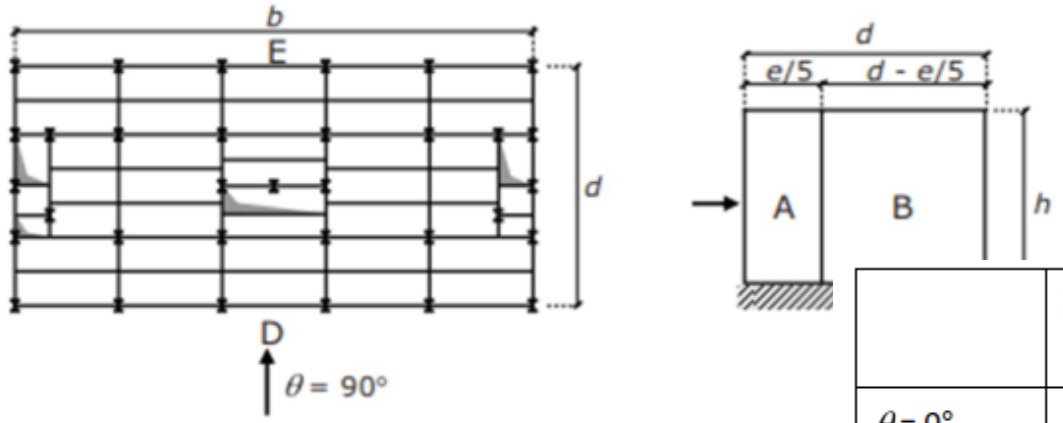
$\theta = 90°$

Wind load: EN 1991-1-4

External pressure coefficients: design example



$\theta = 0°$



$\theta = 90°$

Values of c_{pe}

From Table B.2:

	Zone	Correlation factor	A	B	C	D	E
$\theta = 0°$	$h/d = 0{,}73$	0,85	-1,20	-0,80	-0,50	+0,76	-0,43
$\theta = 90°$	$h/d = 1{,}57$	0,87	-1,20	-0,80	No C zone	+0,80	-0,53

Wind load: EN 1991-1-4

Internal pressure coefficients: design example

B.6 Internal surface pressures

(5) For buildings where the only openings originate from the background permeability, or for buildings with evenly distributed openings of similar size, then c_{pi} should be taken as the more onerous of +0,2 and −0,3 for exterior walls and roof.

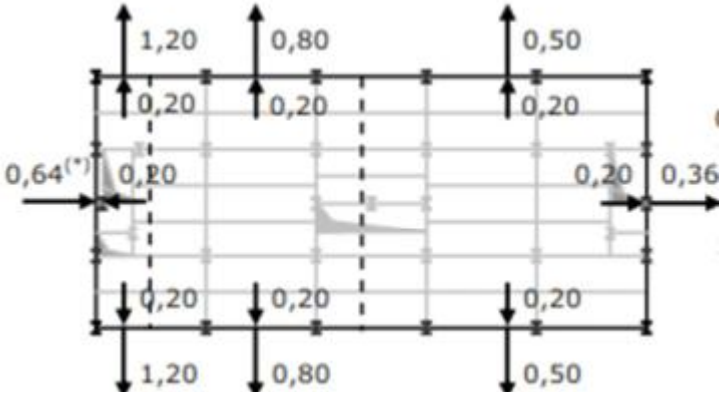
NOTE 1 Background permeability the effect of unintended or intended, distributed leakage of the façade finishing is typically in the range 0,01 % to 0,1 % of the face area. Reference values are given in Table B.18.

NOTE 2 Evenly distributed openings of similar size can be small openings such as doors, windows, ventilators, chimneys etc.

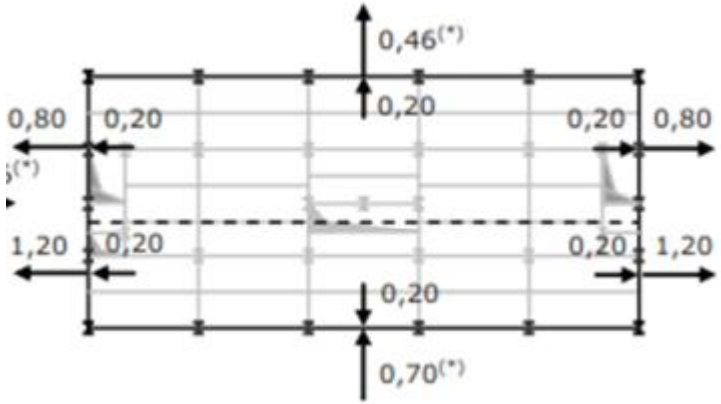
Wind load: EN 1991-1-4

External and internal pressure coefficients: design example

Values of c_{pe}, c_{pi}



θ = 0°



θ = 90°

Wind load: EN 1991-1-4

Main text contains general procedures

Structure-specific coefficients in Annexes

Structural factor

8 Structural factor c_{sd}

8.1 General

(1) The effect on wind actions from the non-simultaneous occurrence of peak wind pressures on the surface together with the effect of the along-wind vibrations of the structure due to along-wind turbulence should be taken into account through the structural factor c_{sd}.

NOTE 1 The structural factor c_{sd} can be derived using the detailed guidance in Annex E.

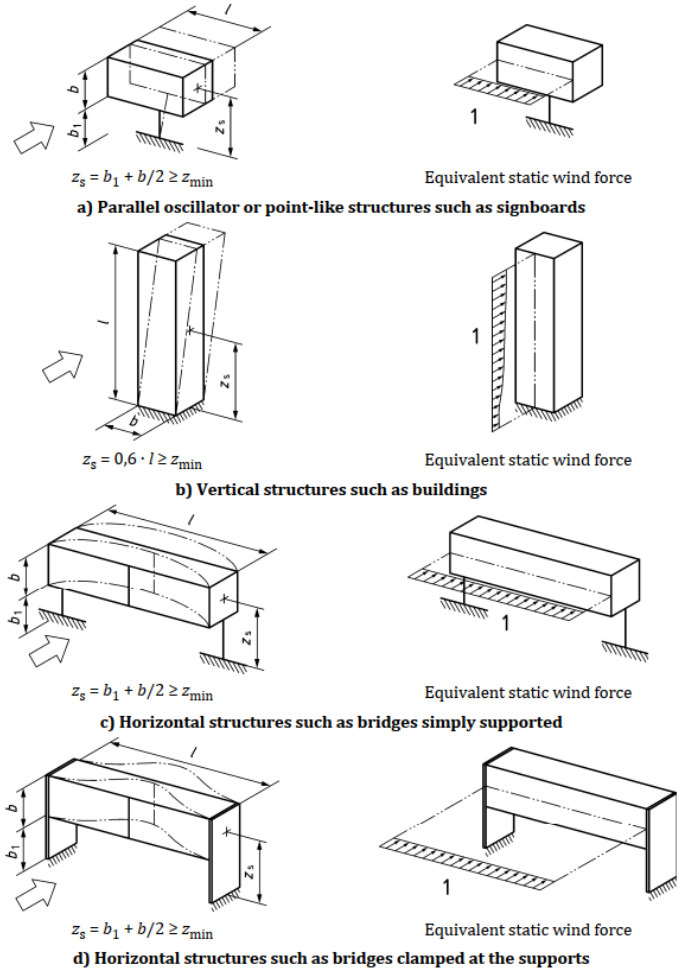
NOTE 2 The National Annex can give guidance on how to determine the structural factor, or the size and dynamic factors, separately.

Wind load: EN 1991-1-4

Structure-specific coefficients in Annexes

Structural factor: Annex E ➡ Informative

E.5.2 Structures covered by the procedure



Wind load: EN 1991-1-4

Structural factor: design example

- h=33m, b=21m, c_{sd} = 0,94
- h=33m, b=45m, c_{sd} = 0,87

E.5.3 c_{sd} values for buildings and chimneys

Multi-storey steel buildings:

Terrain roughness length – solid lines	z_o = 0,05 m
Terrain roughness length (dashed lines)	z_o = 0,3 m
Basic wind velocity	v_b = 28 m/s
Total logarithmic decrement for aerodynamic damping	δ_a = 0
Total logarithmic decrement for structural damping	δ_s = 0,05

The natural frequencies are derived from Formula (H.1).

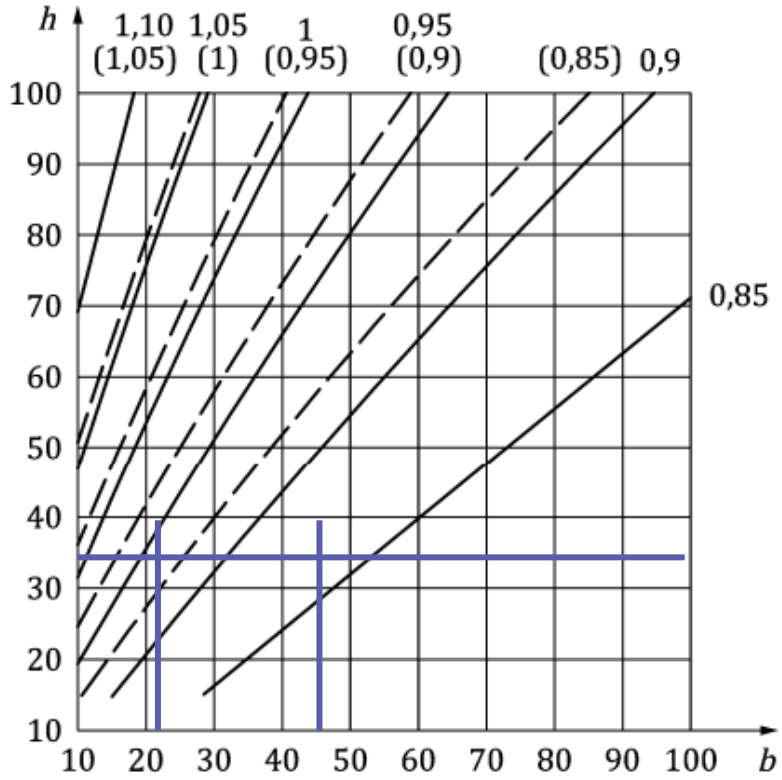


Figure E.3 —c_{sd} for multi-storey steel buildings with rectangular ground plan and vertical external walls, with regular distribution of stiffness and mass

Wind load: EN 1991-1-4

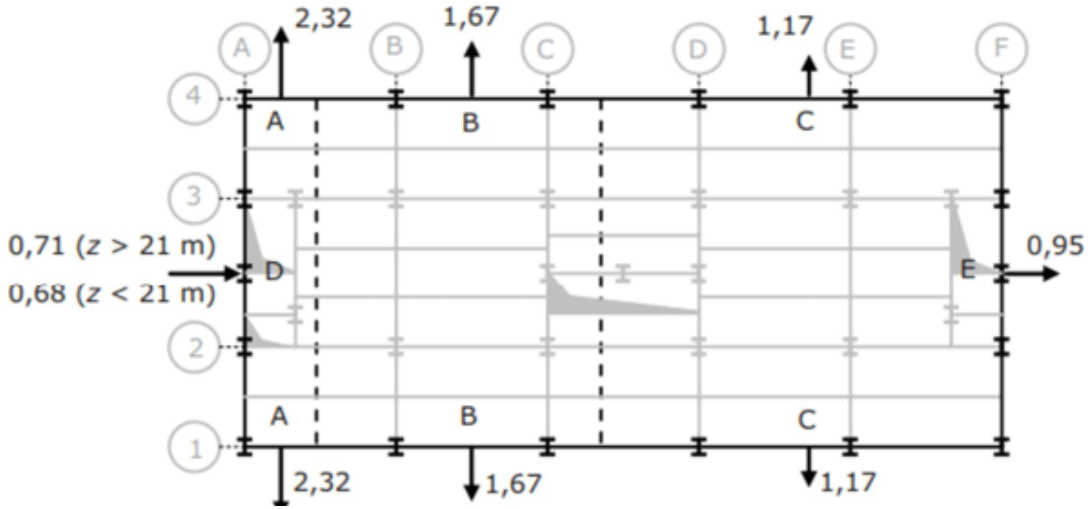
Calculation of pressure coefficients: design example

Combining q_p, c_{pe} or c_{pi}, c_{sd}:

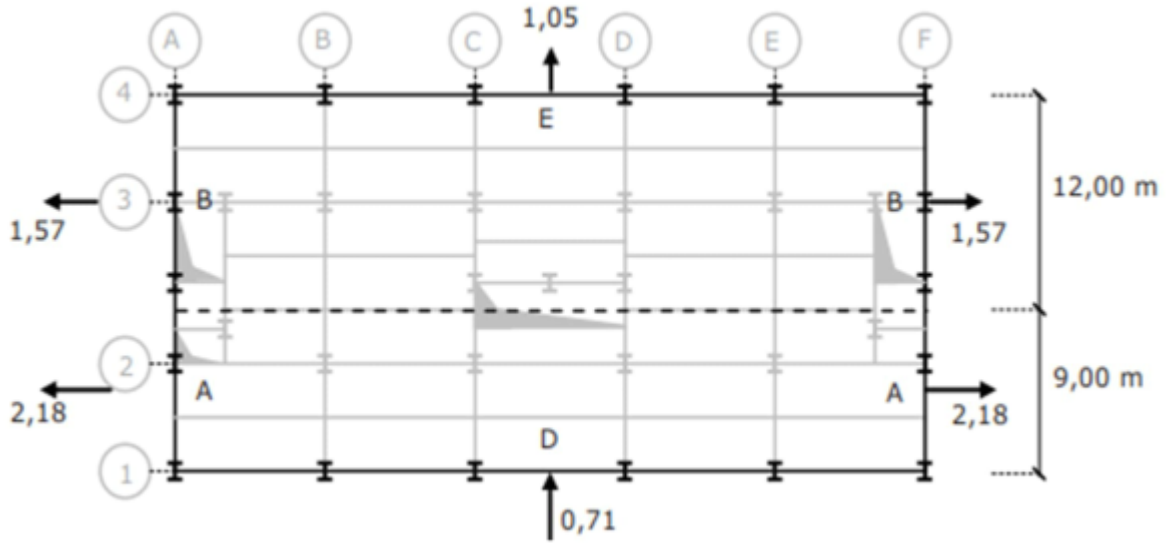
Pressures (to be multiplied by area to obtain force):

		A	B	C	D		E
					Z<21	z>21	
$\theta = 0°$	$c_{sd}\,p_e$	-1,97	-1,32	-0,82	+1,01	+1,06	-0,60
	p_i	+0,35	+0,35	+0,35	+0,33	+0,35	+0,35
$\theta = 90°$	$c_{sd}\,p_e$	-1,83	-1,22	No C zone	+1,06		-0,71
	p_i	+0,35	+0,35	No C zone	+0,35		+0,35

Wind load: EN 1991-1-4



$\theta = 0°$



$\theta = 90°$

mples

Design example: agenda

- Case study – building example
- Permanent actions
- Imposed loads
- Snow load
- Wind load

Thank you!

Mungo Stacy

Vice-chair of CEN/TC 250/SC 1