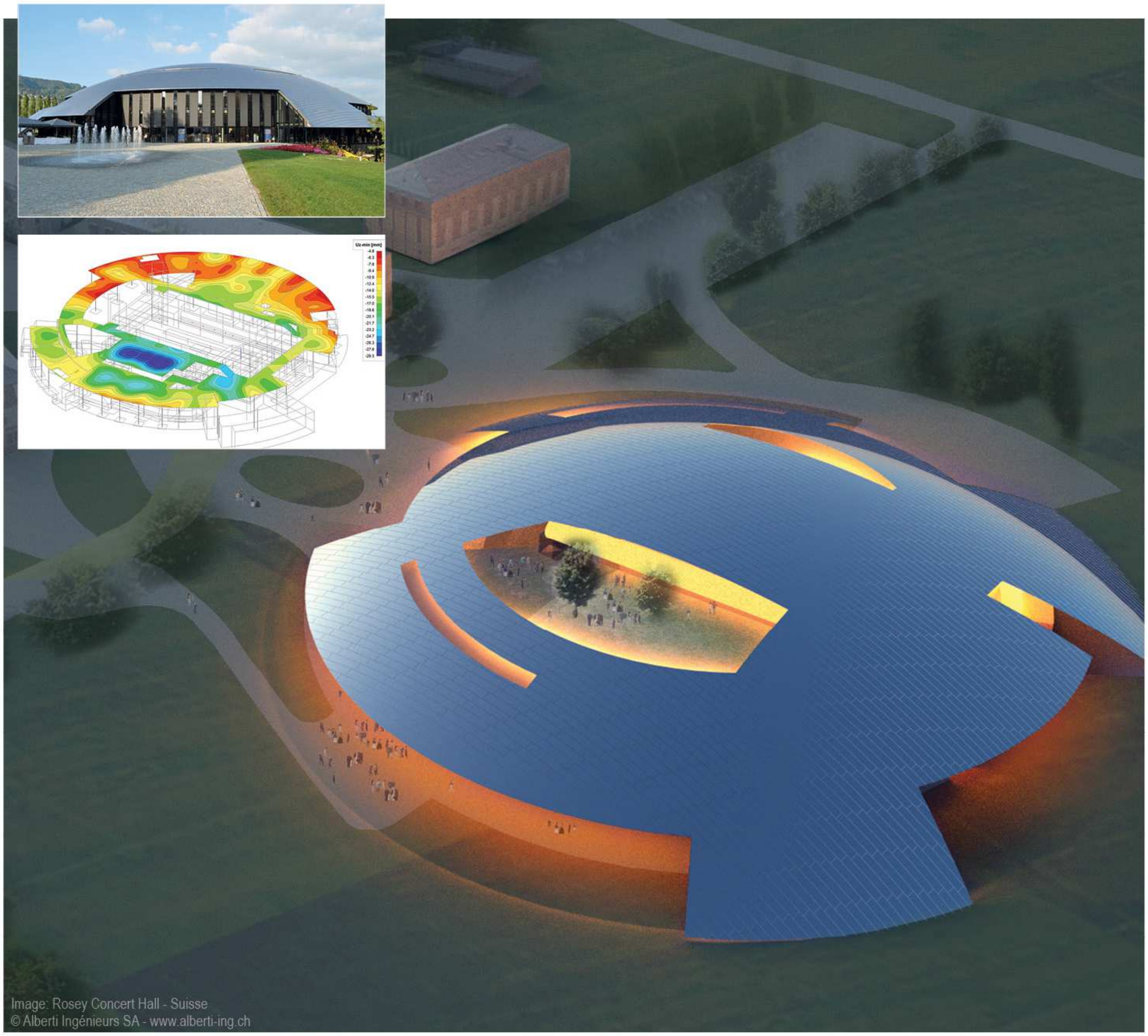
SCIA ENGINEER




# Eurocode Training

## EN 1991: Actions on structures

# Table of contents

# Overview

The Structural Eurocode programme comprises the following standards generally consisting of a number of parts:

| | | |
|---|---|---|
| EN 1990 | Eurocode: | Basis of structural design |
| EN 1991 | Eurocode 1: | Action on structures |
| EN 1992 | Eurocode 2: | Design of concrete structures |
| EN 1993 | Eurocode 3: | Design of steel structures |
| EN 1994 | Eurocode 4: | Design of composite steel and concrete structures |
| EN 1995 | Eurocode 5: | Design of timber structures |
| EN 1996 | Eurocode 6: | Design of masonry structures |
| EN 1997 | Eurocode 7: | Geotechnical design |
| EN 1998 | Eurocode 8: | Design of structures for earthquake resistance |
| EN 1999 | Eurocode 9: | Design of aluminium structures |

Eurocode 1 is divided in various parts:

| | |
|---|---|
| EN 1991-1 | General actions |
| EN 1991-2 | Traffic loads on bridges |
| EN 1991-3 | Actions induced by cranes and machinery |
| EN 1991-4 | Silos and tank |

In this Eurocode workshop some general actions will be discussed:

| | |
|---|---|
| EN 1991-1-1 | Densities, selfweight, imposed loads for buildings |
| EN 1991-1-2 | Actions on structures exposed to fire |
| EN 1991-1-3 | Snow loads |
| EN 1991-1-4 | Wind actions |
| EN 1991-1-5 | Thermal actions |
| EN 1991-1-6 | Actions during execution |
| EN 1991-1-7 | Accidental actions |

# EN 1991-1-1: Densities, selfweight, imposed loads for buildings

The following subjects are dealt with in EN 1991-1-1:

| | |
|---|---|
| Section 1: | General |
| Section 2: | Classification of actions |
| Section 3: | Design situations |
| Section 4: | Densities of construction and stored materials |
| Section 5: | Self-weight of construction works |
| Section 6: | Imposed loads on buildings |

**National annex for EN 1991-1-1**
This standard gives alternative procedures, values and recommendations for classes with notes indicating where National choices have to be made, therefore the National Standard implementing EN 1991-1-1 should have a National Annex containing all Nationally Determined Parameters to be used for the design of buildings and civil engineering works to be constructed in the relevant country.

National choice is allowed in EN 1991-1-1 through:

– 2.2(3),
– 5.2.3(1) to 5.2.3(5),
– 6.3.1.1 (Table 6.1),
– 6.3.1.2(1)P (Table 6.2),
– 6.3.1.2(10) & (11),
– 6.3.2.2 (1)P (Table 6.4),
– 6.3.2.2 (3),
– 6.3.3.2(1) (Table 6.8),
– 6.3.4.2 (Table 6.10) and
– 6.4 (1)(P) (Table 6.12)

# Section 1: General

## Scope:

EN 1991-1-1 gives design guidance and actions for the structural design of buildings and civil engineering works including some geotechnical aspects for the following subjects:

- Densities of construction materials and stored materials (section 4 and Annex A)
- Self-weight of construction works (Section 5)
- Imposed loads for buildings (Section 6) according to different categories of use:
  - residential, social, commercial and administration areas;
  - garage and vehicle traffic areas;
  - areas for storage and industrial activities;
  - roofs;
  - helicopter landing areas.

## Terms and Definitions

Definition of some terms, used in the EN 1991-1-1 are given:

- **bulk weight density** is the overall weight per unit volume of a material, including a normal distribution of micro-voids, voids and pores.
- **angle of repose** is the angle which the natural slope of the sides of a heaped pile of loose material makes to the horizontal.
- **gross weight of vehicle** contains the self-weight of the vehicle together with the maximum weight of the goods it is permitted to carry
- **partitions** are non load bearing walls

## Symbols

| | |
|---|---|
| $A$ | loaded area |
| $A_0$ | basic area |
| $Q_k$ | characteristic value of a variable concentrated load |
| $g_k$ | weight per unit area, or weight per unit length |
| $q_k$ | characteristic value of a uniformly distributed load, or line load |
| $\rho$ | bulk weight density |
| $\alpha$ | reduction factor |
| $\alpha_n$ | reduction factor |
| $\phi$ | angle of repose |

# Section 2: Classification of actions

## Self-weight

The self-weight of construction works should be classified as a **permanent fixed action**.

Where this self-weight can vary in time, it should be taken into account by the upper and lower characteristic values (see EN 1990, 4.1.2).

However, in some cases where it is free (e.g. for movable partitions, see 6.3.1.2(8)), it should be treated as an additional imposed load.

Also to be considered as permanent actions are loads due to ballast and earth loads on roofs. Variations in properties (moisture, content, dept) during the design life have to be taken into account.

## Imposed loads

Imposed loads shall be classified as **variable free actions**, unless otherwise specified in this standard.

Generally the imposed load is considered as a static load, which may be increased by a dynamic magnification factor.

Actions which cause significant acceleration of the structure or structural members shall be classified as dynamic actions and shall be considered using a dynamic analysis.

# Section 3: Design situations

## General

In each design situation identified in accordance with EN 1990, 3.2. (persistent, transient, accidental and seismic design situation) the most critical load cases should be considered. The most critical load cases should be determined taking into account the most unfavorable influence area of every single action.

## Permanent loads

The total self-weight of structural and non-structural members is taken as a single action when combinations of actions are being considered.

The following has to be taken into account in relevant design situations:

- Removal or adding of structural and non-structural elements
- Self-weight of new coatings, distribution conduits which are added after execution
- Water level
- Moisture content of bulk materials

## Imposed loads

### General

For areas which are intended to be subjected to different categories of loadings the design shall consider the most critical load case.

When imposed loads act simultaneously with other variable actions (e.g. wind, snow, cranes or machinery) the total of those imposed loads may be considered as a single action.

### Additional provisions for buildings

On roofs, imposed loads, and snow loads or wind actions should not be applied together simultaneously.

When the imposed load is considered as an accompanying action, in accordance with EN 1990, only one of the two factors $\psi$ (EN 1990, Table A1.1) and $\alpha_n$ (6.3.1.2(11)) shall be applied.

The imposed loads to be considered for serviceability limit state verifications should be specified in accordance with the service conditions and the requirements concerning the performance of the structure.

# Section 4: Densities of construction and stored materials

This section contains information about which densities of building materials and stored materials are to be used.

The term “density” ,in EN 1991-1-1, is used for the weight per unit volume, area or length.

In general density is random variable, which in some cases (e.g. in case when moisture content and degree of consolidation may affect the density) may have a considerable scatter.

Annex A gives mean values (which are usually accepted as the characteristic values) for densities and angles of repose for stored materials. When a range is given it is assumed that the mean value will be highly dependent on the source of the material and may be selected considering each individual project.

- Table A.1 - Construction materials-concrete and mortar
- Table A.2 - Construction materials-masonry
- Table A.3 - Construction materials-wood
- Table A.4 - Construction materials-metals
- Table A.5 - Construction materials- other materials
- Table A.6 - Bridge materials
- Table A.7 - Stored materials - building and construction
- Table A.8 - Stored products – agricultural
- Table A.9 - Stored products – foodstuffs
- Table A.10 - Stored products - liquids
- Table A.11 - Stored products - solid fuels
- Table A.12 - Stored products - industrial and general

For materials that are not in Annex A either:

- the characteristic value of density needs to be determined in the National Annex,
- a reliable direct assessment is carried out (eventually) according to EN 1990 Annex D

# Section 5: Self-weight of construction works

## Representation of actions

The self-weight of the construction should be calculated on the basis of the nominal dimensions and the characteristic values of the densities. It includes the structural and non-structural elements including fixed services as well as the weight of earth and ballast.

Non-structural elements include roofing, surfacing and coverings, partitions and linings, hand rails, safety barriers, parapets and kerbs, wall cladding, suspended ceiling, thermal insulation, bridge furniture and fixed services.

Fixed services include:

- equipments for lifts and moving stairways
- heating, ventilating and air conditioning equipment
- electrical equipment
- pipes without their contents
- cable trunking and conduits

## Characteristic values of self-weight

### General

Self-weight of construction elements shall be determined considering nominal dimensions (shown on drawings) and characteristic values of densities.

Upper and lower characteristics should be considered for densities of materials expected to consolidate during use, e.g. ballast on railway bridges.

### Additional provisions for buildings

For manufactured elements such as flooring systems, facades and ceilings, lifts and equipment for buildings, data may be provided by the manufacturer.

For determining the effect of the self-weight due to movable partitions, an equivalent uniformly distributed load shall be used and added to the imposed load.

### Additional provisions specific for bridges

Materials can consolidate, become saturated, during use. Also the variability of the thickness or dept may be large. Therefore upper and lower characteristic values of densities and nominal dimensions for non structural parts, such as ballast on railway bridges, or fill above buried structures should be taken into account.

.

# Section 6 Imposed loads on buildings

## Representation of actions

Imposed loads on buildings are those arising from occupancy. Values given in this section include :

- normal use by persons
- furniture and moveable objects
- vehicles
- rare events such as concentrations of people and furniture, or the moving or stacking of objects during times of re-organization and redecoration

Floor and roof areas in buildings are sub-divided into 10 categories (A,B,C,D,E,F,G,H,I,J and K) according to their use. Definitions of these areas are provide in tables 6.1, 6.3 and 6.7

| Category | Specific Use | Example |
|---|---|---|
| A | Areas for domestic and residential activities | Rooms in residential buildings and houses; bedrooms and wards in hospitals;<br>bedrooms in hotels and hostels kitchens and toilets. |
| B | Office areas | |
| C | Areas where people may congregate (with the exception of areas defined under category A, B, and D[1]) | **C1**: Areas with tables, etc.<br>e.g. areas in schools, cafés, restaurants, dining halls, reading rooms, receptions.<br><br>**C2**: Areas with fixed seats,<br>e.g. areas in churches, theatres or cinemas, conference rooms, lecture halls, assembly halls, waiting rooms, railway waiting rooms.<br><br>**C3:** Areas without obstacles for moving people, e.g. areas in museums, exhibition rooms, etc. and access areas in public and administration buildings, hotels, hospitals, railway station forecourts.<br><br>**C4**: Areas with possible physical activities, e.g. dance halls, gymnastic rooms, stages.<br><br>**C5**: Areas susceptible to large crowds, e.g. in buildings for public events like concert halls, sports halls including stands, terraces and access areas and railway platforms. |
| D | Shopping areas | **D1:** Areas in general retail shops<br><br>**D2**: Areas in department stores |
| [1] Attention is drawn to 6.3.1.1(2), in particular for C4 and C5. See EN 1990 when dynamic effects need to be considered. For Category E, see Table 6.3 | | |
| NOTE 1 Depending on their anticipated uses, areas likely to be categorised as C2, C3, C4 may be categorised as C5 by decision of the client and/or National annex.<br><br>NOTE 2 The National annex may provide sub categories to A, B, C1 to C5, D1 and D2<br><br>NOTE 3 See 6.3.2 for storage or industrial activity | | |

**Table 6.1 - Categories of use**

| Category | Specific use | Example |
|---|---|---|
| E1 | Areas susceptible to accumulation of goods, including access areas | Areas for storage use including storage of books and other documents. |
| E2 | Industrial use | |

**Table 6.3 -Categories of storage and industrial use**

| Categories of traffic areas | Specific Use | Examples |
|---|---|---|
| F | Traffic and parking areas for light vehicles (≤ 30 kN gross vehicle weight and ≤ 8 seats not including driver) | garages;<br>parking areas, parking halls |
| G | Traffic and parking areas for medium vehicles (>30 kN, ≤ 160 kN gross vehicle weight, on 2 axles) | access routes; delivery zones; zones accessible to fire engines (≤ 160 kN gross vehicle weight) |
| NOTE 1 Access to areas designed to category F should be limited by physical means built into the structure.<br><br>NOTE 2 Areas designed to categories F and G should be posted with the appropriate warning signs. | | |

**Table 6.7 - Traffic and parking areas in buildings**

Imposed loads specified in this section are represented by uniformly distributed loads, concentrated loads, line loads or combinations of these loads.

Heavy equipment (e.g. in communal kitchens, radiology or boiler rooms) are not included in this section.

# Load arrangements

## Floors, beams and roofs

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 unfavorable part of the influence area of the action effects considered. Where the loads on other storey's contribute to the resulting load effect, they may be considered as uniformly distributed (fixed) actions.

The imposed load may be reduced by the reduction factor $\alpha_A$ due to the extent of the loaded area A.

$$\alpha_A = \frac{5}{7}\psi_0 + \frac{A_0}{A} \leq 1$$

Where:

$A_0 = 10m^2$
A is the loaded area

The national annex may give an alternative method.

Remark: This value $\alpha_n$ can not be taken into account in the Netherlands (see National Annex).

## Columns and walls

For the design of a particular vertical element (column or wall) loaded from several storey's the total imposed load may be considered in each storey as uniformly distributed.

The imposed load acting on a vertical element from several storey's may be reduced by the factor $\alpha_n$ due to the number n (>2) of loaded storey's.

$$\alpha_n = \frac{2 + (n-2)\psi_0}{n}$$

Where:

n is the number of storeys (n>2) above the loaded structural elements from the same category.

# Characteristic values of Imposed Loads

## Residential, social, commercial and administration areas

Areas in residential, social, commercial and administration buildings shall be divided into categories according to their specific uses shown in Table 6.1.

Characteristic values $q_k$ (uniformly distributed load) and $Q_k$ (concentrated load) for these categories are given in table 6.2.

| Categories of loaded areas | $q_k$ [kN/m²] | $Q_k$ [kN] |
|---|---|---|
| **Category A** | | |
| **- Floors** | 1,5 to2,0 | 2,0 to 3,0 |
| **- Stairs** | 2,0 to4,0 | 2,0 to 4,0 |
| **- Balconies** | 2,5 to 4,0 | 2,0 to 3,0 |
| **Category B** | 2,0 to 3,0 | 1,5 to 4,5 |
| **Category C** | | |
| - C1 | 2,0 to 3,0 | 3,0 to 4,0 |
| - C2 | 3,0 to 4,0 | 2,5 to 7,0 (4,0) |
| - C3 | 3,0 to 5,0 | 4,0 to 7,0 |
| - C4 | 4,5 to 5,0 | 3,5 to 7,0 |
| - C5 | 5,0 to 7,5 | 3,5 to 4,5 |
| **category D** | | |
| - D1 | 4,0 to 5,0 | 3,5 to 7,0 (4,0) |
| - D2 | 4,0 to 5,0 | 3,5 to 7,0 |

**Table 6.2 - Imposed loads on floors, balconies and stairs in buildings**

Where a range is given in this table, the value may be set by the National annex. The recommended values, intended for separate application, are underlined. $q_k$ is intended for determination of general effects and $Q_k$ for local effects. The National annex may define different conditions of use of this table.

Where floors are subjected to multiple use, they shall be designed for the most unfavourable category of loading which produces the highest effects of actions (e.g. forces or deflection) in the member under consideration.

Provided that a floor allows a lateral distribution of loads, the self-weight of movable partitions may be considered as an equivalent uniformly distributed load $q_k$ which should be added to the imposed loads of floors obtained from Table 6.2. This defined uniformly distributed load is dependent on the self-weight of the partitions as follows:

- for movable partitions with a self-weight ≤ 1,0 kN/m wall length: $q_k$ =0,5 kN/m²;
- for movable partitions with a self-weight ≤ 2,0 kN/m wall length: $q_k$ =0,8 kN/m²;
- for movable partitions with a self-weight ≤ 3,0 kN/m wall length: $q_k$ =1,2 kN/m²;

For movable partition walls having greater self-weight than 3,0 kN/m, their actual weight, potential location and orientation should be considered.

## Areas for storage and industrial activities

Areas for storage and industrial activities shall be divided into the two categories according to Table 6.3.

Characteristic values for uniformly distributed loads ($q_k$) and concetraded loads ($Q_k$) for category E1 are given in table 6.4

| Categories of loaded areas | $q_k$ [kN/m$^2$] | $Q_k$ [kN] |
|---|---|---|
| Category E1 | 7,5 | 7,0 |

**Table 6.4 - Imposed loads on floors due to storage**

The loading arrangement shall be defined so that the most unfavorable conditions are obtained.

The characteristic value of the imposed loads need to be multiplied by a dynamic factor if appropriate.

For storage areas, the characteristic values of vertical loads should be derived by taking into account the density and the upper design values for stacking heights. Effects caused by filing and emptying need to be included in the design.

Actions due to forklifts should be considered as concentrated loads acting together with appropriate distributed loads (given in tables 6.2, 6.4, 6.8).

Forklifts are classified into 6 classes (see table 6.5) depending on net weight, dimensions and hoisting loads.

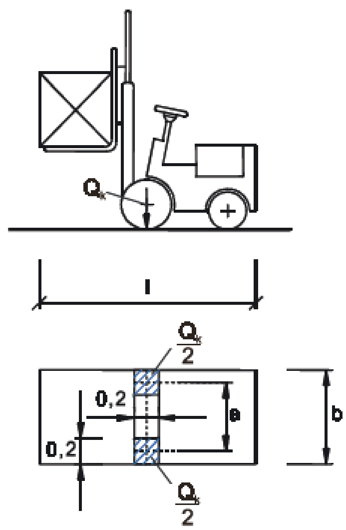



**Figure 6.1 - Dimensions of forklifts**

| Class of Forklift | Net weight [kN] | Hoisting load [kN] | Width of axle *a* [m] | Overall width *b* [m] | Overall length *l* [m] |
|---|---|---|---|---|---|
| FL 1 | 21 | 10 | 0,85 | 1,00 | 2,60 |
| FL 2 | 31 | 15 | 0,95 | 1,10 | 3,00 |
| FL 3 | 44 | 25 | 1,00 | 1,20 | 3,30 |
| FL 4 | 60 | 40 | 1,20 | 1,40 | 4,00 |
| FL 5 | 90 | 60 | 1,50 | 1,90 | 4,60 |
| FL 6 | 110 | 80 | 1,80 | 2,30 | 5,10 |

**Table 6.5 - Dimensions of forklift according to classes FL**

The statical vertical axle load $Q_k$ of a fork lift (related to its class) are given in table 6.6.

| Class of forklifts | Axle load $Q_k$ [kN] |
|---|---|
| FL 1 | 26 |
| FL 2 | 40 |
| FL 3 | 63 |
| FL 4 | 90 |
| FL 5 | 140 |
| FL 6 | 170 |

**Table 6.6 - Axle loads of forklifts**

The dynamic characteristic value $Q_{k,dyn}$ is obtained by multiplying the statical value with the dynamic factor φ.

$$Q_{k,dyn} = \varphi\, Q_k$$

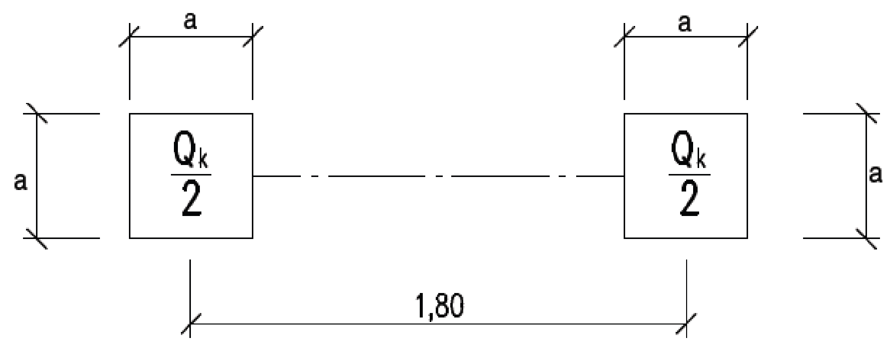
The dynamic factor takes into account the inertial effects caused by acceleration and deceleration of the hoisting load. For pneumatic tyres, φ should be taken equal to 1.4; for solid tyres, φ = 2.

Horizontal loads due to acceleration and deceleration may be taken as 30% of the vertical axle load $Q_k$.

## Garages and vehicle traffic areas (excluding bridges)

Traffic and parking areas in buildings are divided into 2 categories according to their accessibility for vehicles (see table 6.7).

The load model which should be used contains a single axle with a load $Q_k$ with dimensions according to Figure 6.2 and a uniformly distributed load $q_k$.




NOTE For category F (see Table 6.8) the width of the square surface is 100 mm and for category G (see Table 6.8) the width of a square surface is 200 mm.

**Figure 6.2 - Dimensions of axle load**

The characteristic values of $q_k$ and $Q_k$ are given in table 6.8.

**Table 6.8 - Imposed loads on garages and vehicle traffic areas**

| **Categories of traffic areas** | $q_k$ [kN/m$^2$] | $Q_k$ [kN] |
|---|---|---|
| **Category F**<br>Gross vehicle weight: ≤ 30 kN | $q_k$ | $Q_k$ |
| **Category G**<br>30 kN < gross vehicle weight ≤ 160 kN | 5,0 | $Q_k$ |
| NOTE 1 For category F. $q_k$ may be selected within the range 1,5 to 2,5 kN/m$^2$ and $Q_k$ may be selected within the range 10 to 20 kN.<br><br>NOTE 2 For category G, $Q_k$ may be selected within the range 40 to 90 kN.<br><br>NOTE 3 Where a range of values are given in Notes 1 & 2, the value may be set by the National annex.<br>The recommended values are underlined. | | |

## Roofs

Roofs shall be categorized according to their accessibility into three categories as shown in Table 6.9.

Imposed loads for roofs of category H are given in Table 6.10.

| **Roof** | $q_k$ [kN/m$^2$] | $Q_k$ [kN] |
|---|---|---|
| **Category H** | $q_k$ | $Q_k$ |
| NOTE 1 For category H $q_k$ may be selected within the range 0,00 kN/m$^2$ to 1,0 kN/m$^2$ and $Q_k$ may be selected within the range 0,9 kN to 1,5 kN.<br><br>Where a range is given the values may be set by the National Annex. The recommended values are:<br><br>$q_k = 0{,}4$ kN/m$^2$, $Q_k = 1{,}0$kN<br>NOTE 2 $q_k$ may be varied by the National Annex dependent upon the roof slope.<br><br>NOTE 3 $q_k$ may be assumed to act on an area A which may be set by the National Annex. The recommended value for $A$ is 10 m$^2$, within the range of zero to the whole area of the roof.<br><br>NOTE 4 See also 3.3.2 (1) | | |

**Table 6.10 - Imposed loads on roofs of category H**

Imposed loads for roofs of category I are given in Tables 6.2, 6.4 and 6.8 according to the specific use.

The loads for roofs of category K which provide areas for helicopter landing areas should be for the helicopter classes HC, see Table 6.11.

| Class of Helicopter | Take-off load $Q$ of helicopter | Take-off load $Q_k$ | Dimension of the loaded area (m x m) |
|---|---|---|---|
| HC1<br>HC2 | $Q \leq 20$ kN<br>20 kN< $Q \leq$ 60 kN | $Q_k = 20$ kN<br>$Q_k = 60$ kN | 0,2 x 0,2<br>0,3 x 0,3 |

**Table 6.11 - Imposed loads on roofs of category K for helicopters**

The dynamic factor $\varphi$ to be applied to the take-off load $Q_k$ to take account of impact effects may be taken as $\varphi = 1{,}40$.

## Horizontal loads on parapets and partition walls acting as barriers

For parapets not higher than 1,20 m, the characteristic values of the line load $q_k$ at the height of the partition wall or parapets should be taken from table 6.12.

When areas can become overcrowded because of public events e.g. for sports stadia, stands, stages, assembly halls or conference rooms, the line load should be taken according to category C5.

| **Loaded areas** | $q_k$ **[kN/m]** |
|---|---|
| **Category A** | $q_k$ |
| **Category B and C1** | $q_k$ |
| **Categories C2 –to C4 and D** | $q_k$ |
| **Category C5** | $q_k$ |
| **Category E** | $q_k$ |
| **Category F** | See Annex B |
| **Category G** | See Annex B |

NOTE 1 For categories A, B and C1, $q_k$ may be selected within the range 0,2 to 1,0 (0,5).
NOTE 2 For categories C2 to C4 and D $q_k$ may be selected within the range 0,8 kN/m –to 1,0 kN/m.
NOTE 3 For category C5 $q_k$ may be selected within the range 3,0 kN/m to 5,0 kN/m.
NOTE 4 For category E $q_k$ may be selected within the range 0,8 kN/m to 2,0 kN/m. For areas of category E the horizontal loads depend on the occupancy. Therefore the value of $q_k$ is defined as a minimum value and should be checked for the specific occupancy.
NOTE 5 Where a range of values is given in Notes 1, 2, 3 and 4, the value may be set by the National Annex. The recommended value is underlined.
NOTE 6 The National Annex may prescribe additional point loads $Q_k$ and/or hard or soft body impact specifications for analytical or experimental verification.

**Table 6.12 - Horizontal loads on partition walls and parapets**

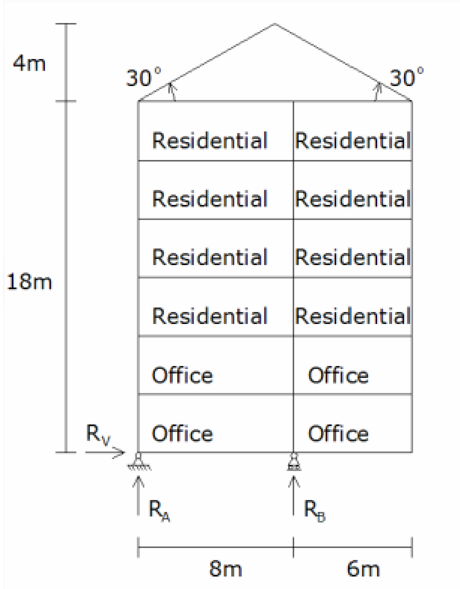
---

**Example: Loads.esa**

This example illustrates the Eurocode action on a six story building. This example is made using Ref.[8].

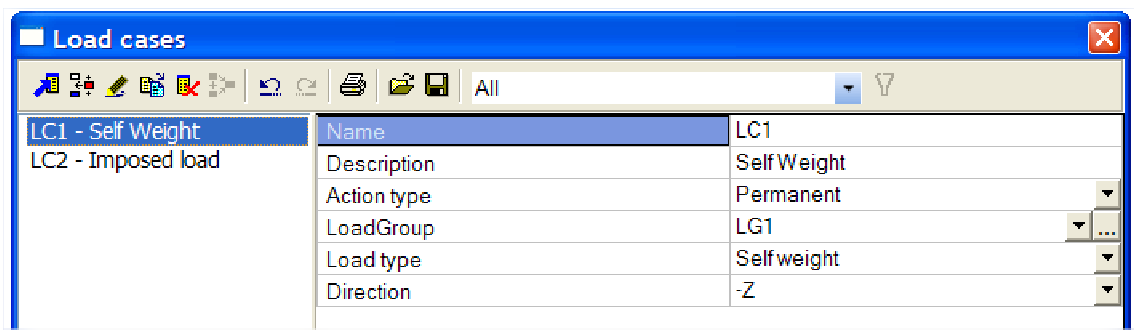
The characteristic actions and design actions on a six storey building are determined. The support reactions are calculated for the actions considered. These cover permanent actions and imposed loads. In the original example also the wind load and snow load are inputted.

The building is 10m long and supported at the ends along the building in the points A and B. The points A and B shown in the figure below illustrate two points, for which the support reactions are calculated.




**Characteristic Permanent Actions (G)**

The characteristic permanent action is inputted in SCIA Engineer as the self weight of the construction:




**Characteristic imposed loads (I)**

**Table 6.1 - Categories of use**

| Category | Specific Use | Example |
|---|---|---|
| A | Areas for domestic and residential activities | Rooms in residential buildings and houses; bedrooms and wards in hospitals; bedrooms in hotels and hostels kitchens and toilets. |
| B | Office areas | |
| C | Areas where people may congregate (with the exception of areas defined | **C1**: Areas with tables, etc. e.g. areas in schools, cafés, restaurants, dining halls, reading rooms, receptions, |

**Table 6.2 - Imposed loads on floors, balconies and stairs in buildings**

| Categories of loaded areas | $q_k$ [kN/m$^2$] | $Q_k$ [kN] |
|---|---|---|
| **Category A** | | |
| **- Floors** | 1,5 to2,0 | 2,0 to 3,0 |
| **- Stairs** | 2,0 to4,0 | 2,0 to 4,0 |
| **- Balconies** | 2,5 to 4,0 | 2,0 to 3,0 |
| **Category B** | 2,0 to 3,0 | 1,5 to 4,5 |

The characteristic imposed uniformly distributed loads q and the load combination factors $\psi_0$ for residential areas and office areas are as follows:

$q_{res}$ = 2,0 kN/m²
$\psi_{0, res}$ = 0,7

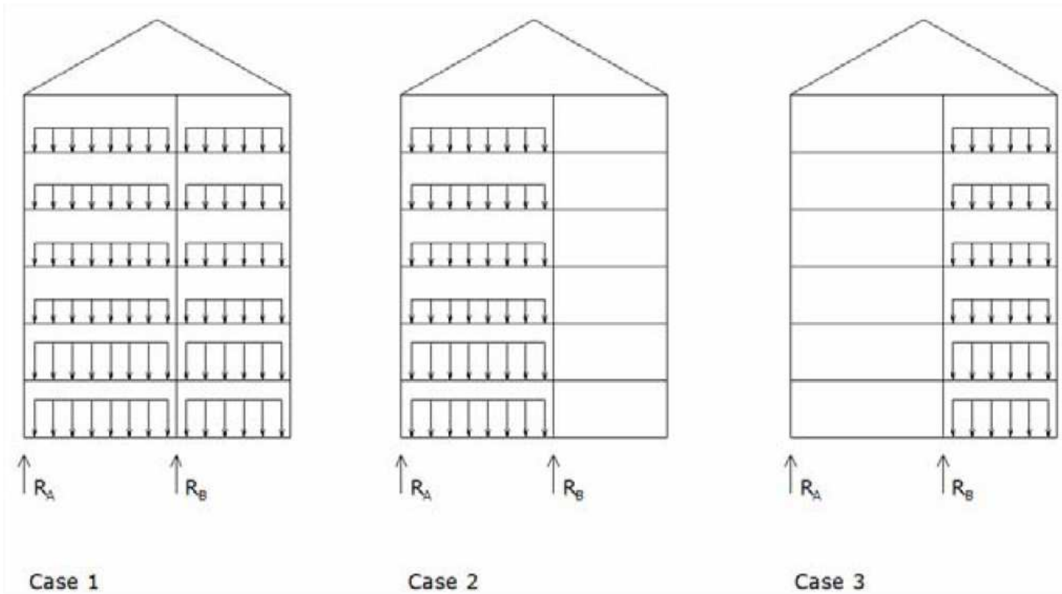
$q_{off}$ = 3,0 kN/m²
$\psi_{0, off}$ = 0,7

The recommended floor reduction factor $\alpha_A$ is calculated by:

$$\alpha_A = \frac{5}{7}\varphi_0 + \frac{A_0}{A} \leq 1{,}0$$

in which $\varphi_0$ is the above-mentioned load combination factor, the area $A_0$=10,0 m², and A is the loaded area.

There are three cases:




For the three cases shown below, the reduced imposed loads are given in table 3.1 below.

| Case no. | $\alpha_A$ | $\alpha_A q_{res}$ | $\alpha_A q_{off}$ |
|---|---|---|---|
| 1 | 0,571 | 1,14 | 1,71 |
| 2 | 0,625 | 1,25 | 1,88 |
| 3 | 0,667 | 1,33 | 2,00 |

Calculation for Case no 1 for $\alpha_A$:

$$\alpha_A = \frac{5}{7}\varphi_0 + \frac{A_0}{A} = \frac{5}{7}0{,}7 + \frac{10}{(8m + 6m)\cdot 10m} = 0{,}571$$

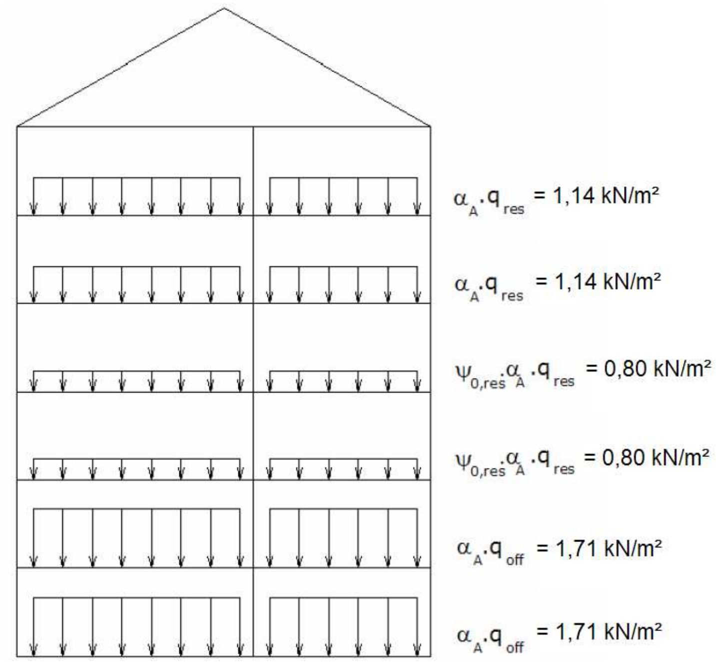
The recommended multi storey reduction factor $\alpha_n$ is calculated by:

$$\alpha_n = \frac{2 + (n-2)\cdot\varphi_0}{n}$$

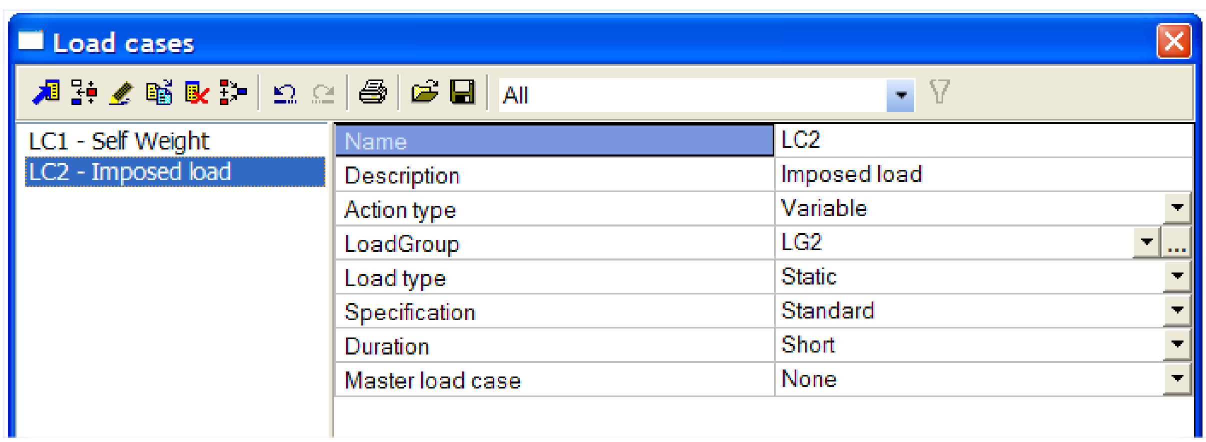
in which n is the number of storeys. Inserting the number of storeys gives:

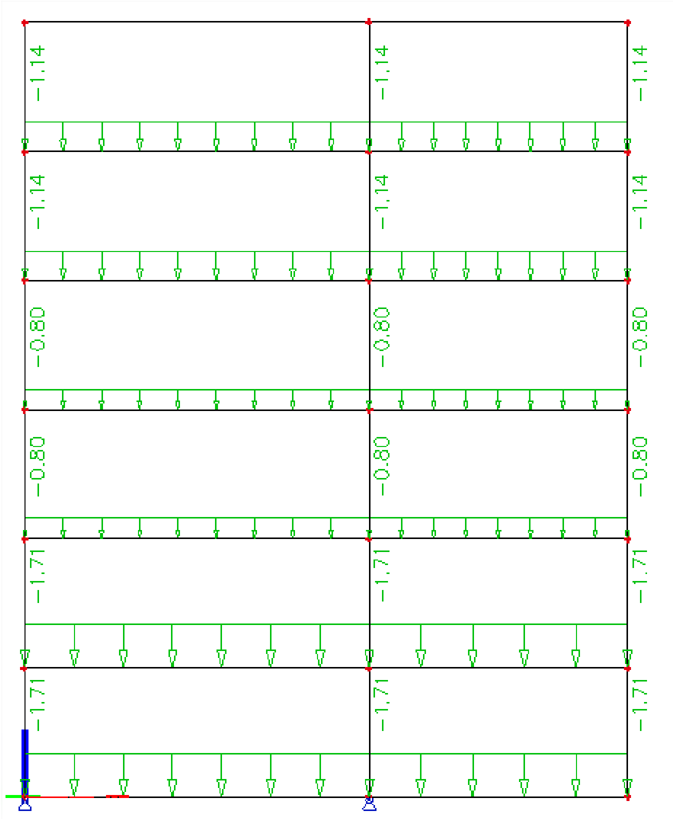
$$\alpha_{4,res} = \frac{2 + (4 - 2) \cdot 0{,}7}{4} = 0{,}85$$

$$\alpha_{2,off} = \frac{2 + (2 - 2) \cdot 0{,}7}{2} = 1{,}0$$




And in SCIA Engineer:




-1.14
-1.14
-1.14
-1.14
-1.14
-1.14
-0.80
-0.80
-0.80
-0.80
-0.80
-0.80
-1.71
-1.71
-1.71
-1.71
-1.71
-1.71

# Annexes

## Annex A (informative)

Annex A provides tables for nominal density of construction materials and nominal density of stored materials and angles of repose for stored materials

## Annex B (informative)

In Annex B rules for the design of vehicle barriers and parapets for car parks are given.

# EN 1991-1-3: Snow loads

The following subjects are dealt with in EN 1991-1-3:

| | |
|---|---|
| Section 1: | General |
| Section 2: | Classification of actions |
| Section 3: | Design situations |
| Section 4: | Snow load on the ground |
| Section 5: | Snow load on roofs |
| Section 6: | Local effects |

**National Annex for EN1991-1-3**
This standard gives alternative procedures, values and recommendations for classes with notes indicating where national choices may have to be made. Therefore the National Standard implementing EN 1991-1-3 should have a National Annex containing nationally determined parameters to be used for the design of buildings and civil engineering works to be constructed in the relevant country.

National choice is allowed in EN 1991-1-3 through clauses:

-1.1(2), 1.1(4)
-2(3), 2(4)
-3.3(1), 3.3(3),
-4.1(1), 4.2(1), 4.3(1)
-5.2(1), 5.2(4), 5.2(5), 5.2(6), 5.2(7), 5.3.3(4), 5.3.4(3), 5.3.5(1), 5.3.5(3),
-5.3.6(1), 5.3.6(3)
-6.2(2), 6.3(1), 6.3(2)
-A(1) (through Table A1)

# Section 1: General

## Scope:

EN 1991-1-3 gives guidance to determine the values of loads due to snow to be used for the structural design of buildings and civil engineering works.

This Part does not apply for sites at altitudes above 1 500 m, unless otherwise specified.

This Part does not give guidance on specialist aspects of snow loading, for example:

- impact snow loads resulting from snow sliding off or falling from a higher roof;
- the additional wind loads which could result from changes in shape or size of the construction works due to the presence of snow or the accretion of ice;
- loads in areas where snow is present all year round;
- ice loading;
- lateral loading due to snow (e.g. lateral loads exerted by drifts);
- snow loads on bridges.

*National annexes:*

*NF:*

- *Clause 1.1(2): La norme NF EN1993-1-3 est applicable jusqu'à l'altitude de 2000 mètres.*
- *Clause 1.1(3): Les conditions d'emploi du Tableau A.1 de la norme NF EN1991-1-3:2004 à prendre en compte sont les suivantes :*
    - *Pour les régions A1, C1 et E définies par la carte fournie en annexe de la présente norme : les conditions normales (nu chute exceptionnelle ni accumulation exceptionnelle de neige à considérer)*
    - *Pour les régions A2, B1, B2, C2 et D : les conditions normales et le cas B1 des conditions exceptionnelles (possibilité de chute exceptionnelle mais sans accumulation exceptionnelle).*

  *Toutefois, si des conditions locales particulières le justifient, les spécifications particulières du projet individuel peuvent prescrire de prendre en compte également le cas B3 des conditions exceptionnelles (possibilité de chute exceptionnelle avec accumulation exceptionnelle).*
- *Clause 1.1(4): Lorsque les spécifications particulières du projet individuel prescrivent de considérer le cas B3 des conditions exceptionnelles, elles peuvent faire référence à l'annexe B de la norme*

*NBN:*

- *§1.1(2): Niet van toepassing: de hoogtes in België zijn niet groter dan 1500m.*
- *§1.1(3) – No NA option: In België wordt geen onderscheid gemaakt in functie van de locatie*
- *§1.1(4): Bijlage B is niet van toepassing in België*

*NEN:*

- *§1.1(2): In the Netherlands no altitudes above 1 500 m can be found.*
- *§1.1(3) – No NA option: Reference is made to the relevant clauses regarding Annex A in this document.*
- *§1.1(4): Reference is made to the relevant clauses regarding Annex B in this document.*
  *NOTE As stated hereafter Annex B is not applicable.*
  *Consequently the following paragraphs are not relevant: 5.3.4 (4), 5.3.6 (3) and 6.2 (2).*

## Design assisted by testing

In some circumstances tests and proven and/or properly validated numerical methods may be used to obtain snow loads on the construction works.

## Terms and Definitions

Definition of some terms, used in the EN 1991-1-3 are given:

- **altitude of the site** is the height above mean sea level of the site where the structure is to be located, or is already located for an existing structure.
- **exceptional snow load on the ground** is the load of the snow layer on the ground resulting from a snow fall which has an exceptionally infrequent likelihood of occurring.
- **undrifted snow load on the roof** is the load arrangement which describes the uniformly distributed snow load on the roof, affected only by the shape of the roof, before any redistribution of snow due to other climatic actions.
- **drifted snow load on the roof** is the load arrangement which describes the snow load distribution resulting from snow having been moved from one location to another location on a roof, e.g. by the action of the wind.
- **roof snow load shape coefficient** is the ratio of the snow load on the roof to the undrifted snow load on the ground, without the influence of exposure and thermal effects.
- **thermal coefficient** is the coefficient defining the reduction of snow load on roofs as a function of the heat flux through the roof, causing snow melting.
- **exposure coefficient** is the coefficient defining the reduction or increase of load on a roof of an unheated building, as a fraction of the characteristic snow load on the ground.
- **load due to exceptional snow drift** is the load arrangement which describes the load of the snow layer on the roof, resulting from a snow deposition pattern which has an exceptionally infrequent likelihood of occurring.

## Symbols

| | |
|---|---|
| $C_e$ | Exposure coefficient |
| $C_t$ | Thermal coefficient |
| $C_{esl}$ | Coefficient for exceptional snow loads |
| A | Site altitude above sea level [m] |
| $S_e$ | Snow load per meter length due to overhang [kN/m] |
| $F_s$ | Force per meter length exerted by a sliding mass of snow [kN/m] |
| $l_s$ | Length of snow drift or snow loaded area [m] |
| s | Snow load on the roof [kN/m²] |
| $s_k$ | Characteristic value of snow on the ground at the relevant site [kN/m²] |
| $s_{Ad}$ | Design value of exceptional snow load on the ground [kN/m²] |
| $\alpha$ | Pitch of roof, measured from horizontal [°] |
| $\beta$ | Angle between the horizontal and the tangent to the curve for a cylindrical roof [°] |
| $\gamma$ | Weight density of snow [kN/m³] |
| $\mu$ | Snow load shape coefficient |
| $\psi_0$ | Factor for combination value of a variable action |
| $\psi_1$ | Factor for frequent value of a variable action |
| $\psi_2$ | Factor for quasi-permanent value of a variable action |

# Section 2 Classification of actions

Snow loads shall be classified as variable, fixed actions (see also 5.2), unless otherwise specified in this standard, see EN 1990:2002, 4.1.1 (1)P and 4.1.1 (4). Snow loads covered in this standard should be classified as static actions.

- **Variable**: *action for which the variation in magnitude with time is neither negligible nor monotonic*

- **Fixed**: *action that has a fixed distribution and position over the structure*

- **Static**: *action that does not cause significant acceleration of the structure or structural members*

In accordance with EN 1990:2002, 4.1.1 (2), for the particular condition of exceptional snow loads and loads due to exceptional snow may be treated as accidental actions depending on geographical locations. The National Annex may give the conditions of use (which may include geographical locations) of this clause.

*National annexes:*

*NF:*

- *§2(4) : Lorsque les spécifications particulières du projet individuel prescrivent de considérer le cas B3 des conditions exceptionnelles, les charges dues aux accumulations exceptionnelles sont traitées comme des actions accidentelles.*

*NBN:*

- *§2(3): OPMERKING : Uitzonderlijke sneeuwbelastingen zijn niet van toepassing in België.*
- *§2(4): Uitzonderlijke sneeuwdrift is niet van toepassing in België*

*NEN:*

- *§2(3): In the Netherlands no exceptional snow loads need to be considered.*

  *NOTE Consequently the following paragraphs are not relevant: 3.3 (1), 3.3 (3), 4.3 and 5.2*
- *§2(4): In the Netherlands no exceptional snow drifts need to be considered.*
  *NOTE Consequently the following paragraphs are not relevant: 1.1 (4), 3.3 (2), 5.2 (2), and 5.2 (3)P c).*

# Section 3: Design situations

## General

The relevant snow loads shall be determined for each design situation identified, in accordance with EN 1990:2002, 3.5.

For local effects described in Section 6 the persistent/transient design situation should be used.

A distinction is being made between normal and exceptional snow loads.

## Normal conditions

For locations where exceptional snow falls and exceptional snowdrifts are unlikely to occur, the transient/persistent design situation should be used for both the undrifted and the drifted snow load arrangements determined using 5.2(3)P a) and 5.3.

## Exceptional conditions

- For locations where exceptional snow falls may occur but not exceptional snow drifts, the following applies:

  a) the transient/persistent design situation should be used for both the undrifted and the drifted snow load arrangements

  b) the accidental design situation should be used for both the undrifted and the drifted snow load arrangements

  **NOTE** : See Annex A case B1.

- For locations where exceptional snow falls are unlikely to occur but exceptional snow drifts may occur the following applies:

  a) the transient/persistent design situation should be used for both the undrifted and the drifted snow load arrangements

  b) the accidental design situation should be used for snow load cases

  **NOTE**: See Annex A case B2.

- For locations where both exceptional snow falls and exceptional snow drifts may occur the following applies:

  a) the transient/persistent design situation should be used for both the undrifted and the drifted snow load arrangements

  b) the accidental design situation should be used for both the undrifted and the drifted snow load arrangements

  c) the accidental design situation should be used for the snow load cases

  **NOTE**: See Annex A case B3.

**Table A.1: Design Situations and load arrangements to be used for different locations**

| Normal | Exceptional conditions | | |
|---|---|---|---|
| Case A | Case B1 | Case B2 | Case B3 |
| No exceptional falls<br>No exceptional drift | Exceptional falls<br>No exceptional drift | No exceptional falls<br>Exceptional drift | Exceptional falls<br>Exceptional drift |
| 3.2(1) | 3.3(1) | 3.3(2) | 3.3(3) |
| *Persistent/transient design situation*<br><br>[1] undrifted $\mu_i\ C_e C_t\ s_k$<br><br>[2] drifted $\mu_i\ C_e C_t\ s_k$ | *Persistent/transient design situation*<br><br>[1] undrifted $\mu_i\ C_e C_t\ s_k$<br><br>[2] drifted $\mu_i\ C_e C_t\ s_k$<br><br>*Accidental design situation (where snow is the accidental action)*<br><br>[3] undrifted $\mu_i\ C_e C_t\ C_{esl}\ s_k$<br><br>[4] drifted $\mu_i\ C_e C_t\ C_{esl}\ s_k$ | *Persistent/transient design situation*<br><br>[1] undrifted $\mu_i\ C_e C_t\ s_k$<br><br>[2] drifted $\mu_i\ C_e C_t\ s_k$ (except for roof shapes in AnnexB)<br><br>*Accidental design situation (where snow is the accidental action)*<br><br>[3] drifted $\mu_i\ s_k$ (for roof shapes in AnnexB) | *Persistent/transient design situation*<br><br>[1] undrifted $\mu_i\ C_e C_t\ s_k$<br><br>[2] drifted $\mu_i\ C_e C_t\ s_k$ (except for roof shapes in AnnexB)<br><br>*Accidental design situation (where snow is the accidental action)*<br><br>[3] undrifted $\mu_i\ C_e C_t\ C_{esl}\ s_k$<br><br>[4] drifted $\mu_i\ s_k$ (for roof shapes in AnnexB) |
| **NOTE 1**: Exceptional conditions are defined according to the National Annex.<br>**NOTE 2**: For cases B1 and B3 the National Annex may define design situations which apply for the particular local effects described in section 6. | | | |

*National annexes (§3):*

*NF:*

- *Clause 3.3(1): Sauf indication contraire des spécifications particulières du projet individuel, il n'y a pas lieu, conformément au 6.1(2) de la norme, de considérer des charges exceptionnelles dans le cadre de l'application de la section 6.*
- *Clause 3.3(3): Sauf indication contraire des spécifications particulières du projet individuel, il n'y a pas lieu, conformément au 6.1(2) de la norme, de considérer des charges exceptionnelles dans le cadre de l'application de la section 6.*

*NBN:*

- *§3.3(1): OPMERKING : Geen enkele ontwerptoestand vereist de toepassing van uitzonderlijke omstandigheden in België.*
- *§3.3(3): OPMERKING : Geen enkele ontwerptoestand vereist de toepassing van uitzonderlijke omstandigheden in België.*

*National annexes (Annex A):*

*NF:*

*Les conditions exceptionnelles à prendre en compte, dans les zones A2, B1, B2, C2, et D de la carte annexée à la présente norme, sont celles du cas B1 du Tableau A.1 de la norme NF EN 1991-1-3 : une chute exceptionnelle, mais pas d'accumulation exceptionnelle. Sauf si certaines conditions particulières d'exposition la justifient, auquel cas les spécifications particulières du projet individuel devront la prévoir, la situation de projet accidentelle de type [4] (une chute exceptionnelle avec accumulation) n'a pas à être prise en compte.*

*Sauf indication contraire des spécifications particulières du projet individuel, il n'y a pas lieu, conformément au 6.1(2) de la norme NF EN 1991-1-3:2004, de considérer des situations de projet accidentelles du fait de la neige pour l'application de la section 6 (Effets locaux) de la norme.*

*NBN:*

Tabel A.1 OPMERKINGEN 1 en 2 : Enkel geval A van Tabel A.1 is van toepassing in België. De uitzonderlijke omstandigheden bepaald in Tabel A.1 zijn niet van toepassing in België (zie 3.3).

NEN:

Case A applies in the Netherlands.
Cases B1, B2 and B3 need not to be considered

# Section 4: Snow load on the ground

## Characteristic values

The characteristic value of snow load on the ground, $s_k$ , is the snow load on the ground based on an annual probability of exceedence of 0,02 excluding exceptional snow loads. The characteristic values of ground snow loads given are referred to mean recurrence interval (MRI) equal to 50 years.

The National Annex specifies the characteristic values to be used. To cover unusual local conditions the National Annex may additionally allow the client and the relevant authority to agree upon a different characteristic value from that specified for an individual project.

Annex C gives the European ground snow load maps. These maps give the characteristic values of the snow loads on sea level for relevant European countries. Several snow load maps are available for different climatic regions. These regions and the associated countries are:

| Climatic Region | Associated Countries |
|---|---|
| Alpine Region | South Germany, Austria, North-West France, North Italy |
| Central East | Denmark, Germany |
| Greece | Greece |
| Iberian Peninsula | Spain, Portugal |
| Mediterranean Region | Italy, South France |
| Central West | The Netherlands, Belgium, Luxembourg, France |
| Sweden, Finland | Sweden, Finland |
| UK, Republic of Ireland | UK, Ireland |
| further maps | Czech Republic, Norway, Iceland, Poland |

**Climatic regions and corresponding countries**

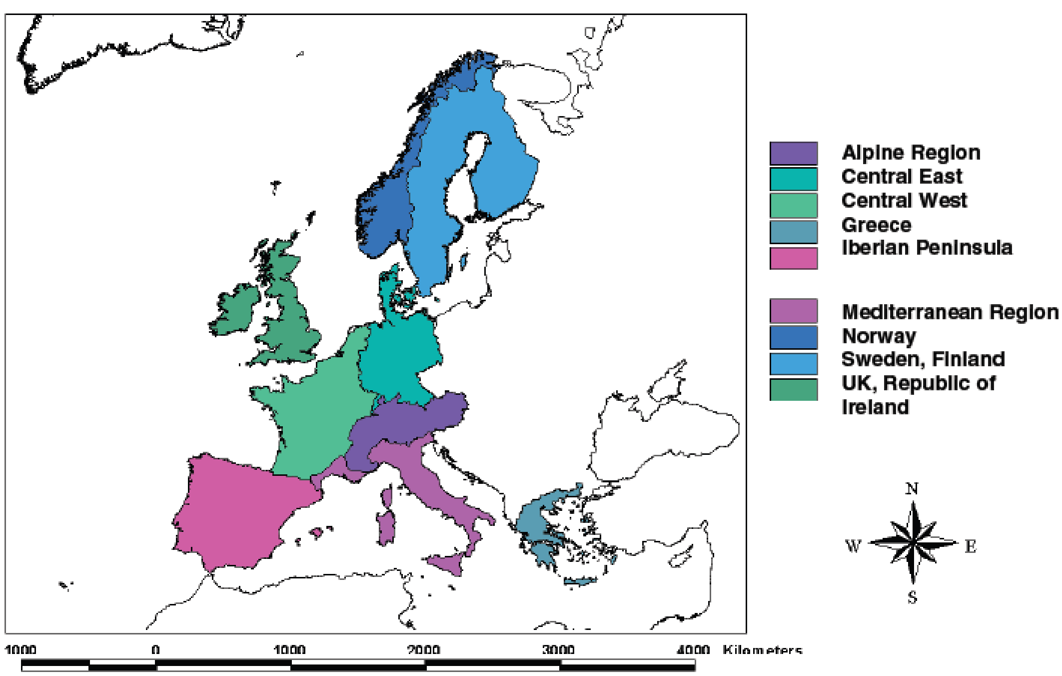



**Figure C.1. European Climatic regions**

The maps for the several climatic regions are subdivided into snow load zones *Z*. In addition to the values of the altitude, the numbers *Z* of these zones are the basic input parameters for the determination of the characteristic value of the ground snow load $s_k$.

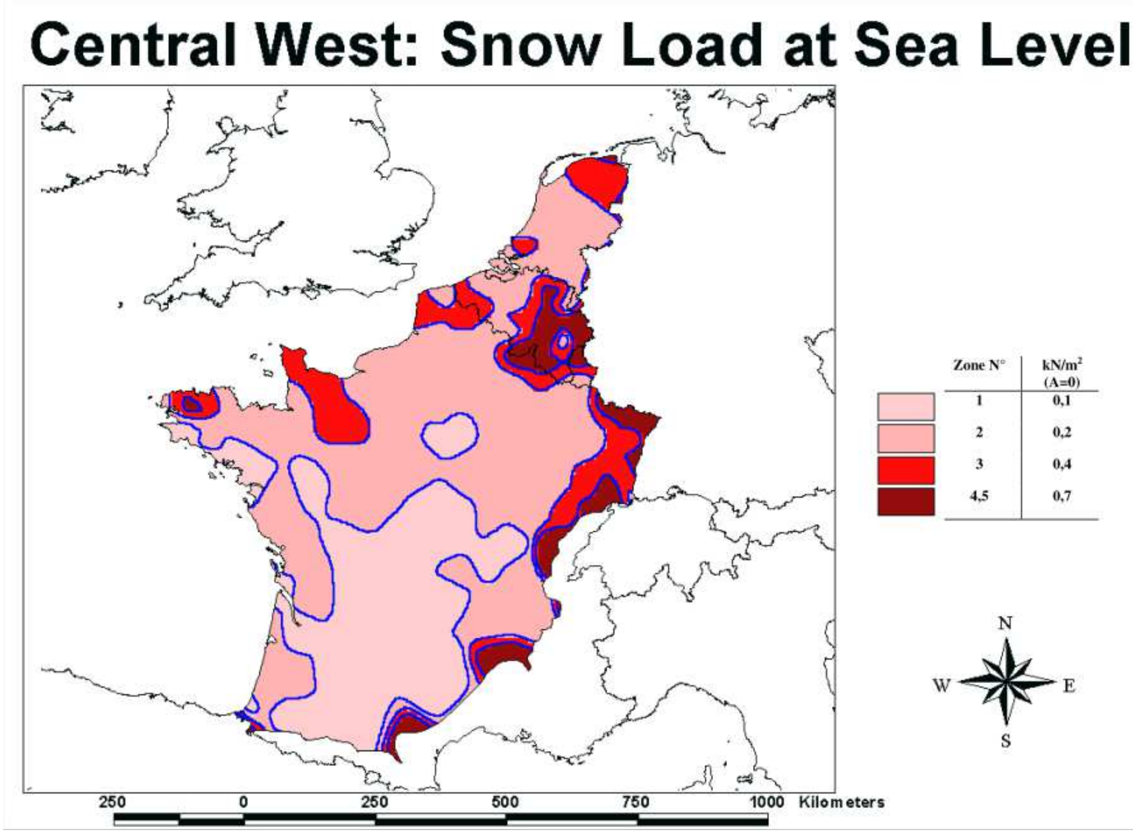
For each climatic region an equation for the calculation of the characteristic value of the ground snow load on the relevant altitude is given.

**Table C.1. Altitude - Snow Load Relationships**

| *Climatic Region* | *Expression* |
|---|---|
| Alpine Region | $s_k = (0{,}642Z + 0{,}009)\left[1 + \left(\frac{A}{728}\right)^2\right]$ |
| Central East | $s_k = (0{,}264Z - 0{,}002)\left[1 + \left(\frac{A}{256}\right)^2\right]$ |
| Greece | $s_k = (0{,}420Z - 0{,}030)\left[1 + \left(\frac{A}{917}\right)^2\right]$ |
| Iberian Peninsula | $s_k = (0{,}190Z - 0{,}095)\left[1 + \left(\frac{A}{524}\right)^2\right]$ |
| Mediterranean Region | $s_k = (0{,}498Z - 0{,}209)\left[1 + \left(\frac{A}{452}\right)^2\right]$ |
| Central West | $s_k = 0{,}164Z - 0{,}082 + \frac{A}{966}$ |
| Sweden, Finland | $s_k = 0{,}790Z + 0{,}375 + \frac{A}{336}$ |
| UK, Republic of Ireland | $s_k = 0{,}140Z - 0{,}1 + \frac{A}{501}$ |

$S_k$ is the characteristic snow load on the ground [kN/m²]
A is the site altitude above Sea Level [m]
Z is the zone number given on the map.

**Figure C.7**



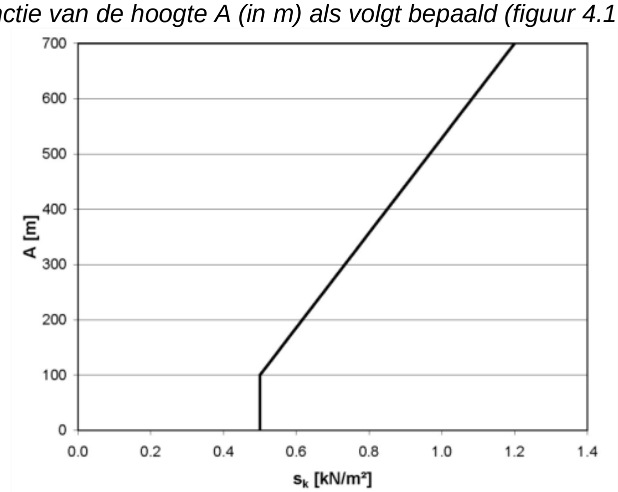

In special cases where more refined data is needed, the characteristic value of snow load on the ground ($s_k$) may be refined using an appropriate statistical analysis of long records taken in a well sheltered area near the site.

Where in particular locations, snow load records show individual, exceptional values which cannot be treated by the usual statistical methods, the characteristic values should be determined without taking into account these exceptional values. The exceptional values may be considered outside the usual statistical methods.

*<u>National annexes:</u>*

*NBN:*

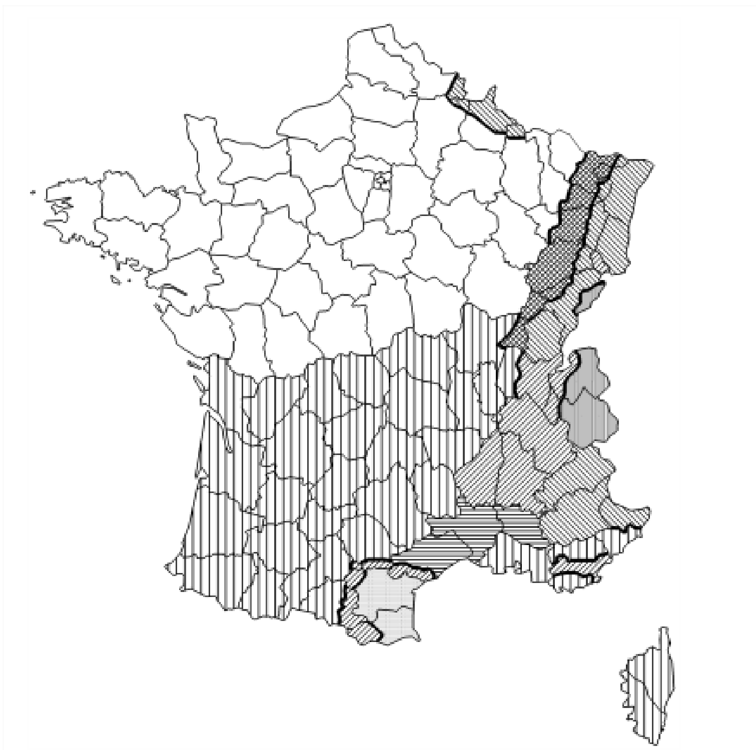
*In België is de karakteristieke waarde $s_k$ (in kN/m²) van de sneeuwbelasting op de grond in functie van de hoogte A (in m) als volgt bepaald (figuur 4.1 ANB):*



- *$s_k$ = 0,50 kN/m² voor A < 100 m*
- *$s_k$ = 0,50 + 0,007(A – 100)/6 voor 100 m < A < 700 m..*

*OPMERKING:*
*Bijlage C geeft geen Europese kaart van de sneeuwbelasting op de grond, maar wel kaarten van acht Europese klimaatgebieden die discontinue waarden vertonen aan de landsgrenzen. Dit is onder andere het geval tussen de gebieden Centraal-Oost en Centraal-West, langs de grens tussen België en Duitsland, hetgeen niet kan gerechtvaardigd worden door invloed van topografie .*
*Bovendien zijn de waarden van het gebied Centraal-West niet in overeenstemming met de resultaten van de metingen uitgevoerd in België. Bijlage C mag daarom niet toegepast worden in België.*

*NF: La Carte des valeurs des charges de neige à prendre en compte sur le territoire national :*



| Régions : | A1 | A2 | B1 | B2 | C1 | C2 | D | E |
|---|---|---|---|---|---|---|---|---|
| Valeur caractéristique ($S_k$) de la charge de neige sur le sol à une altitude inférieure à 200 m : | 0,45 | 0,45 | 0,55 | 0,55 | 0,65 | 0,65 | 0,90 | 1,40 |
| Valeur de calcul ($S_{Ad}$) de la charge exceptionnelle de neige sur le sol : | — | 1,00 | 1,00 | 1,35 | — | 1,35 | 1,80 | — |
| Loi de variation de la charge caractéristique pour une altitude supérieure à 200 : | $\Delta s_1$ | | | | | | | $\Delta s_2$ |

(charges en KN/m²)

| **Altitude A** | $\Delta s_1$ | $\Delta s_2$ |
|---|---|---|
| de 200 à 500 m | A/1000 – 0,20 | 1,5 A/1000 – 0,30 |
| de 500 à 1000 m | 1,5 A/1000 – 0,45 | 3,5 A/1000 – 1,30 |
| de 1000 à 2000 m | 3,5 A/1000 – 2,45 | 7 A/1000 – 4,80 |

*In this annex of NF those values will also be found in tables.*

NEN:
The characteristic values of the snow load on the ground (s k ) for every site in the Netherlands shall be taken as $s_k$ = 0,7 kN/m 2 .
NOTE 3 Consequently the following paragraphs are not relevant: 4.1 (2) and 4.1 (3).

## Other representative values

The other representative values for snow load on the roof are as follows:

- Combination value $\psi_0\ s$
- *Frequent value* $\psi_1\ s$
- *Quasi-permanent value* $\psi_2\ s$

The recommended values of the coefficients $\psi_0$, $\psi_1$ and $\psi_2$ for buildings are dependent upon the location of the site being considered.

**Table 4.1 Recommended values of coefficients $\psi_0$, $\psi_1$ and $\psi_2$ for buildings.**

| Regions | $\psi_0$ | $\psi_1$ | $\psi_2$ |
|---|---|---|---|
| Finland<br>Iceland<br>Norway<br>Sweden | 0,70 | 0,50 | 0,20 |
| Reminder of other CEN member states, for sites located at altitude H > 1000 m above sea level | 0,70 | 0,50 | 0,20 |
| Reminder of other CEN member states, for sites located at altitude H ≤ 1000 m above sea level | 0,50 | 0,20 | 0,00 |

*National annexes (Annex A):*

*NBN:*
*Tabel 4.1 is niet van toepassing. De waarden van de coëfficiënten $\psi_0$, $\psi_1$ en $\psi_2$ zijn bepaald door de Nationale Bijlage NBN EN 1990-1-ANB:2005, in Tabel A1.1 ANB voor de gebouwen en Tabel A2.1 ANB voor de bruggen.*

*NF:*
Le Tableau 4.1 est remplacé par le tableau suivant :

| | $\psi_0$ | $\psi_1$ | $\psi_2$ |
|---|---|---|---|
| Pour tous les sites dont l'altitude est supérieure à 1 000 mètres au dessus du niveau de la mer | 0,70 | 0,50 | 0,20 |
| Pour tous les sites dont l'altitude est inférieure à 1 000 mètres au dessus du niveau de la mer | 0,50 | 0,20 | 0 |

NEN:
In the National Annex of NEN-EN 1990 the following values are specified for snow loads:
$\psi_0 = 0$, $\psi_1 = 0{,}2$ *en* $\psi_2 = 0$.

## Treatment of exceptional snow loads on the ground

For locations where exceptional snow loads on the ground can occur, they may be determined by:

$$s_{Ad} = C_{esl}\, s_k$$

- $s_{Ad}$ is the design value of exceptional snow load on the ground for the given location;
- $C_{esl}$ is the coefficient for exceptional snow loads;
- $s_k$ is the characteristic value of snow load on the ground for a given location.

The coefficient $C_{esl}$ may be set by the National Annex. The recommended value for $C_{esl}$ is 2,0.

*National annexes (Annex A):*

*NBN:*
*De uitzonderlijke sneeuwbelastingen worden niet toegepast in België ($C_{esl}$ =1)*

*NF:*
*Les valeurs de $s_{Ad}$ sont données directement par la carte annexée à la présente norme. Il est rappelé que ces valeurs sont indépendantes de l'altitude.*

# Section 5: Snow load on roofs

## Nature of the load

The snow deposit on roof can have different patterns. The design has to take these patterns into account.

Properties of a roof or other factors causing different patterns can include:

- the shape of the roof;
- thermal properties;
- the roughness of its surface;
- the amount of heat generated under the roof;
- the proximity of nearby buildings;
- the surrounding terrain;
- the local meteorological climate, in particular its windiness, temperature variations, and likelihood of precipitation (either as rain or as snow).

## Load arrangements

Two primary load arrangements shall be taken into account:

- undrifted snow load on roofs
- drifted snow load on roofs

Snow loads on roofs shall be determined as follows:

- for the persistent / transient design situations

$$s = \mu_i C_e C_t s_k$$

- for the accidental design situations where exceptional snow load is the accidental action

$$s = \mu_i C_e C_t s_{Ad}$$

- for the accidental design situations where exceptional snow drift is the accidental action and where Annex B applies

$$s = \mu_i s_k$$

where:

- $\mu_i$ is the snow load shape coefficient
- $s_k$ is the characteristic value of snow load on the ground
- $s_{Ad}$ is the design value of exceptional snow load on the ground for a given location
- $C_e$ is the exposure coefficient
- $C_t$ is the thermal coefficient

The load should be assumed to act vertically and refer to a horizontal projection of the roof area.

When artificial removal or redistribution of snow on a roof is anticipated the roof should be designed for suitable load arrangements.

In regions with possible rainfalls on the snow and consecutive melting and freezing, snow loads on roofs should be increased, especially in cases where snow and ice can block the drainage system of the roof.

The exposure of a structure or of a roof to wind effects as well as the thermal transfer from a heated room through a non-insulated roof influences the accumulation of the snow. In order to take into account these effects EN 1991-1-3 introduces the exposure coefficient $C_e$ and the thermal coefficient $C_t$.

In general the exposure factor is chosen as $C_e = 1{,}0$. Only in case of exceptional circumstances where the roof is located either in open terrain or in surroundings which represent shelter the exposure factor should be adjusted. If the building is placed in open terrain the roof is denoted as “windswept” and the exposure coefficient may be reduced to $C_e = 0{,}8$. In case the building sheltered due to dense vegetation or due to adjacent higher buildings the exposure factor should be enhanced to $Ce = 1{,}2$.

**Table 5.1 Recommended values of *C*e for different topographies**

| **Topography** | $C_e$ |
|---|---|
| Windswept [a] | 0,8 |
| Normal [b] | 1,0 |
| Sheltered [c] | 1,2 |

[a] *Windswept topography*: flat unobstructed areas exposed on all sides without, or little shelter afforded by terrain, higher construction works or trees.

[b] *Normal topography*: areas where there is no significant removal of snow by wind on construction work, because of terrain, other construction works or trees.

[c] *Sheltered topography*: 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.

The thermal coefficient is also set to $C_t = 1{,}0$ for the normal situation. Only where roofs of heated buildings are not or poorly insulated (glass roofs / thermal transmittance > 1W/m²K) it is allowed to use a reduced factor $C_t$.

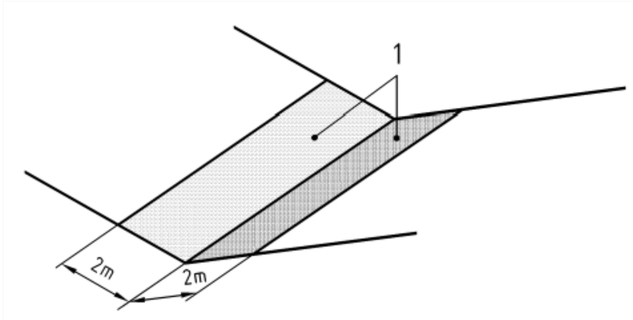
Recommendations for these reduction factors can be found in the National Annexes.

*National annexes:*

*NF:*
*§5.2(2): L’utilisation de l’annexe B est limitée aux cas où les spécifications particulières du projet individuel prescrivent de considérer le cas B3 du Tableau A.1 de la norme NF EN 1991-1-3:2004.*

*§5.2(5): Les spécifications particulières du projet individuel peuvent fixer, le cas échéant, des dispositions de charge adaptées.*

*§5.2(6): Lorsque la toiture comporte des zones dont la pente vis-à-vis de l’écoulement de l’eau est inférieure à 5 %, il y a lieu, pour tenir compte de l’augmentation en cas de pluie de la densité de la neige résultant des difficultés d’évacuation de l’eau, de majorer la charge de neige sur ces zones de 0,2 kN/m2 lorsque leur pente est inférieure à 3 %, et de 0,1 kN/m2 si elle est comprise entre 3 % et 5 %.*
*La majoration doit être appliquée non seulement à la zone à faible pente considérée mais également sur une distance de 2 mètres dans toutes les directions au-delà de ses limites.*
*La figure ci-dessous montre les surfaces où appliquer la majoration dans le cas particulier d’une noue, lorsque la pente du fil d’eau à l’intersection est faible (inférieure ou égale à 5 %) et celle de chacun des deux versants supérieure à 5 %. La zone à pente faible d’écoulement est en effet dans ce cas réduite à la ligne d’intersection,et les surfaces où appliquer la majoration sont uniquement celles correspondant à la distance des 2 mètres indiquée plus haut.*




*§5.2(7): Le Tableau 5.1 de la norme NF EN 1991-1-3 est remplacé par le tableau suivant :*

| | $C_e$ |
|---|---|
| Lorsque les conditions d'abri quasi permanentes des toitures dues aux bâtiments voisins conduisent à empêcher pratiquement le déplacement de la neige par le vent | 1,25 |
| Dans tous les autres cas | 1,0 |

*§5.2(8): Les bâtiments normalement chauffés étant systématiquement isolés, il convient de prendre $C_t$ = 1,0 sauf spécifications particulières dûment justifiées du projet individuel.*

*NBN:*
*§5.2(2): Bijlage B is niet van toepassing in België.*
*§5.2(5): Geen bijkomende bepalingen op nationaal vlak.*
*§5.2(6): Geen bijkomende bepalingen op nationaal vlak.*
*§5.2(7): In België beschouwt men $C_e$ = 1, onafhankelijk van de topografie.*
*§5.2(8): In België beschouwt men $C_t$ = 1 in alle gevallen.*

*NEN:*
*§5.2(5): No further guidance is given.*
*§5.2(6): In the Netherlands rainfalls on snow, melting and freezing need not be considered.*
*§5.2(7): The exposure coefficient for every site in the Netherlands is $C_e$ = 1,0.*
*§5.2(8): The thermal coefficient for every building in the Netherlands is $C_t$ = 1,0 unless specified differently in an other Dutch standard.*

## Roof shape coefficients

Low wind velocities are sufficient to blow snow accumulations from a roof or to cause a drift of snow which could lead to a local enhancement of the snow load. Roof shape coefficients are needed for an adjustment of the ground snow load to a snow load on the roof taking into account these effects. EN 1991-1-3 gives a set of roof coefficients for a variety of roof geometries.

For some roof shapes several load cases have to be taken into account because different load arrangements (with or without drifted snow) are possible. Then the most unfavorable load situation has to be chosen for the design.

Here the roof shape coefficients for undrifted and drifted snow load arrangements for all types of roofs are identified in this standard, with the exception of the consideration of exceptional snow drifts defined in Annex B, where its use is allowed.

## Monopitched roofs

The snow load shape coefficient $\mu_1$ that should be used for monopitch roofs is given in Table 5.2 and shown in Figure 5.1 and Figure 5.2.

**Table 5.2: Snow load shape coefficients**

| Angle of pitch of roof $\alpha$ | $0° \leq \alpha \leq 30°$ | $30° < \alpha < 60°$ | $\alpha \geq 60°$ |
|---|---|---|---|
| $\mu_1$ | 0,8 | 0,8(60 - $\alpha$)/30 | 0,0 |
| $\mu_2$ | 0,8 + 0,8 $\alpha$/30 | 1,6 | -- |

**Figure 5.1: Snow load shape coefficients**

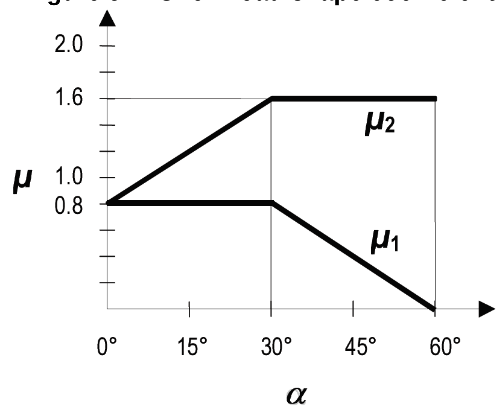
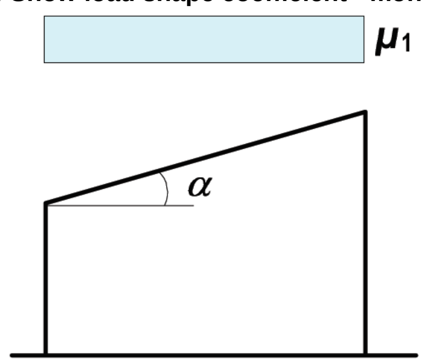



**Figure 5.2: Snow load shape coefficient - monopitch roof**




The values given in Table 5.2 apply when the snow is not prevented from sliding off the roof. Where snow fences or other obstructions exist or where the lower edge of the roof is terminated with a parapet, then the snow load shape coefficient should not be reduced below 0,8.

The load arrangement of Figure 5.2 should be used for both the undrifted and drifted load arrangements.

---

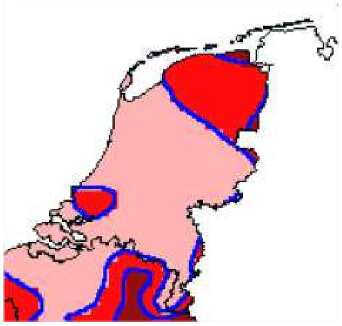
**Example: Snow_Monopitch.esa**

This example is situated in the Netherlands

Calculated following the standard EN1991-1-3:

$$s_k = 0{,}164Z - 0{,}082 + \frac{A}{966}$$

Met
Z =2
A = 0m

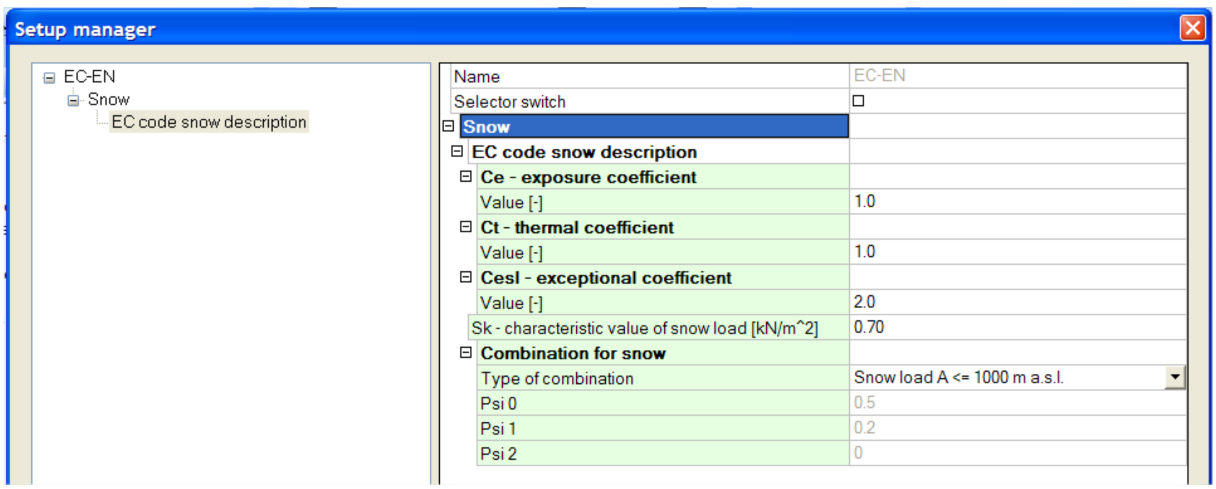


| | Zone N° | kN/m² (A=0) |
|---|---|---|
| | 1 | 0,1 |
| | 2 | 0,2 |
| | 3 | 0,4 |
| | 4,5 | 0,7 |

$s_k = 0{,}164 \cdot 2 - 0{,}082 + \frac{0}{966} = 0{,}25\ kN/m^2$

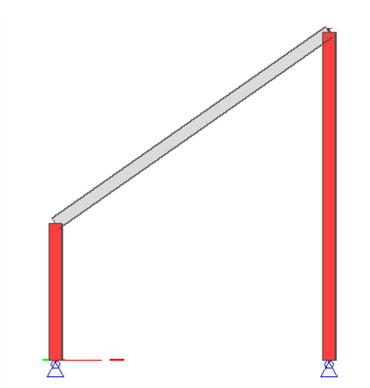
When using the NA from the Netherlands:

$s_k = 0{,}7\ kN/m^2$ (for every site)




We are calculating the persistent / transient design situation

$s = \mu_i \cdot C_e \cdot C_t \cdot s_k$

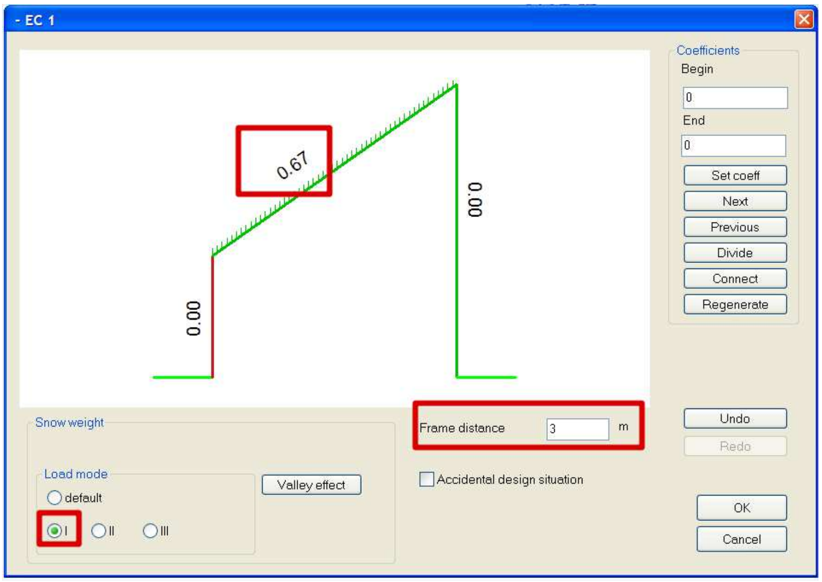


$\alpha = 35°$ => $\mu_1 = 0{,}8\frac{60-\alpha_1}{30} = 0{,}667$ => $s_1 = 0{,}667 \cdot 1 \cdot 1 \cdot 0{,}7 = 0{,}467$ kN/m²

This will be multiplied in SCIA Engineer by the Frame distance of 3m:

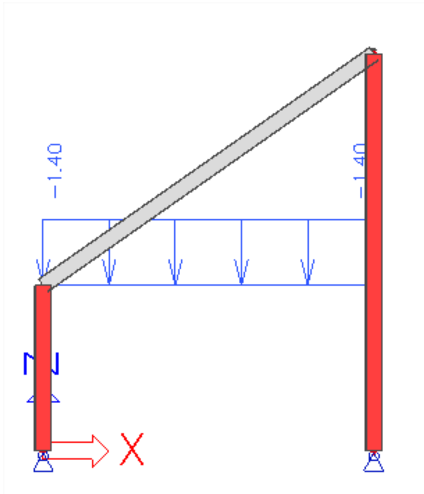
$s = 1{,}4\ kN/m$

In SCIA Engineer:
Run the Snow generator and fill in a Frame Distance of 3m




In this window $\mu_1$is indicated for the persistent / transient design situation (I).

Afterwards the line load of 1,4kN/m will be shown:



**Pitched roofs**

The snow load shape coefficients that should be used for pitched roofs are given in Figure 5.3.

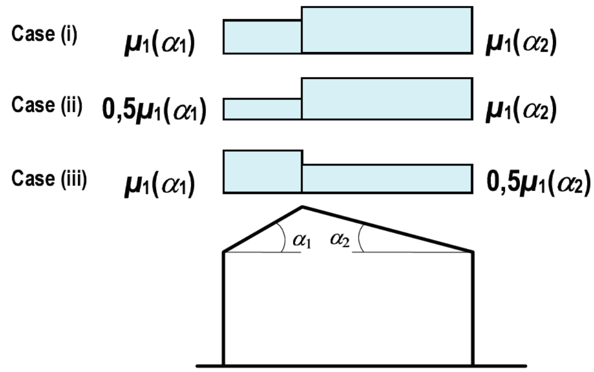



**Figure 5.3: Snow load shape coefficients - pitched roofs**

Three cases are to be considered:

- Case (i) represents the undrifted load arrangement.
- Case (ii) and Case (iii) represent the drifted load arrangement, unless specified for local conditions

**NOTE:** An alternative drifting load arrangement may be given in the National Annex.

$\mu_1$ is given in Table 5.2 and shown in Figure 5.1.

*National annexes:*

*NF:*
*§5.3.3(4): La disposition de charge avec accumulation à considérer est celle définie par la norme, sauf lorsque les spécifications particulières du projet individuel définissent une disposition différente justifiée par les conditions locales.*

*NBN :*
*§5.3.3(4): Geen complementaire nationale bepalingen*

*NEN :*
*§5.3.3(4): No alternative drifting load arrangement is given*

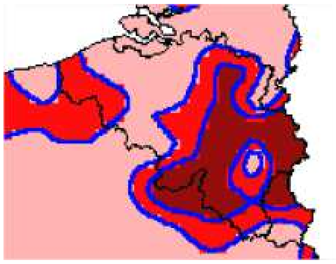
**Example: Snow_Duopitch.esa**

This example is situated in Belgium

Calculated following the standard EN1991-1-3:

$$s_k = 0{,}164Z - 0{,}082 + \frac{A}{966}$$

Met
Z =3
A = 300m

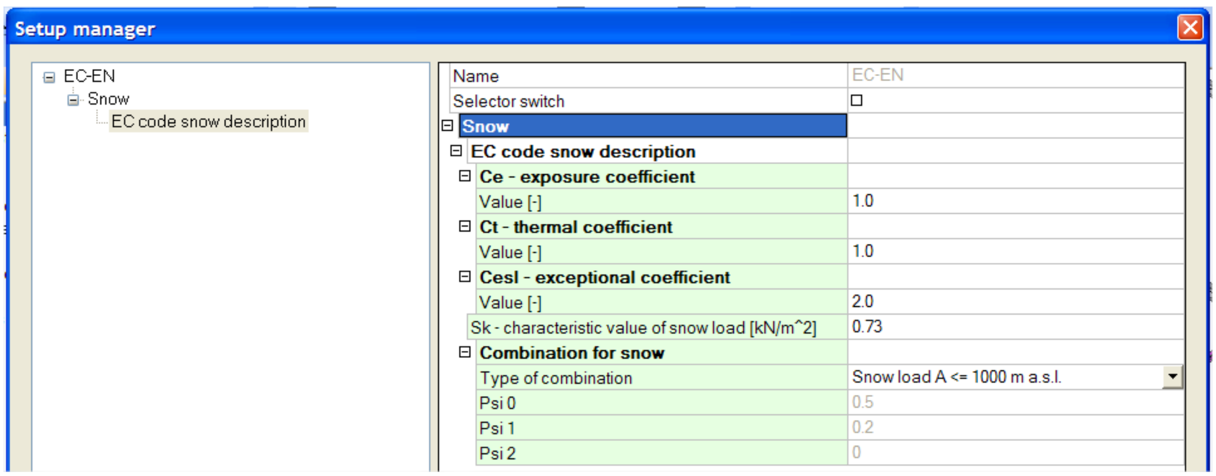


| | Zone N° | kN/m² (A=0) |
|---|---|---|
| | 1 | 0,1 |
| | 2 | 0,2 |
| | 3 | 0,4 |
| | 4,5 | 0,7 |

$$s_k = 0{,}164 \cdot 3 - 0{,}082 + \frac{300}{966} = 0{,}72 kN/m^2$$

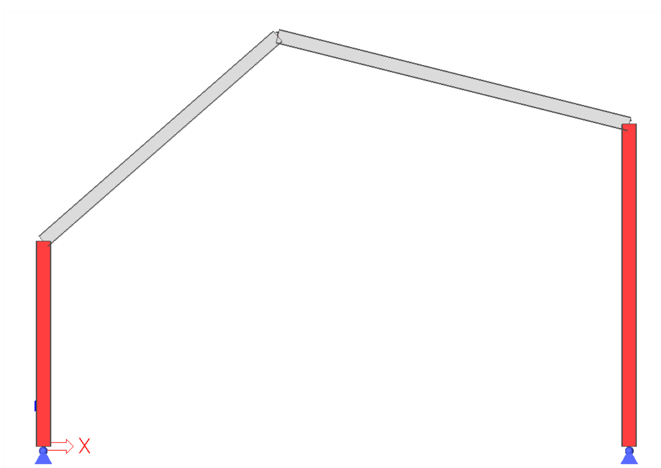
But calculated following the NA of Belgium:

$s_k = 0{,}5 + 0{,}007(A - 100)/6 = 0{,}73 kN/m^2$ for Z>100m




We are calculating the persistent / transient design situation

$$s = \mu_i \cdot C_e \cdot C_t \cdot s_k$$



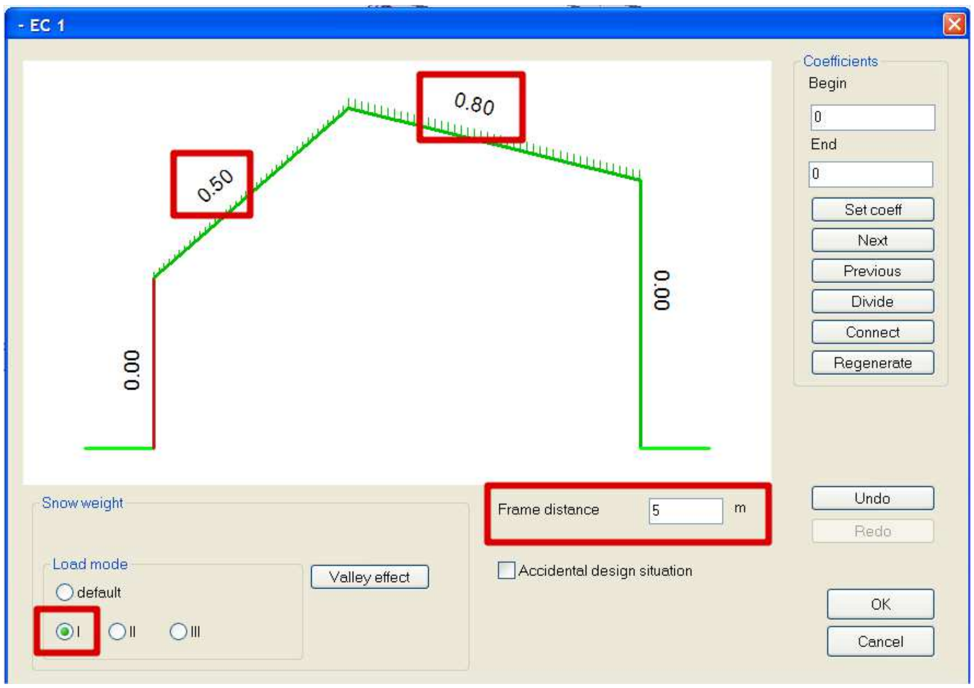

$\alpha_1 = 41{,}19°$ => $\mu_1 = 0{,}8\frac{60-\alpha_1}{30} = 0{,}5$ => $s_1 = 0{,}5 \cdot 1 \cdot 1 \cdot 0{,}73 = 0{,}37$ kN/m²

$\alpha_2 = 14{,}04°$ => $\mu_1 = 0{,}8$ => $s_2 = 0{,}8 \cdot 1 \cdot 1 \cdot 0{,}73 = 0{,}584$ kN/m²

This will be multiplied in SCIA Engineer by the Frame distance of 5m:

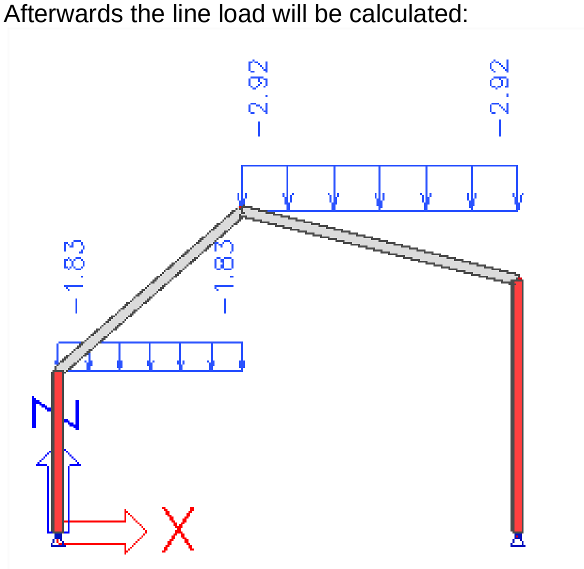
$s_1 = 1{,}83$ kN/m
$s_2 = 2{,}92$ kN/m

In SCIA Engineer:
Run the Snow generator and fill in a Frame Distance of 5m




In this window the values for $\mu_1$ are indicated for the persistent / transient design situation (I).

Afterwards the line load will be calculated:



**Multi-span roofs**

For multi-span roofs the snow load arrangements are shown in Figure 5.4.

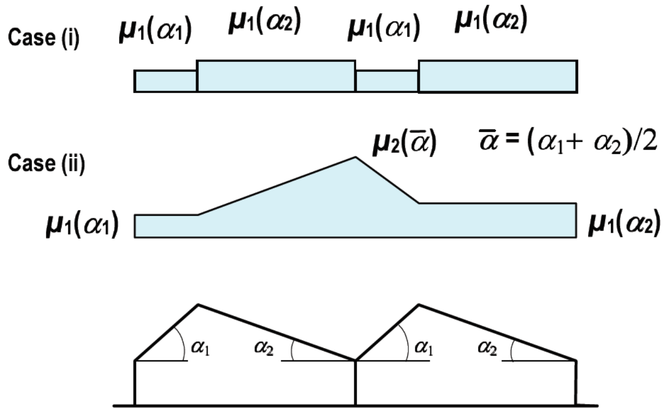



**Figure 5.4: Snow load shape coefficients for multi-span roofs**

- Case (i) represents the undrifted load arrangement.
- Case (ii) represent the drifted load arrangement, unless specified for local conditions

The snow load shape coefficients are given in Table 5.2

Special consideration should be given to the snow load shape coefficients for the design of multi-span roofs, where one or both sides of the valley have a slope greater than 60°.

*National annexes:*

*NF:*
*§5.3.4(3) : L'utilisation de l'annexe B est limitée aux cas où les spécifications particulières du projet individuel demandent de considérer le cas B3 du Tableau A.1 de la norme NF EN 1991-1-3:2004*
*.*
*§5.3.4(4) : Lorsque l'une des pentes est supérieure à 60° tandis que l'autre est inférieure à 45°, la règle définie par les clauses 5.3.4 (1) et (2) de la norme NF EN 1991-1-3:2004 est appliquée. Lorsque l'autre pente est supérieure à 45°, une analyse particulière à partir des phénomènes de base (glissement de la neige et redistribution par le vent) est à faire pour la détermination des coefficients de forme.*

*NBN :*
*§5.3.4(3): Bijlage B is niet van toepassing..*

*§5.3.4(4): Geen bijkomende bepalingen voor hellingen groter dan 60°.*

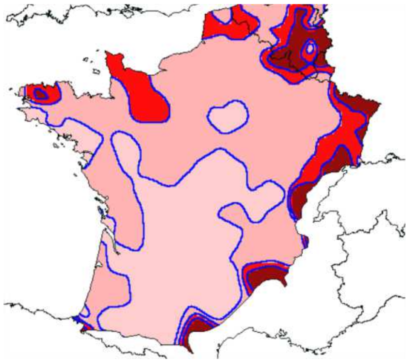
---

**Example: Snow_MultiSpanRoof.esa**

This example is situated in Belgium

$$s_k = 0{,}164Z - 0{,}082 + \frac{A}{966}$$

Met
Z =1
A = 0m



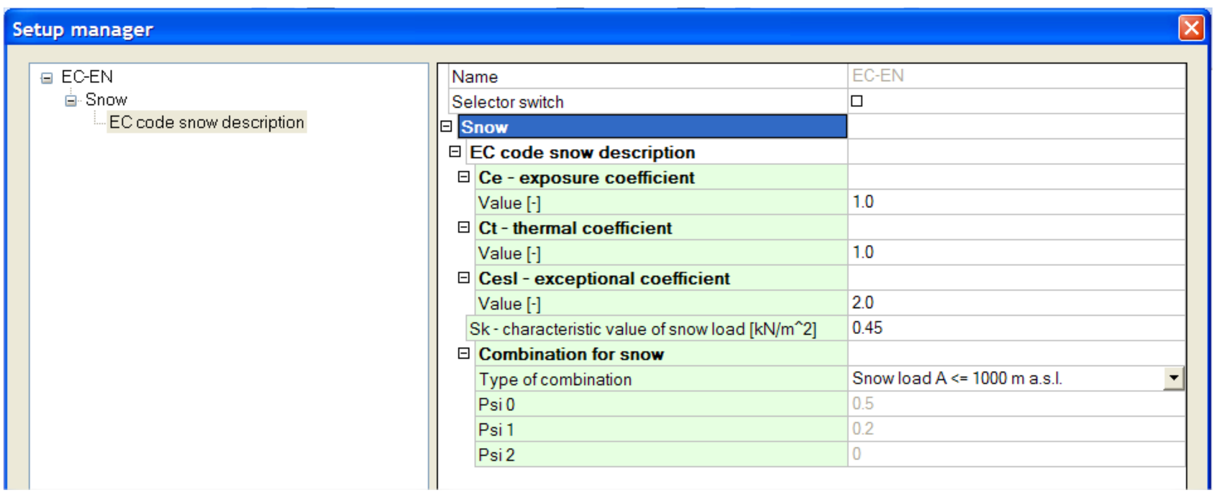
| Zone N° | $kN/m^2$ (A=0) |
|---|---|
| 1 | 0,1 |
| 2 | 0,2 |
| 3 | 0,4 |
| 4,5 | 0,7 |

Calculated following the standard EN1991-1-3:

$$s_k = 0{,}164 \cdot 1 - 0{,}082 + \frac{0}{966} = 0{,}08\ kN/m^2$$

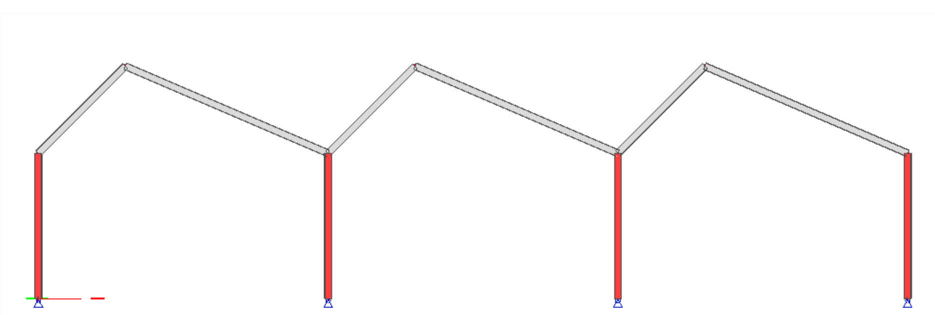
Calculated following the NF:

$s_k = 0{,}45\ kN/m^2$ (for Zone A2)




We are calculating the case with the drifted load arrangement.

$s = \mu_i \cdot s_k$



$\alpha_1 = 45°$

$\alpha_2 = 23{,}20°$

$\bar{\alpha} = \frac{(\alpha_1+\alpha_2)}{2} = 34{,}1°$

$\mu_1(\alpha_1) = 0{,}8\frac{60-\alpha_1}{30} = 0{,}4$ => $s_1 = 0{,}4 \cdot 1 \cdot 1 \cdot 0{,}45 = 0{,}18$ kN/m²

$\mu_1(\alpha_2) = 0{,}8$ => $s_1 = 0{,}8 \cdot 1 \cdot 1 \cdot 0{,}45 = 0{,}36$ kN/m²

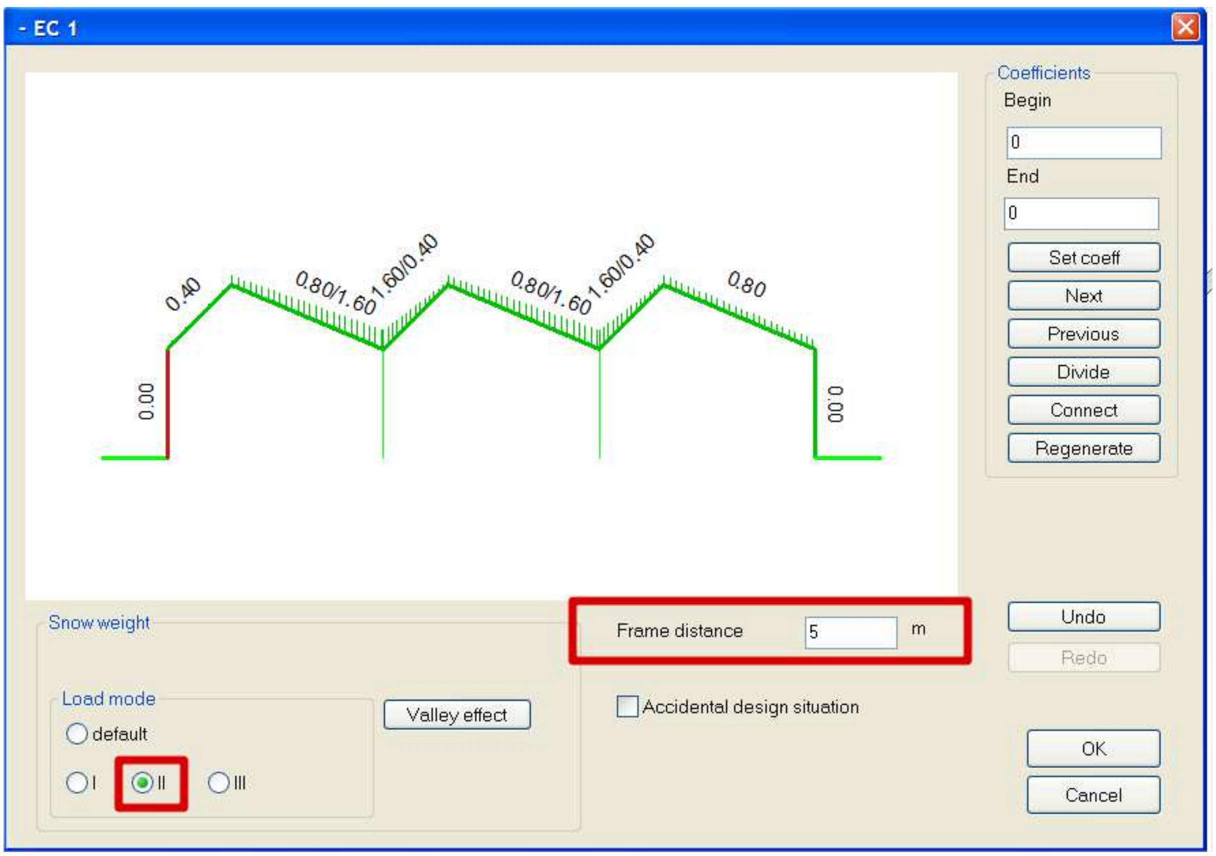
$\mu_2(\bar{\alpha}) = 1{,}6$ => $s_1 = 1{,}6 \cdot 1 \cdot 1 \cdot 0{,}45 = 0{,}72$ kN/m²

This will be multiplied in SCIA Engineer by the Frame distance of 5m:

In the corners and on the tops:
$s_1 = 0{,}9\ kN/m$
$s_2 = 1{,}8\ kN/m$

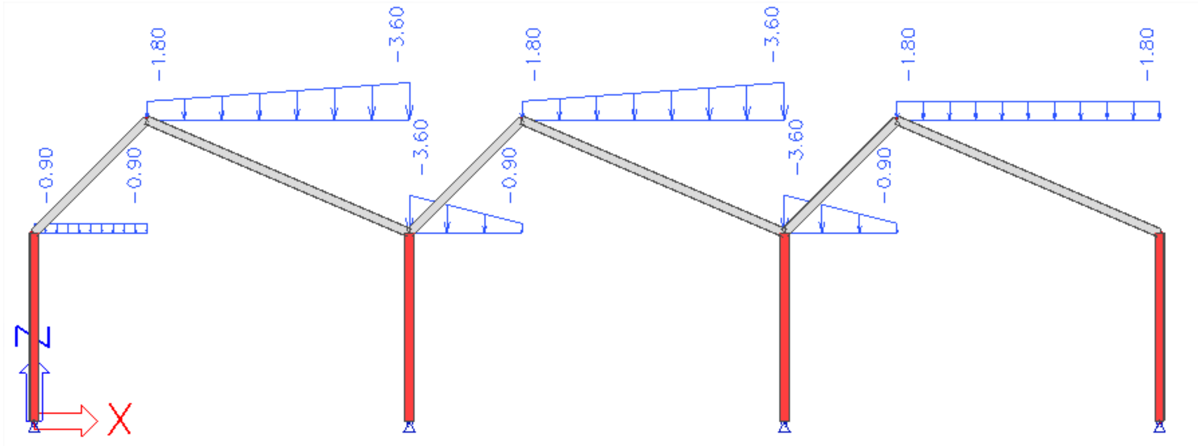
In the "valleys" of the roof:
$s_{top} = 3{,}6\ kN/m$

In SCIA Engineer:
Run the Snow generator and fill in a Frame Distance of 5m




In this window the values for $\mu_1$ are indicated for the persistent / transient design situation (I).

Afterwards the line load will be calculated:




## Cylindrical roofs

The snow load shape coefficients that should be used for cylindrical roofs, in absence of snow fences, are given in Figure 5.6.

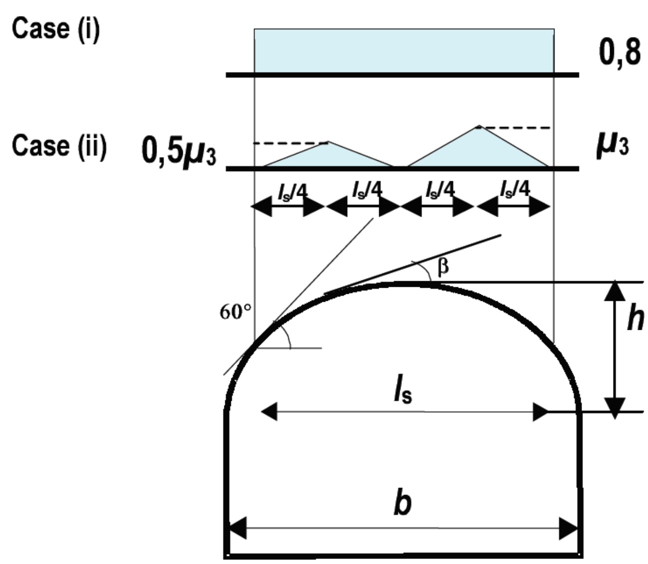



**Figure 5.6: Snow load shape coefficients for cylindrical roof**

Case (i) represents the undrifted load arrangement.

Case (ii) represents the drifted load arrangement, unless specified for local conditions.

The snow load shape coefficient $\mu_3$ is given figure 5.5 and by the following expressions:

- For $\beta > 60°$; $\mu_3 = 0$
- For $\beta \leq 60°$; $\mu_3 = 0,2 + 10\ h/b$

An upper value of $\mu_3$ should be specified. The recommended upper value is 2,0 but may be specified in the National Annex.

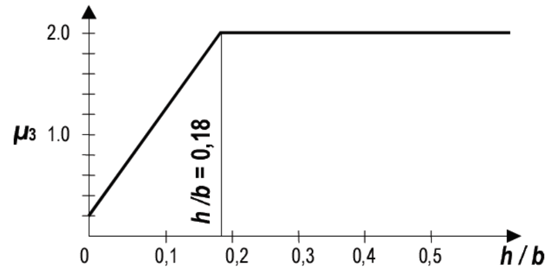



**Figure 5.5: Recommended snow load shape coefficient for cylindrical roofs.**

*National annexes:*

*NF:*
*§5.3.5(1): La valeur maximale fixée pour le coefficient de forme $\mu_3$ est la valeur recommandée (2,0). Lorsqu'il y a des barres à neige, la valeur du coefficient de forme du cas (i) de la Figure 5.6 de la norme NF EN 1991-1-3:2004 est maintenue égale à 0,8.*

*§5.3.5(3): La disposition de charge avec accumulation à considérer est celle définie par la norme, sauf lorsque les spécifications particulières du projet individuel définissent une disposition différente justifiée par les conditions locales.*

*NBN :*
*§5.3.5(1): Figuur 5.5 wordt toegepast zonder verandering (de bovenwaarde van $\mu_3$ is 2,0).*

*§5.3.5(3): Geen alternatieve nationale bepalingen.*

*NEN:*
*§5.3.5(1): The upper value of $\mu_3$ is 2,0.*

*§5.3.5(3): No alternative drifting load arrangement is given.*

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

The snow load shape coefficients that should be used for roofs abutting to taller construction works are shown in Figure 5.7.a.

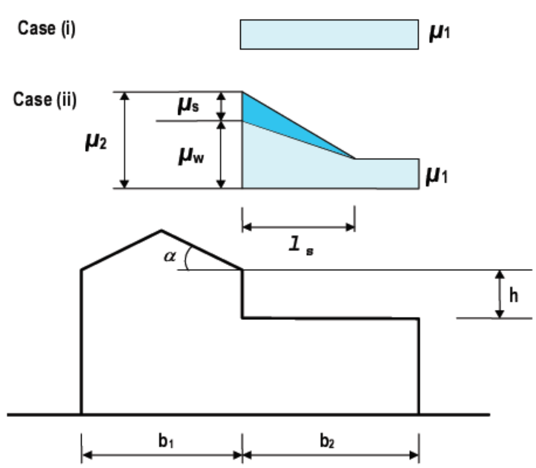


**Figure 5.7.a: Snow load shape coefficients for roofs abutting to taller construction works ($b_2 > l_s$)**

The undrifted load arrangement is represented by case (i). The drifted load arrangement is represented by case (ii), unless specified for local conditions. Where permitted by the National Annex, Annex B may be used to determine the load case due to drifting.

The snow load shape coefficients are given by the following equations:

- $\mu_1 = 0{,}8$ (assuming the lower roof is flat)
- $\mu_2 = \mu_s + \mu_w$ (5.7)

$\mu_s$ is the snow load shape coefficient due to sliding of snow from the upper roof

- For $\alpha \leq 15$ $\mu_s = 0$
- For $\alpha > 15$ $\mu_s$ is determined from an additional load amounting to 50 % of the maximum total snow load, on the adjacent slope of the upper roof calculated for pitched roofs

$\mu_w$ is the snow load shape coefficient due to wind

$$\mu_w = (b1 + b2)/2h \leq \gamma\, h/s_k,$$

$\gamma$ is the weight density of snow, which for this calculation may be taken as 2 kN/m³.

An upper and a lower value of $\mu_w$ should be specified. The recommended range is $0{,}8 \leq \mu_w \leq 4$. The range for $\mu_w$ may be fixed in the National Annex.

The drift length $l_s$ is determined as follows:

$$l_s = 2h$$

A restriction for $l_s$ may be given in the National Annex. The recommended restriction is $5 \leq l_s \leq 15$ m

If $b_2 < l_s$ the coefficient at the end of the lower roof is determined by interpolation between $\mu_1$ and $\mu_2$ truncated at the end of the lower roof (see Figure 5.7.b).

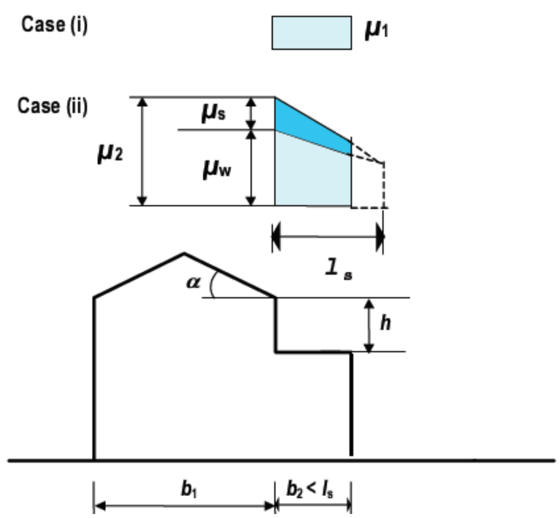



**Figure 5.7.b: Snow load shape coefficients for roofs abutting to taller construction works ($b_2 < l_s$)**

*<u>National annexes:</u>*

*NBN:*
*§5.3.6(1): Het domein van $\mu_w$ is $0{,}8 < \mu_w < 2{,}0$.*

*§5.3.6(2): Het domein van $l_s$ is 5 m < $l_s$ < 15 m.*
*§5.3.6(4):* Bijlage B is niet van toepassing.

*NF :*
*§5.3.6(1): Les limites du champ de variation pour $\mu_w$ sont fixées à 0,8 et 2,8.*
*§5.3.6(2): Les limites fixées pour la variation de $l_s$ sont les limites recommandées (5 et 15 mètres).*
*§5.3.6(4):* L'utilisation de l'annexe B est limitée aux cas où les spécifications particulières du projet individuel demandent de prendre en compte le cas B3 prévu par le Tableau A.1 de la norme NF EN 1991-1-3:2004.

*NEN:*
*§5.3.6(1): The range of $\mu_w$ is: $0,8 \leq \mu_w \leq 4$*
*§5.3.6(2): The range of $l_s$ is: $5 \leq l_s \leq 15$ m.*

# Section 6 Local effects

## General

This section gives forces to be applied for the local verifications of:

- drifting at projections and obstructions;
- the edge of the roof;
- snow fences.

The design situations to be considered are persistent/transient.

## Drifting at projections and obstructions

In windy conditions drifting of snow can occur on any roof which has obstructions as these cause areas of aerodynamic shade in which snow accumulates.

The snow load shape coefficients and drift lengths for quasi-horizontal roofs should be taken as follows (see Figure 6.1), unless specified for local conditions:

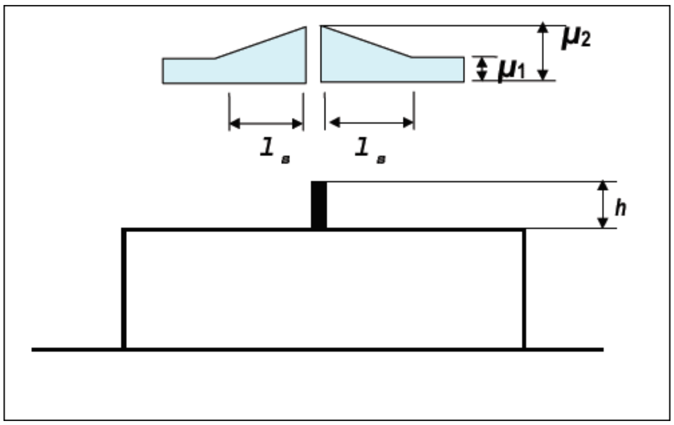



**Figure 6.1: Snow load shape coefficients at projections and obstructions**

- $\mu_1 = 0{,}8$
- $\mu_2 = \gamma\, h/s_k$ (with the restriction: $0{,}8 \leq \mu_2 \leq 2{,}0$)

  $\gamma$ is the weight density of snow, which for this calculation may be taken as 2 kN/m³.

The drift length $l_s = 2h$ (with the restriction is $5 \leq l_s \leq 15$ m)

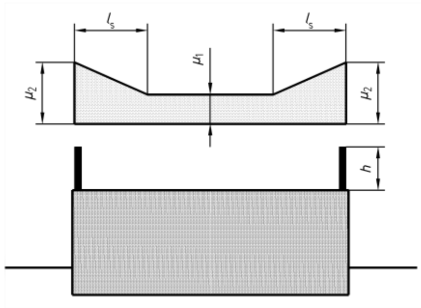
Where permitted by the National Annex, Annex B may be used to determine the load case due to drifting.

*National annexes:*

*NBN:*
*§6.2(2): Bijlage B is niet van toepassing.*

*NF :*
*§6.2(2): L'utilisation de l'annexe B est limitée aux cas où les spécifications particulières du projet individuel demandent de considérer le cas B3 prévu par le Tableau A.1 de la norme NF EN 1991-1-3:2004.*

*Dans le cas de deux acrotères la figure 6-1 de la norme NF EN 1991-1-3 devient la suivante, dans laquelle $\mu_2$ peut être limité supérieurement à 1,6 (au lieu de 2).*



## Snow overhanging the edge of a roof

Snow overhanging the edge of a roof should be considered for sites above 800 meters above sea level. The National Annex may specify the conditions of use for this clause.

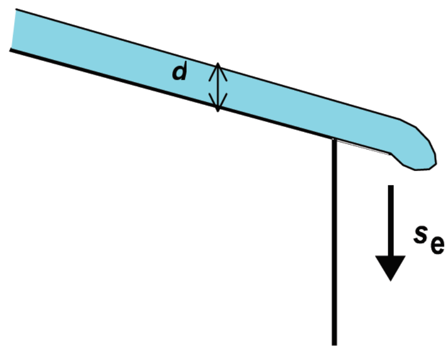



**Figure 6.2 Snow overhanging the edge of a roof**

The design of those parts of a roof cantilevered out beyond the walls should take account of snow overhanging the edge of the roof, in addition to the load on that part of the roof. The loads due to the overhang may be assumed to act at the edge of the roof and may be calculated as follows:

$$s_e = k\, s^2 / \gamma$$

where:

$s_e$ is snow load per metre length due to the overhang

s is the most onerous undrifted load case appropriate for the roof under consideration

$\gamma$ is the weight density of snow which for this calculation may be taken as 3 kN/m³

k is a coefficient to take account of the irregular shape of the snow
The values of k may be given in the National Annex. The recommended way for calculating k is as follows: $k = 3/d$, but $k \leq d$ . Where d is the depth of the snow layer on the roof in meters.

*National annexes:*

*NEN:*
*§6.3(1): In the Netherlands snow overhanging the edge of a roof need not be considered.*
*NOTE: Consequently the following paragraph is not relevant: 6.3 (2).*

*NBN:*
*§6.3(1): Gezien de hoogte van de locaties in België nooit 800 m overschrijdt, is de overhangende sneeuw aan dakrand niet van toepassing.*

*§6.3(2): Deze parameter is in België niet nodig. De coëfficiënt $k = 3/d$ met $k < d.\gamma$ is van toepassing volgens figuur 6.2, b.*

*NF :*

*§6.3(1): Cette clause est à appliquer pour tous les sites dont l'altitude au dessus du niveau de la mer est supérieure à 900 mètres, ainsi que, lorsque les spécifications particulières du projet individuel le prescrivent, pour les sites d'une altitude inférieure.*

*Il est précisé que l'épaisseur d de neige est mesurée verticalement, et que sa valeur en mètres peut être prise égale au quotient de la charge de neige s exprimée en kN par un poids volumique égal à 3 kN/m3.*

*§6.3(2) : On calculera k par la formule k = 3/d (d étant l'épaisseur de la couche de neige sur la toiture, en mètres), avec une borne supérieure égale à d$\gamma$.*

## Snow loads on snowguards and other obstacles

Under certain conditions snow may slide down a pitched or curved roof. The coefficient of friction between the snow and the roof should be assumed to be zero. For this calculation the force $F_s$ exerted by a sliding mass of snow, in the direction of slide, per unit length of the building should be taken as:

$$F_s = s\ b\ \sin\alpha$$

where:

s is the snow load on the roof relative to the most onerous undrafted load case appropriate for roof area from which snow could slide

b is the width on plan (horizontal) from the guard or obstacle to the next guard or to the ridge

$\alpha$ pitch of the roof, measured from the horizontal

# Annexes

## Annex A (normative)

Annex A gives a summarizing table of the design situations and load arrangements to be used for different locations. (see section 3 table A.1)

## Annex B (normative)

This annex gives snow shape coefficients to determine load arrangements due to exceptional snow drifts for the following types of roofs:

- Multi-span roofs;

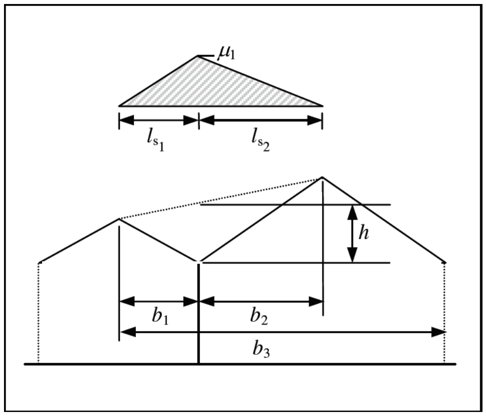



**Figure B1: Shape coefficient and drift lengths for exceptional snow drifts valleys of multi-span roofs**

- Roofs abutting and close to taller construction works;

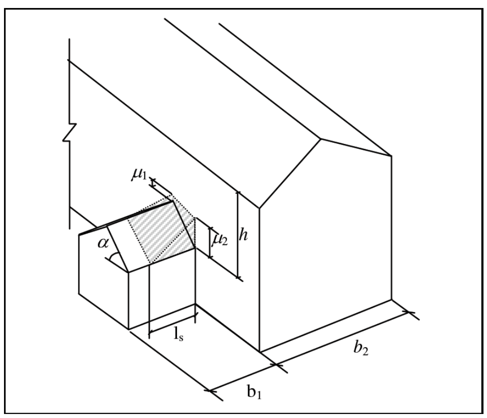



**Figure B2: Shape coefficients and drift lengths for exceptional snow drifts Roofs abutting and close to taller structures**

- Roofs where drifting occurs at projections, obstructions and parapets.

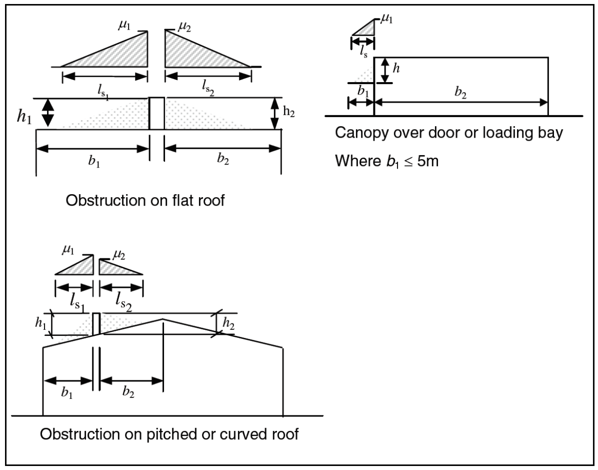



**Figure B3: Shape coefficients for exceptional snow drifts Roofs where drifting occurs at obstructions**

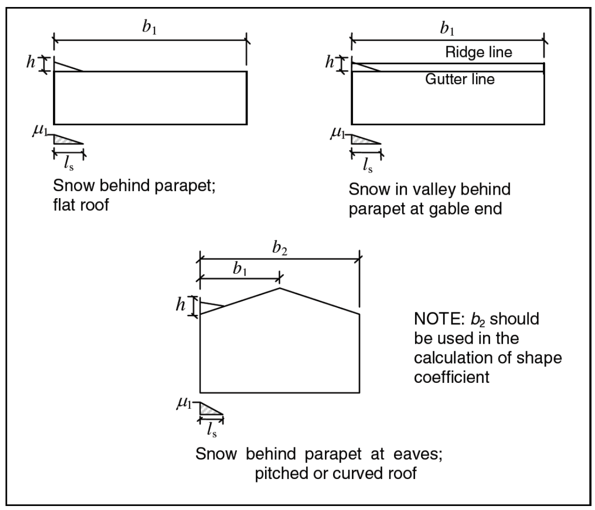



**Figure B4 : Shape coefficients for exceptional snow drifts roofs where drifting occurs at parapets**

When considering load cases using snow load shape coefficients obtained from this Annex it should be assumed that they are exceptional snow drift loads and that there is no snow elsewhere on the roof.

## Annex C (informative) European Ground Snow Load Maps

## Annex D (informative) Adjustment of the ground snow load according to return period

## Annex E (informative) Bulk weight density of snow

# 1991-1-4: Wind actions

The following subjects are dealt with in EN 1991-1-4:

| | |
|---|---|
| Section 1: | General |
| Section 2: | Design situations |
| Section 3: | Modeling of wind actions |
| Section 4: | Wind velocity and velocity pressure |
| Section 5: | Wind actions |
| Section 6 | Structural factor $c_s c_d$ |
| Section 7: | Pressure and force coefficients |
| Section 8: | Wind actions on bridges |

**National Annex for EN 1991-1-4**
This standard gives alternative procedures, values and recommendations for classes with notes indicating where national choice may be made. Therefore the National Standard implementing EN 1991-1-4 should have a National Annex containing Nationally Determined Parameters to be used for the design of buildings and civil engineering works to be constructed in the relevant country.

National choice is allowed for EN 1991-1-4 through clauses:

**-1.1 (11) Note1**
**-1.5 (2)**

**-4.1 (1)**
**-4.2 (1)P Note 2**
**-4.2 (2)P Notes 1, 2, 3 and 5**
**-4.3.1 (1) Notes 1 and 2**
**-4.3.2 (1)**
**-4.3.2 (2)**
**-4.3.3 (1)**
**-4.3.4 (1)**
**-4.3.5 (1)**
**-4.4 (1) Note 2**
**-5.3 (5)**

**-6.1 (1)**
**-6.3.1 (1) Note 3**
**-6.3.2 (1)**

**-7.1.2 (2)**
**-7.1.3 (1)**
**-7.2.1 (1) Note 2**
**-7.2.2 (1)**
**-7.2.2 (2) Note 1**
**-7.2.8 (1)**
**-7.2.9 (2)**
**-7.2.10 (3) Notes 1 and 2**
**-7.4.1 (1)**
**-7.6 (1) Note 1**
**-7.7 (1) Note 1**
**-7.8 (1)**
**-7.10 (1) Note 1**
**-7.11 (1) Note 2**
**-7.13 (1)**
**-7.13 (2)**

**-8.1 (1) Notes 1 and 2**

**-8.1 (4)**
**-8.1 (5)**
**-8.2 (1) Note 1**
**-8.3 (1)**
**-8.3.1 (2)**
**-8.3.2 (1)**
**-8.3.3 (1) Note 1**
**-8.3.4 (1)**
**-8.4.2 (1) Notes 1 and 2**

**-A.2 (1)**

**-E.1.3.3 (1)**
**-E.1.5.1 (1) Notes 1 and 2**
**-E.1.5.1 (3)**
**-E.1.5.2.6 (1) Note 1**
**-E.1.5.3 (2) Note 1**
**-E.1.5.3 (4)**
**-E.1.5.3 (6)**
**-E.3 (2)**

# Section 1: General

## Scope:

EN 1991-1-4 gives guidance on the determination of natural wind actions for the structural design of building and civil engineering works for each of the loaded areas under consideration. This includes the whole structure or parts of the structure or elements attached to the structure, e. g. components, cladding units and their fixings, safety and noise barriers.

This Part is applicable to:

- Buildings and civil engineering works with heights up to 200 m.
- Bridges having no span greater than 200m, provided that they satisfy the criteria for dynamic response.

This part does not give guidance on the following aspects:

- Wind actions on lattice towers with non-parallel chords (see EN 1993-3-1 Annex A)
- Wind actions on guyed masts and guyed chimneys (see EN 1993-3-1 Annex A)
- torsional vibrations, e.g. tall buildings with a central core
- bridge deck vibrations from transverse wind turbulence
- cable supported bridges
- vibrations where more than the fundamental mode needs to be considered

## Design assisted by testing

In supplement to calculations wind tunnel tests and proven and/or properly validated numerical methods may be used to obtain load and response information, using appropriate models of the structure and of the natural wind.

Load and response information and terrain parameters may be obtained by appropriate full scale data.

## Terms and Definitions

**fundamental basic wind velocity**
the 10 minute mean wind velocity with an annual risk of being exceeded of 0,02, irrespective of wind direction, at a height of 10 m above flat open country terrain and accounting for altitude effects (if required)

**basic wind velocity**
the fundamental basic wind velocity modified to account for the direction of the wind being considered and the season (if required)

**mean wind velocity**
the basic wind velocity modified to account for the effect of terrain roughness and orography

**pressure coefficient**
external pressure coefficients give the effect of the wind on the external surfaces of buildings; internal pressure coefficients give the effect of the wind on the internal surfaces of buildings.

The external pressure coefficients are divided into overall coefficients and local coefficients. Local coefficients give the pressure coefficients for loaded areas of 1 $m^2$ or less e.g. for the design of small elements and fixings; overall coefficients give the pressure coefficients for loaded areas larger than 10 $m^2$.

Net pressure coefficients give the resulting effect of the wind on a structure, structural element or component per unit area.

## Symbols

| | |
|---|---|
| $A$ | area |
| $A_{fr}$ | area swept by the wind |
| $A_{ref}$ | reference area |
| $F_{fr}$ | resultant friction force |
| $F_w$ | resultant wind force |
| $I_v$ | turbulence intensity |
| | |
| $c_{alt}$ | altitude factor |
| $c_d$ | dynamic factor |
| $c_{dir}$ | directional factor |
| $cf$ | force coefficient |
| $cfr$ | friction coefficient |
| $c_{prob}$ | probability factor |
| $c_r$ | roughness factor |
| $c_o$ | orography factor |
| $c_s$ | size factor |
| $c_{season}$ | seasonal factor |
| $q_b$ | reference mean (basic) velocity pressure |
| $q_p$ | peak velocity pressure |
| $v_m$ | mean wind velocity |
| $v_{b,0}$ | fundamental value of the basic wind velocity |
| $v_b$ | basic wind velocity |
| $w$ | wind pressure |
| $z_0$ | roughness length |
| $z_e$, $z_i$ | reference height for external wind action, internal pressure |
| $z_{max}$ | maximum height |
| $z_{min}$ | minimum height |
| | |
| $\rho$ | air density |
| $\sigma_v$ | standard deviation of the turbulence |

## Section 2: Design situations

The relevant wind actions shall be determined for each design situation identified in accordance with EN 1990, 3.2.

Other actions (such as snow, traffic or ice) which will modify the effects due to wind should be taken into account.

The changes to the structure during stages of execution (such as different stages of the form of the structure, dynamic characteristics, etc.), which may modify the effects due to wind, should be taken into account.

Where in design windows and doors are assumed to be shut under storm conditions, the effect of these being open should be treated as an accidental design situation.

Fatigue due to the effects of wind actions should be considered for susceptible structures.

# Section 3: Modeling of wind actions

## Nature

Wind actions fluctuate with time and act directly as pressures on the external surfaces of enclosed structures and, because of porosity of the external surface, also act indirectly on the internal surfaces. They may also act directly on the internal surface of open structures. Pressures act on areas of the surface resulting in forces normal to the surface of the structure or of individual cladding components. Additionally, when large areas of structures are swept by the wind, friction forces acting tangentially to the surface may be significant.

## Representation of wind actions

The wind action is represented by a simplified set of pressures or forces whose effects are equivalent to the extreme effects of the turbulent wind.

## Classification of wind actions

Unless otherwise specified, wind actions should be classified as variable fixed actions.
(see EN 1990, 4.1.1)

## Characteristic values

The wind actions calculated using EN 1991-1-4 are characteristic values (See EN 1990, 4.1.2). They are determined from the basic values of wind velocity or the velocity pressure.

The basic values are characteristic values having annual probabilities of exceedence of 0,02, which is equivalent to a mean return period of 50 years.

## Models

The effect of the wind on the structure (i.e. the response of the structure), depends on the size, shape and dynamic properties of the structure. This Part covers dynamic response due to along-wind turbulence in resonance with the along-wind vibrations of a fundamental flexural mode shape with constant sign.

The response of structures should be calculated according to Section 5 from the peak velocity pressure, $q_p$, at the reference height in the undisturbed wind field, the force and pressure coefficients and the structural factor $c_s c_d$ (see Section 6). $q_p$ depends on the wind climate, the terrain roughness and orography, and the reference height. $q_p$ is equal to the mean velocity pressure plus a contribution from short-term pressure fluctuations.

Aero elastic response should be considered for flexible structures such as cables, masts, chimneys and bridges.

# Section 4: Wind velocity and velocity pressure

## Basis for calculation

The wind velocity and the velocity pressure are composed of a mean and a fluctuating component.

The mean wind velocity $v_m$ should be determined from the basic wind velocity $v_b$ which depends on the wind climate, and the height variation of the wind determined from the terrain roughness and orography.

The fluctuating component of the wind is represented by the turbulence intensity $I_v$.

The National Annex may provide National climatic information from which the mean wind velocity $v_m$, the peak velocity pressure $q_p$ and additional values may be directly obtained for the terrain categories considered.

## Basis values

The fundamental value of the basic wind velocity, $v_{b,0}$, is the characteristic 10 minutes mean wind velocity, irrespective of wind direction and time of year, at 10 m above ground level in open country terrain (corresponds to category II in table 4.1) with low vegetation such as grass and isolated obstacles with separations of at least 20 obstacle heights.

The value of the basic wind velocity, $v_{b,0}$, may be given in the National Annex.

The basic wind velocity can be obtained from the following equation:

$$v_b = c_{dir} \; c_{season} \; v_{b,0}$$

where:

$v_b$ is the basic wind velocity, defined as a function of wind direction and time of year at 10 m above ground of terrain category II

$v_{b,0}$ is the fundamental value of the basic wind velocity

$c_{dir}$ is the directional factor.
The value of the directional factor, $c_{dir}$, for various wind directions may be found in the National Annex. The recommended value is 1,0.

$c_{season}$ is the season factor
The value of the season factor, $c_{season}$, may be given in the National Annex. The recommended value is 1,0.

For temporary structures and for all structures in the execution phase, the seasonal factor $c_{season}$ may be used. For transportable structures, which may be used at any time in the year, $c_{season}$ should be taken equal to 1,0.

**Note**: The 10 minutes mean wind velocity having the probability $p$ for an annual exceedence is determined by multiplying the basic wind velocity $v_b$ by the probability factor, $c_{prob}$

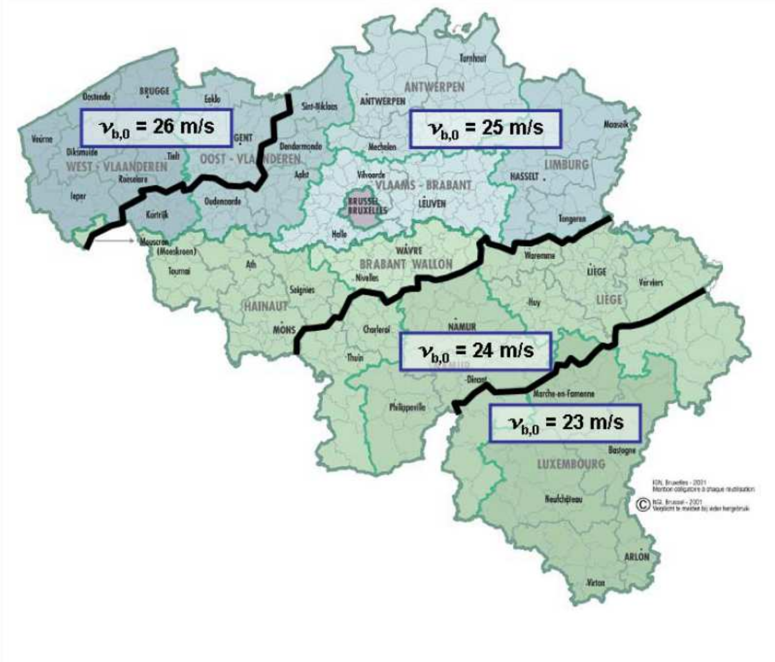
$$c_{prob} = \left(\frac{1 - K \cdot \ln(-\ln(1-p))}{1 - K \cdot \ln(-\ln(0.98))}\right)^n$$

The values for $K$ and $n$ may be given in the National Annex. The recommended values are 0,2 for $K$ and 0,5 for $n$.

*<u>National annexes:</u>*

*NBN:*
*De fundamentele basiswindsnelheid mag gelijk genomen worden aan $v_{b,0}$ = 26 m/s voor gans België.*

*Wanneer een meer gedetailleerde waarde wordt gezocht, kan de waarde v b,0 bekomen worden met de figuur 4.3 ANB of met tabel 4.2 ANB door de zone te kiezen van de ligging van de constructie.*




**Figuur 4.3 ANB: Basiswindsnelheden $v_{b,0}$ bepaald per gebied**

*Those values are also given in this National Annex as tabled values.*

*De tornado's of windhozen zijn niet beschouwd bij de fundamentele basiswindsnelheden gegeven in figuur 4.3 ANB en tabel 4.2 ANB.*
*Deze opgaande wervelwinden met vernielende effecten kunnen zich om de 2 tot 3 jaar voordoen in België. Ze zijn gekenmerkt door veel hogere windsnelheden (om en bij de 100 m/s, hetgeen overeenkomt met een stuwdruk van om en bij 6000 Pa), maar de getroffen zone is relatief beperkt (om en bij 100 m breed en 10 km lang, hetzij 1 km² of nog 1/30.000 van het Belgisch territorium), zodat het jaarlijks risico van optreden op een gegeven plaats zeer klein is (10 -5 /jaar) en het niet nodig is om er zich tegen te beschermen.*
*Evenwel is, in de speciale gevallen waarbij de constructie getoetst wordt voor een betrouwbaarheidsklasse RC3 volgens NBN EN 1990 Bijlage B, de windhoos één van de buitengewone belastingen A d waarmee moet gerekend worden. In dit geval is de waarde van de extreme stuwdruk $q_p$ = 6000 N/m² onafhankelijk van de hoogte boven de grond en de terreincategorie.*

*De invloed van de hoogteligging is begrepen in de waarden $v_{b,0}$ gegeven in de figuur 4.3 ANB en de tabel 4.2 ANB.*

*In this national annex, also values for $c_{dir}$, $c_{season}$ and $c_{prob}$ are given in tables:*

**Tabel 4.3 ANB: windrichtingsfactor $c_{dir}$**

| RICHTING WAARUIT DE WIND KOMT | 0° N | 22,5° | 37,75° | 45° | 56,25° | 90° O | 120° | 150° | 180° Z | 270° W |
|---|---|---|---|---|---|---|---|---|---|---|
| $c_{dir}$ | 1,0 | 1,0 | 0,95 | 0,90 | 0,85 | 0,85 | 0,90 | 0,95 | 1,0 | 1,0 |
| $(c_{dir})^2$ | 1,0 | 1,0 | 0,90 | 0,81 | 0,72 | 0,72 | 0,81 | 0 ,90 | 1,0 | 1,0 |

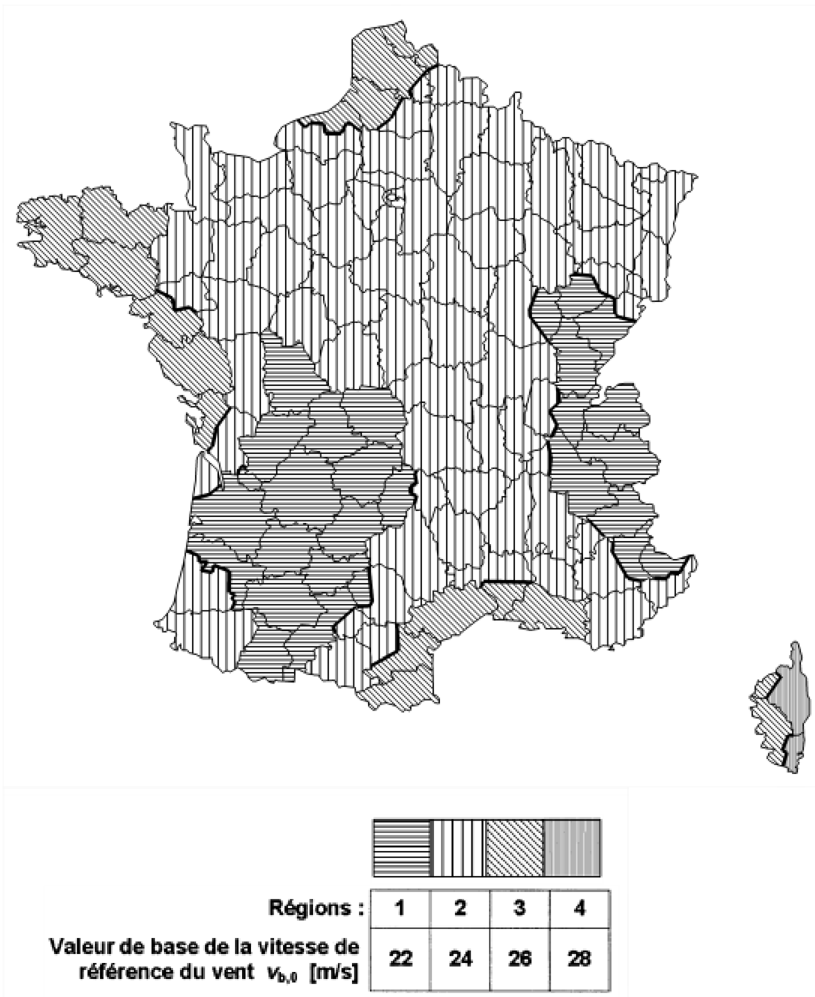
**Tabel 4.4 –ANB: seizoensfactor $c_{season}$**

| MAAND | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $c_{season}$ | 0,96 | 0,96 | 0,92 | 0,88 | 0,83 | 0,83 | 0,83 | 0,83 | 0,88 | 0,92 | 1,0 | 0,96 |
| $(c_{season})^2$ | 0,92 | 0,92 | 0,85 | 0,77 | 0,69 | 0,69 | 0,69 | 0,69 | 0,77 | 0,85 | 1,0 | 0,92 |

**Tabel 4.5 ANB: waarschijnlijkheidsfactor $c_{prob}$**

| WAARSCHIJNLIJKHEID $p$ (per jaar) | 0,63 | 0,50 | 0,20 | 0,10 | 0,05 | 0,02 | 0,01 | 0,005 | 0,002 | 0,001 |
|---|---|---|---|---|---|---|---|---|---|---|
| Terugkeerperiode (jaren) | 1 | 2 | 5 | 10 | 20 | 50 | 100 | 200 | 500 | 1000 |
| $c_{prob}$ | 0,75 | 0,78 | 0,85 | 0,90 | 0,95 | 1,0 | 1,04 | 1,08 | 1,12 | 1,16 |
| $(c_{prob})^2$ | 0,56 | 0,60 | 0,72 | 0,81 | 0,90 | 1,0 | 1,08 | 1,17 | 1,25 | 1,35 |

*NF:*
*La valeur de base de la vitesse de référence $v_{b,0}$ est donné dans le tableau 4.2(NA), selon la région climatique concernée. La figure 4.3(NA) est une carte illustrant les régions métropolitaines, dont la définition précise est donnée ci-après, par départements et, lorsque c'est nécessaire, par cantons.*




*L'étude statistique des données météorologiques en France n'a pas montré d'influence de l'altitude sur la vitesse de référence du vent $v_b$.*

*In this national annex, also values for $c_{dir}$, $c_{season}$ and $c_{prob}$ are given in tables and cartes.*

*NEN:*
*De waarde voor $v_{b,0}$ moet zijn bepaald volgens tabel NB.1, waarbij onderscheid is gemaakt tussen de windgebieden I, II en III volgens figuur NB.1. De gebieden omvatten respectievelijk:*

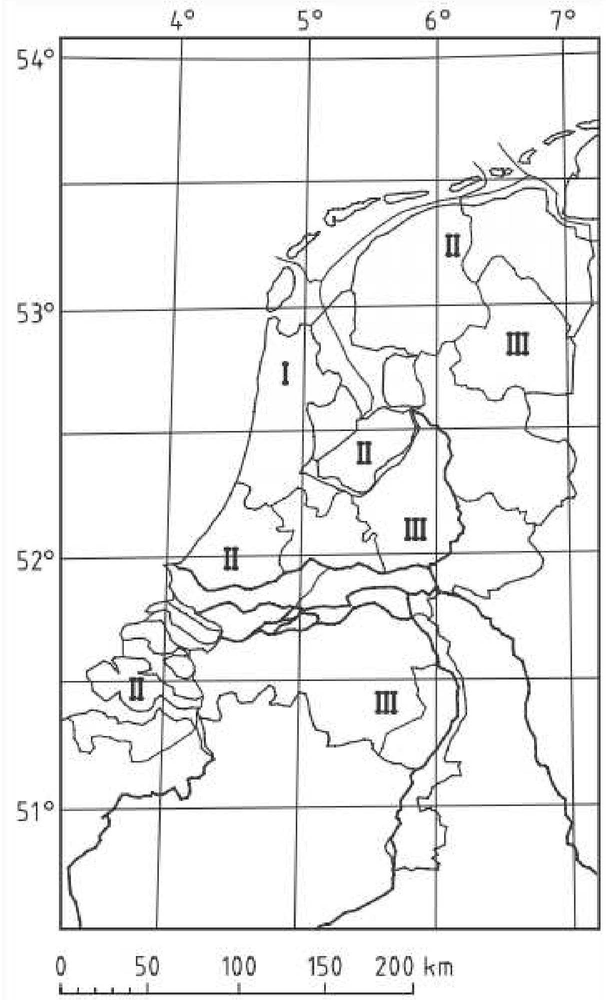
*gebied I: Markermeer, IJsselmeer, Waddenzee, Waddeneilanden en de provincie Noord-Holland ten noorden van de gemeenten Heemskerk, Uitgeest, Wormerland, Purmerend en Edam-Volendam;*

*gebied II: het resterende deel van de provincie Noord-Holland, het vasteland van de provincies Groningen en Friesland en de provincies Flevoland, Zuid-Holland en Zeeland;*

*gebied III: het resterende deel van Nederland.*

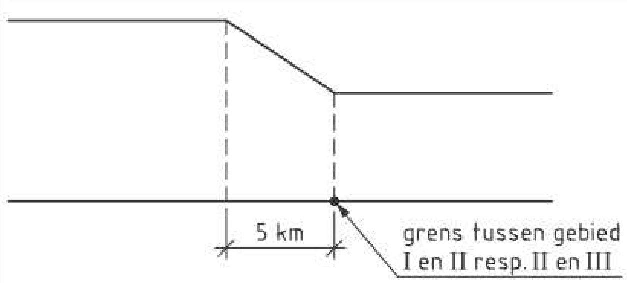
**Tabel NB.1 — Waarden voor $v_{b,0}$ voor toepassing in Nederland**

| Windgebied | $v_{b,0}$ m/s |
|---|---|
| I | 29,5 |
| II | 27,0 |
| III | 24,5 |




*Ter plaatse van de grenzen van de windgebieden moet een continue overgang zijn aangenomen overeenkomend met de volgende interpolatieregels (zie figuur NB.2):*

— *van een punt in gebied I, 5 km vanaf de grenslijn met gebied II naar de grenslijn zelf;*
— *van een punt in gebied II, 5 km vanaf de grenslijn met gebied III naar de grenslijn zelf.*




**Figuur NB.2 — Overgangsgebied tussen de windgebieden**

*Vervang de definities van de factoren $c_{dir}$ en $c_{season}$ door:*
$c_{dir}$ *is de windrichtingsfactor*
$c_{season}$ *is de seizoensfactor*
*Voor c dir moet een waarde gelijk aan 1 zijn genomen.*
*Voor c season moet een waarde gelijk aan 1 zijn genomen.*

*De terreinhoogte is niet van toepassing. Voor K en n moeten voor de drie windgebieden de waarden volgens tabel NB.2 zijn aangehouden.*

**Tabel NB.2 — Waarden voor de factoren *K* en *n* voor toepassing in Nederland**

| Windgebied | I | II | III |
|---|---|---|---|
| *K* | 0,2 | 0,234 | 0,281 |
| *n* | 0,5 | 0,5 | 0,5 |

## Mean wind

**Variation with height**

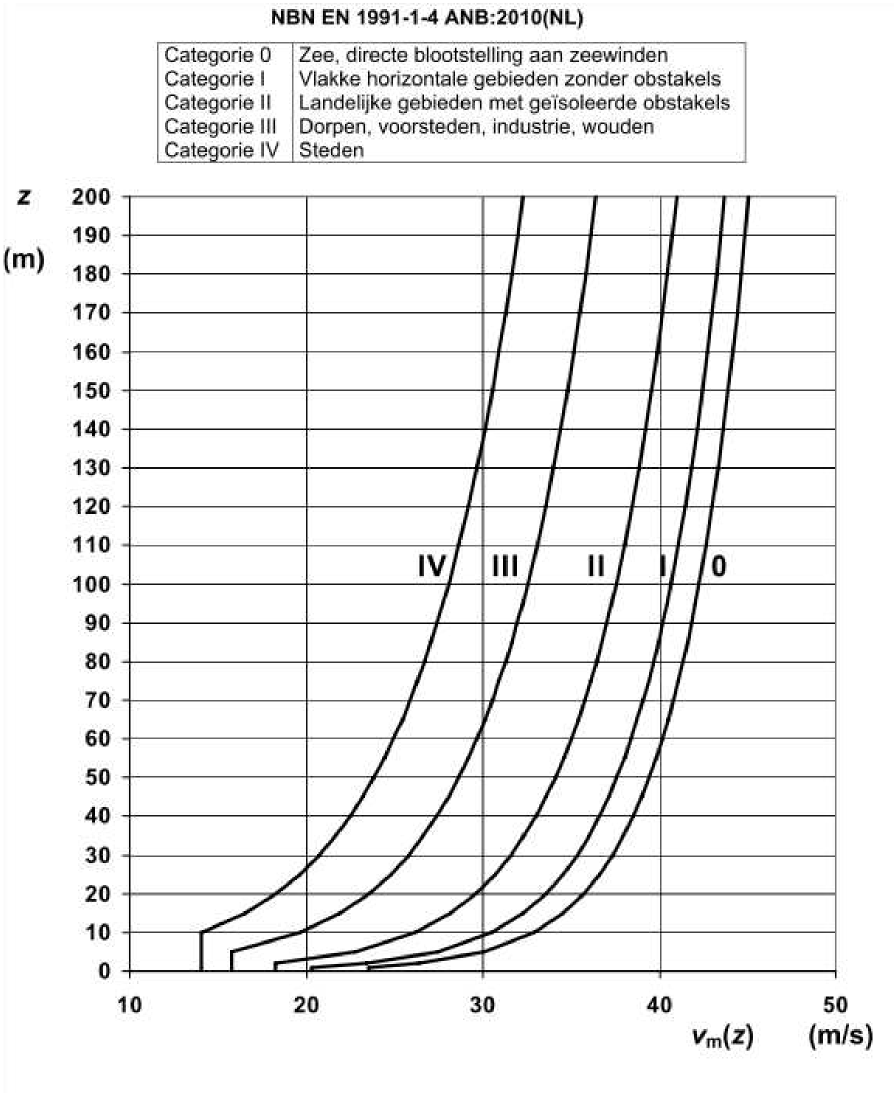
The mean wind velocity $v_m(z)$ at a height $z$ above the terrain depends on the terrain roughness and orography and on the basic wind velocity, $v_b$:

$$v_m(z) = c_r(z)\ c_o(z)\ v_b(z)$$

where: $c_r(z)$ is the roughness factor
$c_o(z)$ is the orography factor

*National annexes:*

*NBN:*
wanneer $v_{b,0}$ = 26 m/s en $c_o(z)$ = 1, kan de waarde $v_m(z)$ direct gelezen worden in de figuur 4.4 ANB.




**Figuur 4.4 ANB: Voorstelling van de gemiddelde wind $v_m(z)$ voor $v_{b,0}$ = 26 m/s en $c_o$ = 1**

**Terrain roughness**

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

- the height above ground level
- the ground roughness of the terrain upwind of the structure in the wind direction considered

The procedure for determining $c_r(z)$ may be given in the National Annex. The recommended procedure for the determination of the roughness factor at height *z* is given by the following expression (based on a logarithmic velocity profile):

$$c_r(z) = k_r \ln(z/z_o) \qquad \text{for } z_{min} \leq z \leq z_{max}$$

$$c_r(z) = c_r(z_{min}) \qquad \text{for } z \leq z_{min}$$

where:

$z_0$ is the roughness length
$z_{min}$ is the minimum height defined in Table 4.1
$z_{max}$ is to be taken as 200 m, unless otherwise specified in the National Annex

$k_r$ is the terrain factor depending on the roughness length $z_0$ calculated using

$$k_r = 0.19\,(z_0 / z_{0,II})^{0.07}$$

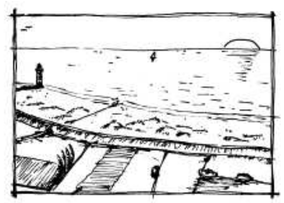
where: $z_{0,II}$ = 0,05 m (terrain category II, Table 4.1)

**Table 4.1 — Terrain categories and terrain parameters**

| Terrain category | | $z_0$ m | $z_{min}$ m |
|---|---|---|---|
| 0 | Sea or coastal area exposed to the open sea | 0,003 | 1 |
| I | Lakes or flat and horizontal area with negligible vegetation and without obstacles | 0,01 | 1 |
| II | Area with low vegetation such as grass and isolated obstacles (trees, buildings) with separations of at least 20 obstacle heights | 0,05 | 2 |
| 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 |
| IV | Area in which at least 15 % of the surface is covered with buildings and their average height exceeds 15 m | 1,0 | 10 |
| The terrain categories are illustrated in Annex A.1. | | | |

**Terrain category 0**

Sea, coastal area exposed to the open sea

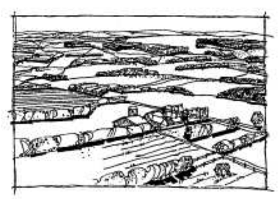


**Terrain category I**

Lakes or area with negligible vegetation and without obstacles

**Terrain category II**

Area with low vegetation such as grass and isolated obstacles (trees, buildings) with separations of at least 20 obstacle heights



**Terrain category 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)

**Terrain category IV**

Area in which at least 15 % of the surface is covered with buildings and their average height exceeds 15 m

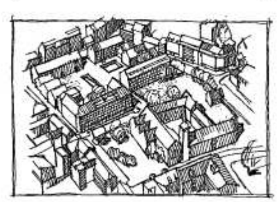
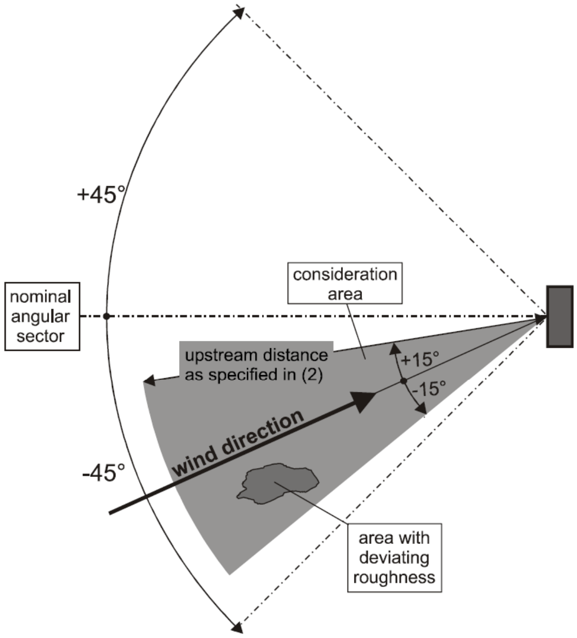


**Figure A.1 Illustrations of the upper roughness of each terrain category**

The terrain roughness to be used for a given wind direction depends on the ground roughness and the distance with uniform terrain roughness in an angular sector around the wind direction. Small areas (less than 10% of the area under consideration) with deviating roughness may be ignored.

**Figure 4.1 — Assessment of terrain roughness**




NOTE The National Annex may give definitions of the angular sector and of the upstream distance. The recommended value of the angular sector may be taken as the 30° angular sector within ±15° from the wind direction. The recommended value for the upstream distance may be obtained from Annex A.2.

When a pressure or force coefficient is defined for a nominal angular sector, the lowest roughness length within any 30° angular wind sector should be used.

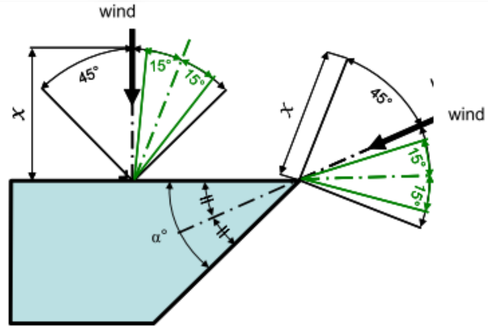
When there is choice between two or more terrain categories in the definition of a given area, then the area with the lowest roughness length should be used.

*<u>National annexes:</u>*

*NBN:*
*§4.3.2(1): De aanbevolen procedure is normatief.*

*§4.3.2(2): De aanbevolen waarde voor de windrichtingsector van ±15° ten opzichte van de windrichting is normatief. De figuur 4.5 ANB geeft voorbeelden van bepalingen van de nominale windrichtingsector (waarin de meest ongunstige richting moet worden gezocht):*

- *voor een windrichting loodrecht op een gevel van een gebouw*
- *voor een windrichting volgens de bissectrice van de hoek van de hoekzone van een dak van een gebouw.*

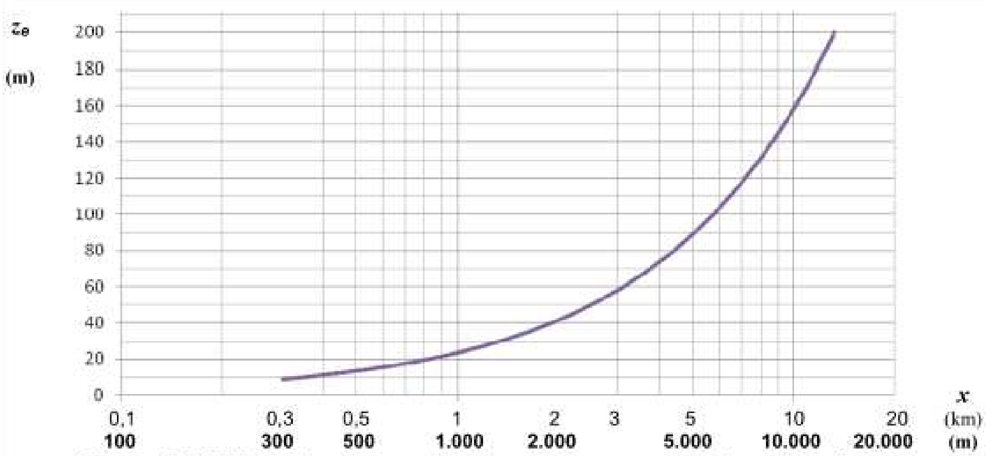



**Figuur 4.5 ANB: Bepaling van de windrichtingssector en de afstand $x$**

*De stroomopwaartse afstand x waarover de terreinruwheid wordt genomen voor de keuze van de terreincategorie is functie van de referentiehoogte $z_e$. De waarde x kan afgelezen worden in figuur 4.6 ANB of berekend met de uitdrukking:*

$x = 23.(z_e)^{1,2}$ *met x $\geq$ 300 m*

*waarbij $z_e$ en x uitgedrukt zijn in meter.*




**Figuur 4.6 ANB: Afstand $x$ voor het in acht nemen van de terreinruwheid**

*NEN:*

*§ 4.3.2(1):*

*De tweede formule van vergelijking (4.4) geldt voor z < z min .*

*Lees formule (4.5) als:* $k_r = 0.19\ (z_0 / \mathbf{0{,}05})^{0.07}$

*Vervang de definitie van $z_{max}$ door: $z_{max}$ is gelijk aan 200 m.*

*Vervang de definities van $z_0$ , $z_{min}$ door: $z_0$ , $z_{min}$ zijn afhankelijk van de terreincategorie en moeten zijn bepaald volgens tabel 4.1.*

*Lees tabel 4.1 als:*

**Tabel 4.1 — Terreincategorieën en terreinparameters**

| Terreincategorie | | $z_0$<br>m | $z_{min}$<br>m |
|---|---|---|---|
| 0 | Zee of kustgebied aan zee | 0,005 | 1 |
| II | Onbebouwd gebied | 0,2 | 4 |
| III | Bebouwd gebied | 0,5 | 7 |

*Also a text in given in this National Annex concerning the calculation of the terraincategorie.*

*NF:*
*§4.3.2(1):*
*Some values are changed concerning the category class:*

**Tableau 4.1(NA) — Catégories et paramètres de terrain**

| Catégorie de terrain | | $z_0$ [m] | $z_{min}$ [m] |
|---|---|---|---|
| 0 | Mer ou zone côtière exposée aux vents de mer ; lacs et plans d'eau parcourus par le vent sur une distance d'au moins 5 km | 0,005 | 1 |
| II | Rase campagne, avec ou non quelques obstacles isolés (arbres, bâtiments, etc.) séparés les uns des autres de plus de 40 fois leur hauteur | 0,05 | 2 |
| IIIa | Campagne avec des haies ; vignobles ; bocage ; habitat dispersé | 0,20 | 5 |
| IIIb | Zones urbanisées ou industrielles ; bocage dense ; vergers | 0,5 | 9 |
| IV | Zones urbaines dont au moins 15 % de la surface sont recouverts de bâtiments dont la hauteur moyenne est supérieure à 15 m ; forêts | 1,0 | 15 |

NOTE 1 Les catégories de terrain sont illustrées par les photographies aériennes des figures 4.6(NA) à 4.14(NA).

NOTE 2 Le coefficient de rugosité, fonction de la catégorie de terrain et de la hauteur *z*, est illustré à la figure 4.15(NA).

*§4.3.2(2):*
*La valeur du secteur angulaire est de 30°, soit ± 15° par rapport à la direction du vent. La distance au vent, ou rayon R du secteur angulaire dans lequel la rugosité du terrain est à qualifier, dépend de la hauteur h de la construction. Elle est donnée par:*

$R = 23 \cdot h^{1,2}$ *avec R > 300m*

*où h et R sont exprimés en mètres.*

**Terrain orography**

In case of structures that are located on elevations like hills etc. the increase of the wind velocity can be taken into account by defining a particular orography factor $c_o(z)$. In general this factor is set to 1,0.

*National annexes:*

*NF: 2 procedures are given for the calculation of this terrain orography.*

*NEN:* $c_0$ *moet bepaald zijn volgens A.3.*

*NBN: In afwijking van (1) wordt* $c_o$ *in rekening gebracht wanneer de helling Φ > 5%. De in A.3 aanbevolen waarde voor de numerieke berekening van de orografiefactor* $c_o(z)$ *is normatief.*

**Large and considerably higher neighbouring structures**

If the structure is to be located close to another structure, that is at least twice as high as the average height of its neighboring structures, then it could be exposed (dependent on the properties of the structure) to increased wind velocities for certain wind directions. Such cases should be taken into account.

The National Annex may give a procedure to take account of this effect. A recommended conservative first approximation is given in Annex A.4.

*National annexes:*

*NF: The procedure of Annex A.4 is rewritten is this National Annex.*

*NEN: Het effect van nabijgelegen, dan wel nabij geplande, hogere bouwwerken moet volgens A.4 zijn bepaald.*
*OPMERKING: Voor geplande gebouwen/bebouwing kan het bestemmingsplan worden geraadpleegd.*

*NBN: De in A.4 aanbevolen procedure voor de bepaling van de hoogte $z_n$ boven de grond voor de berekening van de extreme stuwdruk, te gebruiken voor een constructie nabij een gebouw met grote hoogte, is normatief.*

**Closely spaced buildings and obstacles**

The effect of closely spaced buildings and other obstacles may be taken into account.

The National Annex may give a procedure. A recommended first approximation is given in Annex A.5. In rough terrain, closely spaced buildings modify the mean wind flow near the ground, as if the ground level was raised to a height called displacement height $h_{dis}$.

*National annexes:*

*NF: Il n'y a pas lieu de tenir compte de l'effet de bâtiments et autres obstacles rapprochés.*

*NEN: De bebouwingsdichtheid mag niet afzonderlijk in rekening zijn gebracht. Voor de verplaatsingshoogte $h_{dis}$ moet 0 m zijn aangehouden.*

*NBN: De in A.5 aanbevolen procedure ter bepaling van de hoogte $h_{dis}$ van verplaatsing naar omhoog van het profiel van de extreme stuwdruk ten opzichte van de hoogte is normatief.*

## Wind turbulence

The turbulence intensity $I_v(z)$ at height $z$ is defined as the standard deviation of the turbulence divided by the mean wind velocity.

$$I_v(z) = \frac{\sigma_v}{v_m(z)} = \frac{k_I}{c_o(z)\ln\left(z/z_0\right)} \qquad \text{for } z_{min} \leq z \leq z_{max}$$

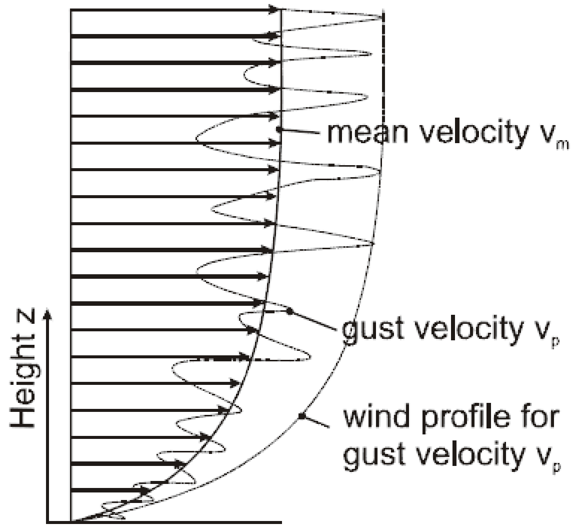
$$I_v(z) = I_v(z_{min}) \qquad \text{for } z < z_{min}$$

Where:

$k_I$ is the turbulence factor. The value of $k_I$ may be given in the National Annex. The recommended value is $k_I = 1,0$.
$c_o$ is the orography factor
$z_0$ is the roughness length

The gust velocity (or peak velocity) $v_p(z)$ at the reference height of the considered terrain category is calculated with the mean velocity and the gust factor $G$:

$$v_p(z) = G \cdot v_m(z) = [1 + 7\, I_v(z)]^{0.5} \cdot v_m(z)$$




**Variation of wind velocity depending on height** z

*National annexes:*

*NF:*
*Pour le calcul de l'intensité de turbulence $I_v(z)$ au moyen de l'expression (4.7), il y a lieu de distinguer deux situations :*

- *en site plat et dans le cas d'orographie constituée d'obstacles bien individualisés (cas 2 défini par la présente Annexe Nationale pour l'application de la clause 4.3.3(1)), le coefficient de turbulence $k_I$ est défini par l'expression (4.19-NA) :*
  $k_I = 1 - 2 \cdot 10^{-4} \, (log_{10}\,(z_o) + 3)^6 \,)$
- *dans le cas d'orographie constituée d'obstacles de hauteurs et de formes variées (cas 1 défini par la présente Annexe Nationale pour l'application de la clause 4.3.3(1)), le coefficient de turbulence $k_I$ est défini par l'expression (4.20-NA) :*

  $k_I = c_o(z)\,(1 - 2 \cdot 10^{-4} \, (log_{10}\,(z_o) + 3)^6 \,)$

*NBN:*
*De aanbevolen regels ter berekening van de turbulentie-intensiteit $I_v(z)$ zijn normatief.*
*De waarde van de turbulentiecoëfficiënt $k_I$ is gegeven door de uitdrukking:*

$$k_I = c_o(z)\,(1 - 2 \cdot 10^{-4} \, (log_{10}\,(z_o) + 3)^6 \,)$$

*Wanneer $c_o(z) = 1$ (helling < 5 %, zie A.3), mag men aannemen:*

- *terreincategorieën 0, I en II:* $k_I = 1$
- *terreincategorie III:* $k_I = 0,95$
- *terreincategorie IV:* $k_I = 0,85$

## Peak velocity pressure

The peak velocity pressure $q_p(z)$ at height $z$, which includes mean and short-term velocity fluctuations, can be determined according to rules given in the National Annex.
The recommended rule is given in the following equation:

$q_p(z) = [1+ 7\, I_v\,(z)] \cdot 1/2 \cdot \rho \cdot v_m^2(z)$
$= [1+ 7\, I_v\,(z)] \cdot 1/2 \cdot \rho \cdot c_r^2(z) \cdot c_o^2(z) \cdot v_b^2(z)$

$= c_e(z) \cdot q_b$

where:

ρ — is the air density, which depends on the altitude, temperature and barometric pressure to be expected in the region during wind storms
The values for ρ may be given in the National Annex. The recommended value is 1,25 kg/m³

$c_e(z)$ — is the exposure factor: $c_e(z)=[1+ 7\, I_v\,(z)] \cdot c_r^2(z) \cdot c_o^2(z)$

$q_b$ — is the basic velocity pressure: $q_b = 1/2 \cdot \rho \cdot v_b^2$

For flat terrain where $c_o(z)$ = 1,0 the exposure factor $c_e(z)$ is illustrated in Figure 4.2 as a function of height above terrain and a function of terrain category as defined in Table 4.1.

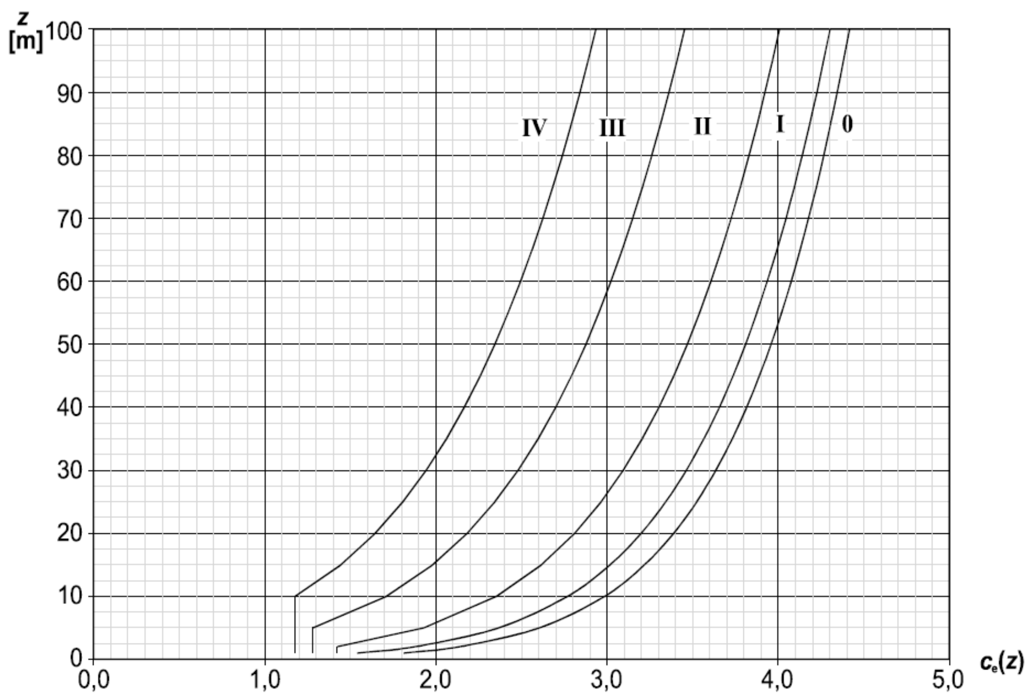
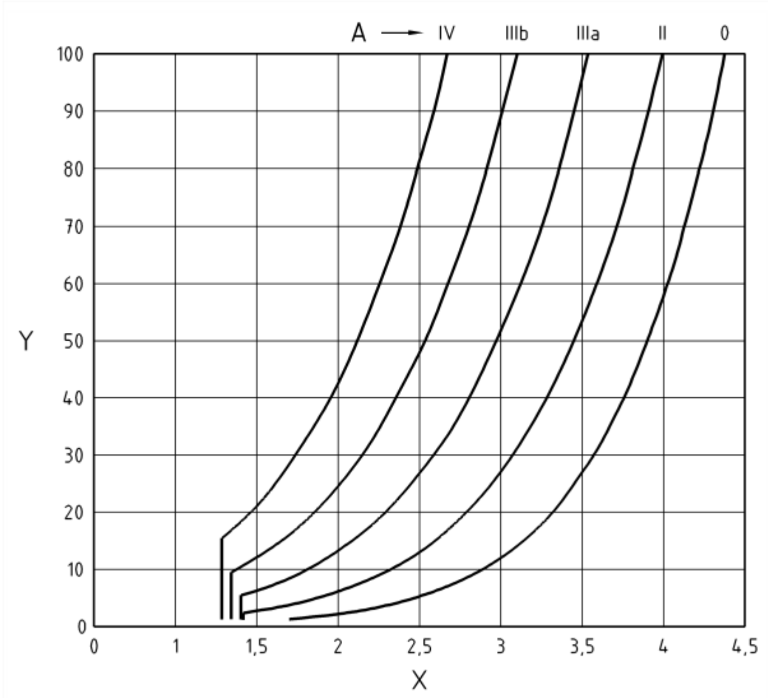



**Figure 4.2 — Illustrations of the exposure factor $c_e(z)$ for $c_O$=1,0, $k_I$=1,0**

*National annexes:*

*NF:* La masse volumique de l'air ρ doit être prise égale à 1,225 kg/m3.
Note : Avec les paramètres retenus dans cette Annexe nationale, la figure 4.2 illustrant le coefficient d'exposition $c_e(z)$ en terrain plat ($c_o$= 1) est remplacée par la figure 4.2(NA) suivante :




NBN : De aanbevolen waarde ρ = 1,25 kg/m³ van de volumemassa van de lucht is normatief.
This National Annex Gives a “Niet-tegenstrijdige National Aanvulling” for the calculation of $q_p(z)$.

NEN : Voor ρ moet 1,25 kg/m³ zijn aangehouden.

# Section 5: Wind actions

## General

In EN 1991-1-4 regulations are given not only for the determination of the external wind pressure $w_e$ on the structure's cladding but also for the application of the internal wind pressure $w_i$ in case of openings in the cladding. Both types of wind pressure depend on the geometry of the considered structure. In addition to that the internal pressure varies with the permeability of the building.

A summary of calculation procedures for the determination of wind actions is given in the following table.

| Parameter | Subject Reference |
|---|---|
| **peak velocity pressure $q_p$** | |
| basic wind velocity $v_b$ | 4.2 (2)P |
| reference height $z_e$ | Section 7 |
| terrain category | Table 4.1 |
| characteristic peak velocity pressure $q_p$ | 4.5 (1) |
| turbulence intensity $I_v$ | 4.4 |
| mean wind velocity $v_m$ | 4.3.1 |
| orography coefficient $c_o(z)$ | 4.3.3 |
| roughness coefficient $c_r(z)$ | 4.3.2 |
| **Wind pressures, e.g. for cladding, fixings and structural parts** | |
| internal pressure coefficient $c_{pi}$ | Section 7 |
| external pressure coefficient $c_{pe}$ | Section 7 |
| external wind pressure: $w_e=q_p\,c_{pe}$ | 5.2 (1) |
| internal wind pressure: $w_i=q_p\,c_{pi}$ | 5.2 (2) |
| **Wind forces on structures, e.g. for overall wind effects** | |
| structural factor: $c_sc_d$ | 6 |
| wind force $F_W$ calculated from force coefficients | 5.3 (2) |
| wind force $F_W$ calculated from pressure coefficients | 5.3 (3) |

**Table 5.1 —Calculation procedures for the determination of wind actions**

## Wind pressure on surfaces

The wind pressure acting on the external surfaces $w_e$ should be obtained from:

$$w_e = q_p(z_e) \cdot c_{pe}$$

where:

$q_p(z_e)$ is the peak velocity pressure
$z_e$ is the reference height for the external pressure
$c_{pe}$ is the pressure coefficient for the external pressure

The wind pressure acting on the internal surfaces, $w_i$ , should be obtained from:

$$w_i = q_p(z_i) \cdot c_{pi}$$

where:

$q_p(z_i)$ is the peak velocity pressure
$z_i$ is the reference height for the internal pressure
$c_{pi}$ is the pressure coefficient for the internal pressure

For the external wind load as well as for the internal wind load the term "pressure" includes also suction: a positive wind load stand for pressure whereas a negative wind load stands for suction on the surface.

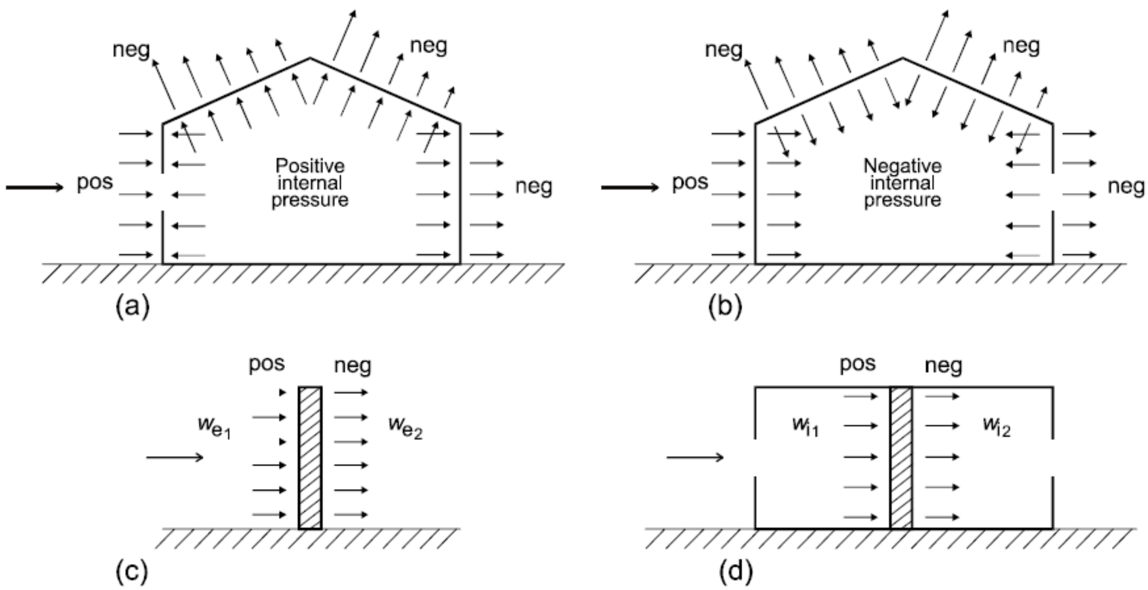



**Figure 5.1 — Pressure on surfaces**

If both, internal and external wind pressure, have to be applied, they have to be superposed if their effect is unfavorable for the design.

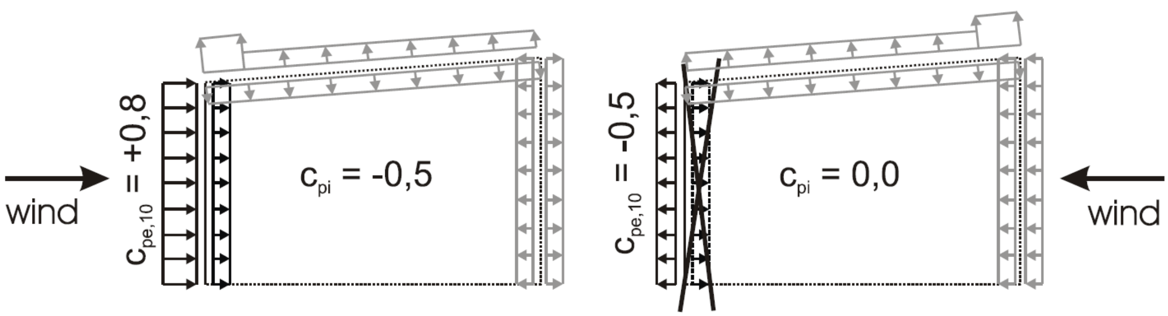



**Figure: Wind load on cladding:**
**Superposition of external pressure with unfavourable internal pressure:**
**(windward, $c_{pi}$ is unfavourable - leeward, $c_{pi}$ has to be taken as 0,0)**

## Wind forces

The resulting wind force can be determined by integration of the wind pressure over the whole surface or by applying appropriate force coefficients.

The wind force $F_w$ acting on a structure or a structural component may be determined directly by using:

$$F_w = c_s c_d \cdot c_f \cdot q_p(z_e) \cdot A_{ref}$$

or by vectorial summation over the individual structural elements by using:

$$F_w = c_s c_d \sum_{elements} c_f \cdot q_p(z_e) \cdot A_{ref}$$

where:

| | |
|---|---|
| $c_s c_d$ | is the structural factor |
| $c_f$ | is the force coefficient for the structure or structural element |
| $q_p(z_e)$ | is the peak velocity pressure at reference height $z_e$ |
| $A_{ref}$ | is the reference area of the structure or structural element |

The wind force, $F_w$ acting on a structure or a structural element may be determined by vectorial summation of the forces $F_{w,e}$, $F_{w,i}$ and $F_{fr}$ calculated from the external and internal pressures and the frictional forces resulting from the friction of the wind parallel to the external surfaces, calculated using following expressions:

external forces:

$$F_{w,e} = c_s c_d \sum_{surfaces} w_e \cdot A_{ref}$$

internal forces:

$$F_{w,i} = \sum_{surfaces} w_i \cdot A_{ref}$$

friction forces:

$$F_{fr} = c_{fr} \cdot q_p(z_e) \cdot A_{fr}$$

where:

$c_s c_d$ is the structural factor
$w_e$ is the external pressure on the individual surface at height $z_e$
$w_i$ is the internal pressure on the individual surface at height $z_i$
$A_{ref}$ is the reference area of the individual surface
$c_{fr}$ is the friction coefficient
$A_{fr}$ is the area of external surface parallel to the wind

For elements (e.g. walls, roofs), the wind force becomes equal to the difference between the external and internal resulting forces.

Friction forces $F_{fr}$ act in the direction of the wind components parallel to external surfaces.

The effects of wind friction on the surface can be disregarded when the total area of all surfaces parallel with (or at a small angle to) the wind is equal to or less than 4 times the total area of all external surfaces perpendicular to the wind (windward and leeward).

# Section 6: Structural factor $c_sc_d$

## General

The structural factor $c_sc_d$ should take into account the effect on wind actions from the non-simultaneous occurrence of peak wind pressures on the surface together with the effect of the vibrations of the structure due to turbulence.

The structural factor $c_sc_d$ may be separated into a size factor $c_s$ and a dynamic factor $c_d$. Information on whether the structural factor $c_sc_d$ should be separated or not may be given in the National Annex.

## Determination of $c_sc_d$

$c_sc_d$ should be determined as follows:

a) For buildings with a height less than 15 m the value of $c_sc_d$ may be taken as 1

b) For facade and roof elements having a natural frequency (see Annex F) greater than 5 Hz, the value of $c_sc_d$ may be taken as 1.

c) For framed buildings which have structural walls and which are less than 100 m high and whose height is less than 4 times the in-wind depth, the value of $c_sc_d$ may be taken as 1.

d) For chimneys with circular cross-sections whose height is less than 60 m and 6,5 times the diameter, the value of $c_sc_d$ may be taken as 1.

e) Alternatively, for cases a), b), c) and d) above, values of $c_sc_d$ may be derived from the formule in the next paragraph.

f) For civil engineering works (other than bridges, and chimneys and buildings outside the limitations given in c) and d) above, $c_sc_d$ should be derived either from the next paragraph or taken from Annex D.

## Detailed procedure

**Structural factor $c_sc_d$**

The detailed procedure for calculating the structural factor $c_sc_d$ is given in the following expression:

$$c_sc_d = \frac{1 + 2 \cdot K_p \cdot I_v(z_s) \cdot \sqrt{B^2 + R^2}}{1 + 7 \cdot I_v(z_s)}$$

where:

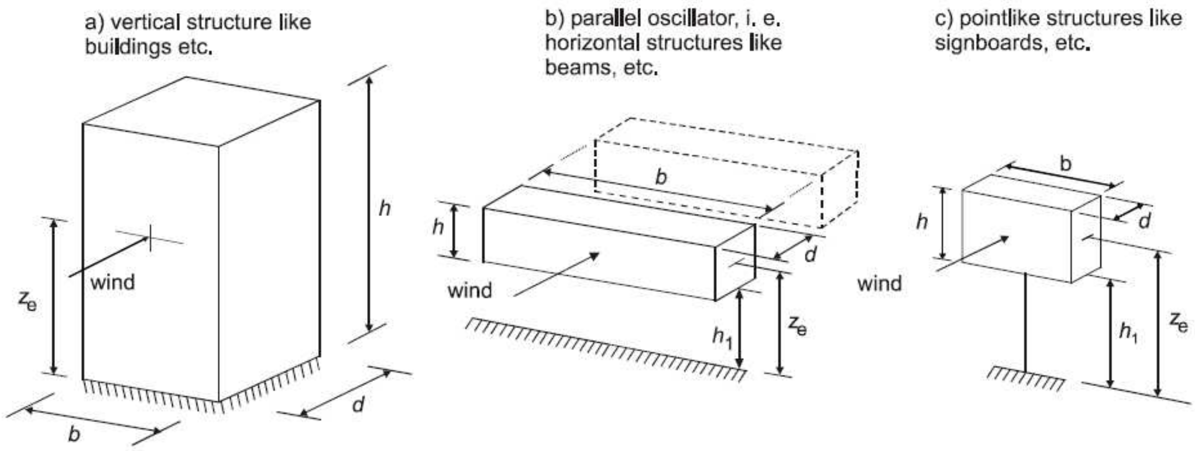
$z_e$ is the reference height, see Figure 6.1. For structures where Figure 6.1 does not apply $z_e$ may be equal to *h,* the height of the structure.

$k_p$ is the peak factor defined as the ratio of the maximum value of the fluctuating part of the response to its standard deviation

$I_v$ is the turbulence intensity

$B^2$ is the background factor, allowing for the lack of full correlation of the pressure on the structure surface

$R^2$ is the resonance response factor, allowing for turbulence in resonance with the vibration mode




NOTE Limitations are also given in 1.1 (2)

$z_e = 0{,}6 \cdot h \geq z_{min}$ $\quad$ $z_e = h_1 + \frac{h}{2} \geq z_{min}$ $\quad$ $z_e = h_1 + \frac{h}{2} \geq z_{min}$

**Figure 6.1 — General shapes of structures covered by the design procedure**

The expression above shall only be used if all of the following requirements are met:

- the structure corresponds to one of the general shapes shown in Figure 6.1
- only the along-wind vibration in the fundamental mode is significant, and this mode shape has a constant sign.

The size factor $c_s$ takes into account the reduction effect on the wind action due to the non-simultaneity of occurrence of the peak wind pressures on the surface and may be obtained from the following expression:

$$c_s = \frac{1 + 7 \cdot I_v(z_s) \cdot \sqrt{B^2}}{1 + 7 \cdot I_v(z_s)}$$

The dynamic factor $c_d$ takes into account the increasing effect from vibrations due to turbulence in resonance with the structure and may be obtained from the following expression:

$$c_d = \frac{1 + 2 \cdot K_p \cdot I_v(z_s) \cdot \sqrt{B^2 + R^2}}{1 + 7 \cdot I_v(z_s) \cdot \sqrt{B^2}}$$

The procedure to be used to determine $k_p$, $B$ and $R$ may be given in the National Annex. A recommended procedure is given in Annex B. An alternative procedure is given in Annex C. As an indication to the users the differences in $c_s c_d$ using Annex C compared to Annex B does not exceed approximately 5%.

National annexes

NF:
§6.1(1): Il n'est généralement pas nécessaire de dissocier le coefficient structural cscd en un coefficient de dimension $c_s$ et un coefficient dynamique $c_d$.

§6.3.1(1) : La procédure à utiliser est la procédure 1 décrite à l'Annexe B. L'Annexe B est normative l'Annexe C n'est pas applicable.

§6.3.2(1) : La méthode à utiliser est donnée à l'Annexe B.
NOTE La force statique équivalente est définie en 5.3.

NEN :
§6.1(1): De ‘gecombineerde factor’ mag niet zijn gesplitst.

§6.3.1(1) : Lees na formule 6.3: De factoren $k_p$, B en R moeten zijn bepaald volgens bijlage B. Indien voor $c_s c_d$ een waarde kleiner dan 0,85 is gevonden, moet een waarde gelijk aan $c_s c_d$ = 0,85 zijn toegepast.

§6.3.2(1) : De dynamische verplaatsingen en versnellingen moeten zijn bepaald volgens bijlage B.

NBN:
§6.3.1(1) : De aanbevolen procedure 1 van de Bijlage B ter berekening van $c_s c_d$ is normatief.
This annex gives also a “NIET TEGENSCHRIJDIGE NATIONAL AANVULLING” on this topic.

§6.3.2(1) : De dynamische verplaatsingen en versnellingen moeten zijn bepaald volgens bijlage B.

§6.3.2(1): De in B.4 gegeven aanbevolen methodes ter bepaling van de verplaatsing in de windrichting (richting x), alsook de standaardafwijking van de versnelling $\sigma_{a,x}(z)$ en de maximale karakteristieke versnelling $a_x = k_p \cdot \sigma_{a,x}(z)$ in de windrichting, zijn normatief. De waarde $k_p$ is gegeven door de uitdrukking (B.4).

# Section 7: Pressure and force coefficients

## General

This section should be used to determine the appropriate aerodynamic coefficients for structures. Depending on the structure the appropriate aerodynamic coefficient will be:

- Internal and external pressure coefficients for:
  - Buildings (using 7.2 (from EN 1991-1-4) for both internal and external pressures)
  - Circular cylinders (using 7.2.9 for the internal and 7.9.1 for the external pressures)

  External pressure coefficients give the effect of the wind on the external surfaces buildings; internal pressure coefficients give the effect of the wind on the internal surfaces of buildings.

  The external pressure coefficients are divided into overall coefficients and local coefficients. Local coefficients give the pressure coefficients for loaded areas of 1m². They may be used for the design of small elements and fixings.
  Overall coefficients give the pressure coefficients for loaded areas of 10 m². They may be used for loaded areas larger than 10 m².

- Net pressure coefficients for:
  - Canopy roofs, (using 7.3)
  - Free-standing walls, parapets and fences (using 7.4)

Net pressure coefficients give the resulting effect of the wind on a structure, structural element or component per unit area.

- Friction coefficients should be determined for walls and surfaces (using 7.5)

- Force coefficients should be determined for:
  - Signboards (using 7.4.3)
  - Structural elements with rectangular cross section (using 7.6)
  - Structural elements with sharp edged section (using 7.7)
  - Structural elements with regular polygonal section (using 7.8)
  - Circular cylinders (using 7.9.2 and 7.9.3)
  - Spheres (using 7.10)
  - Lattice structures and scaffoldings (using 7.11)
  - Flags (using 7.12)

  A reduction factor depending on the effective slenderness of the structure may be applied (using 7.13)

  Force coefficients give the overall effect of the wind on a structure, structural element or component as a whole, including friction, if not specifically excluded.

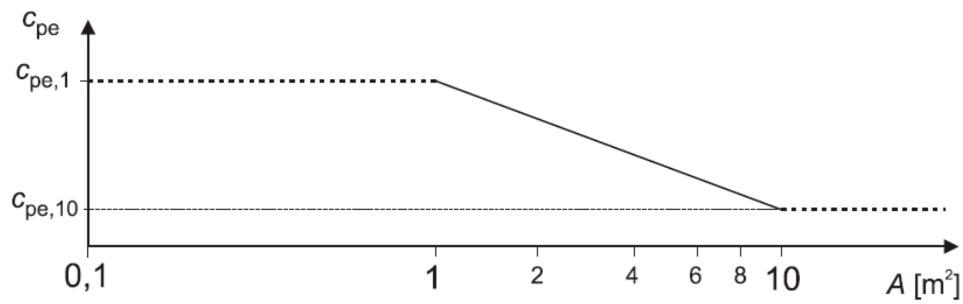
## Pressure coefficients for buildings

**General**

The external pressure coefficients $c_{pe}$ for buildings and parts of buildings depend on the size of the loaded area $A$, which is the area of the structure, that produces the wind action in the section to be calculated. The external pressure coefficients are given for loaded areas $A$ of 1 m² and 10 m² in the tables for the appropriate building configurations as $c_{pe,1}$, for local coefficients, and $c_{pe,10}$, for overall coefficients, respectively.

Values for $c_{pe,1}$ are intended for the design of small elements and fixings with an area per element of 1 m² or less such as cladding elements and roofing elements.
Values for $c_{pe,10}$ may be used for the design of the overall load bearing structure of buildings.

The National Annex may give a procedure for calculating external pressure coefficients for loaded areas above 1 m² based on external pressure coefficients $c_{pe,1}$ and $c_{pe,10}$. The recommended procedure for loaded areas up to 10 m² is given in Figure 7.2.




The figure is based on the following:
for 1 m² < $A$ < 10 m² $\quad c_{pe} = c_{pe,1} - (c_{pe,1} - c_{pe,10}) \log_{10} A$

**Figure 7.2 — Recommended procedure for determining the external pressure coefficient $c_{pe}$**

The values $c_{pe,10}$ and $c_{pe,1}$ should be used for the orthogonal wind directions 0°, 90°, 180°. These values represent the most unfavorable values obtained in a range of wind direction $\theta = \pm 45°$ either side of the relevant orthogonal direction.

For protruding roof corners the pressure on the underside of the roof overhang is equal to the pressure for the zone of the vertical wall directly connected to the protruding roof; the pressure at the top side of the roof overhang is equal to the pressure of the zone, defined for the roof.

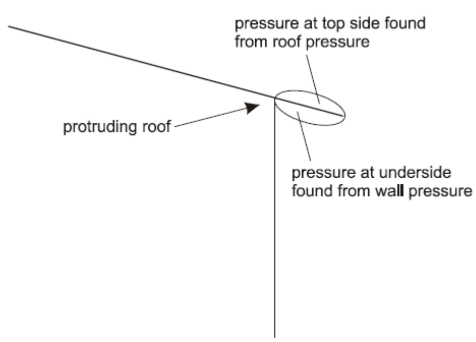


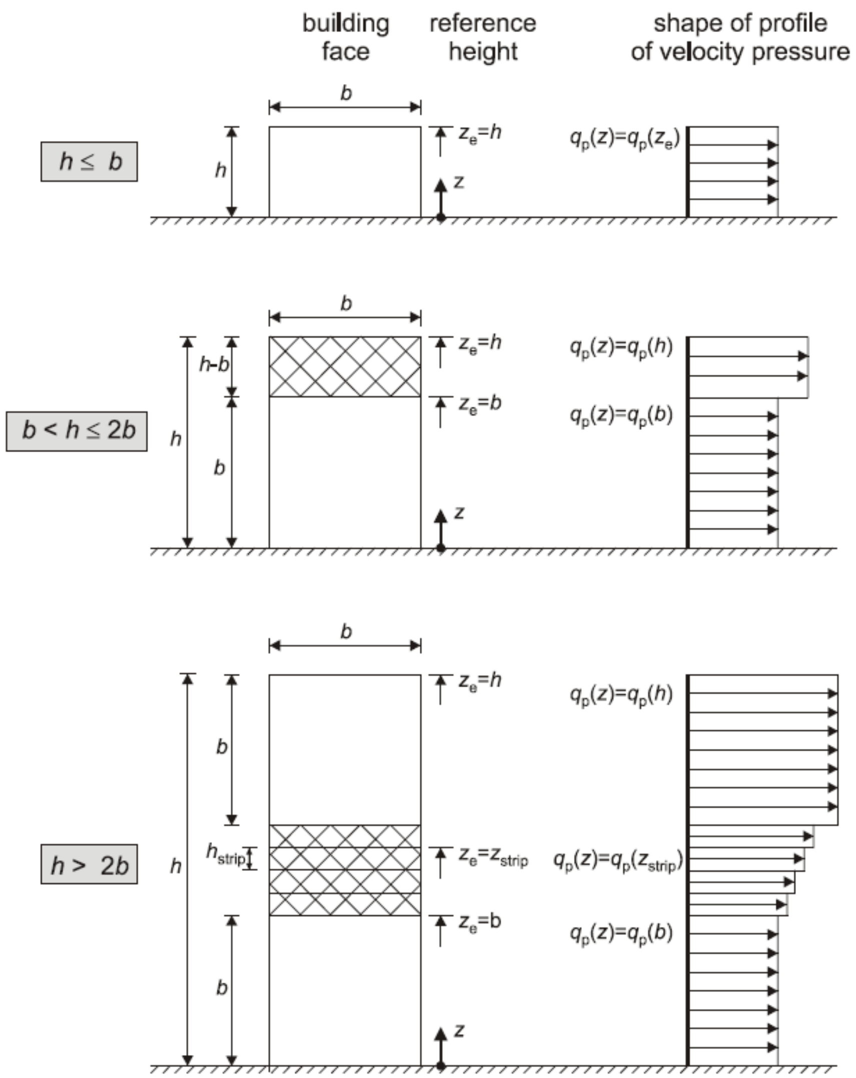

**Figure 7.3 — Illustration of relevant pressures for protruding roofs**

**<u>Vertical walls of rectangular plan buildings</u>**

The reference heights, $z_e$, for windward walls of rectangular plan buildings (zone D, see Figure 7.5) depend on the aspect ratio $h/b$ and are always the upper heights of the different parts of the walls. They are given in Figure 7.4 for the following three cases:

- A building, whose height $h$ is less than $b$ should be considered to be one part.
- A building, whose height $h$ is greater than $b$, but less than $2b$, may be considered to be two parts, comprising:
    - a lower part extending upwards from the ground by a height equal to $b$
    - an upper part consisting of the remainder.

- A building, whose height $h$ is greater than $2b$ may be considered to be in multiple parts, comprising:
    - a lower part extending upwards from the ground by a height equal to $b$
    - an upper part extending downwards from the top by a height equal to $b$
    - a middle region, between the upper and lower parts, which may be divided into horizontal strips with a height $h_{strip}$ as shown in Figure 7.4.




NOTE The velocity pressure should be assumed to be uniform over each horizontal strip considered.

**Figure 7.4 — Reference height, $z_e$, depending on *h* and *b*, and corresponding velocity pressure profile**

The rules for the velocity pressure distribution for leeward wall and sidewalls (zones A, B, C and E, see Figure 7.5) may be given in the National Annex or be defined for the individual project. The recommended procedure is to take the reference height as the height of the building.

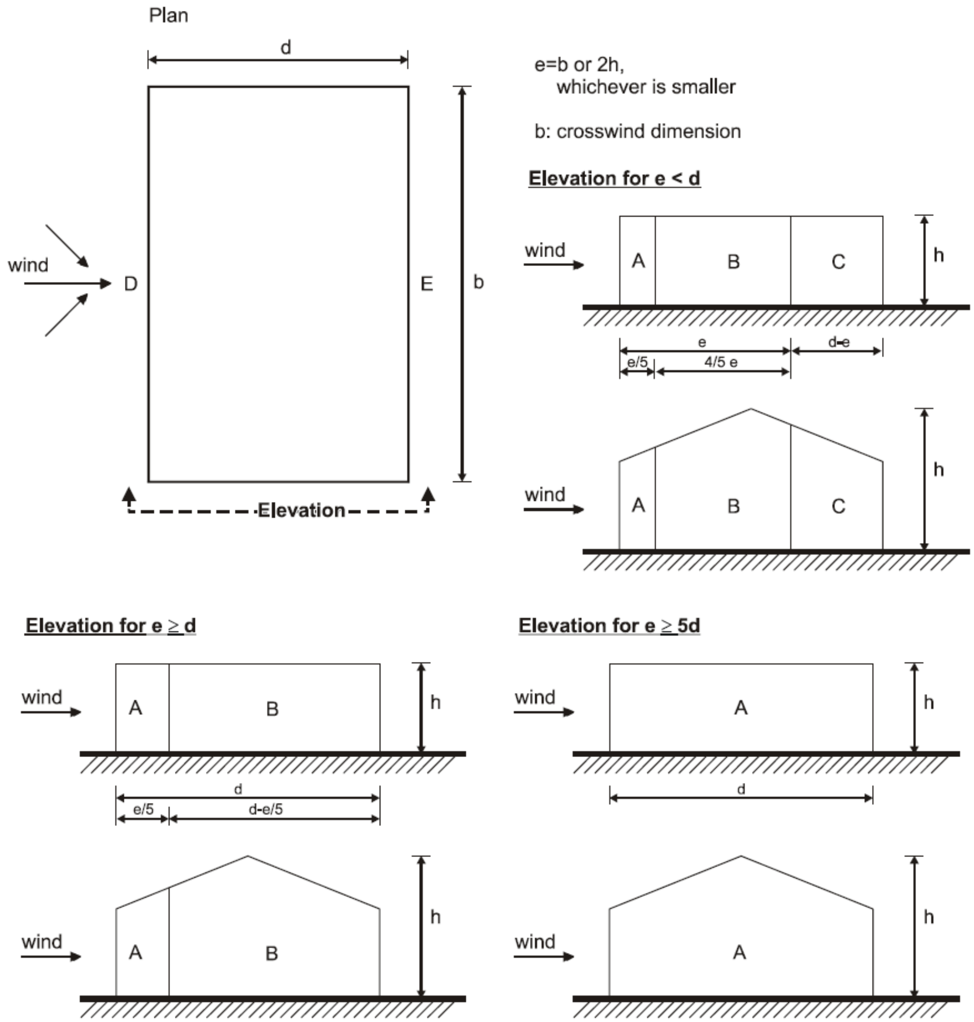



**Figure 7.5 — Key for vertical walls**

The values of $c_{pe,10}$ and $c_{pe,1}$ may be given in the National Annex. The recommended values are given in Table 7.1, depending on the ratio *h*/*d*. For intermediate values of *h*/*d*, linear interpolation may be applied. The values of Table 7.1 also apply to walls of buildings with inclined roofs, such as duopitch and monopitch roofs.

| Zone | A | | B | | C | | D | | E | |
|---|---|---|---|---|---|---|---|---|---|---|
| *h*/*d* | $c_{pe,10}$ | $c_{pe,1}$ | $c_{pe,10}$ | $c_{pe,1}$ | $c_{pe,10}$ | $c_{pe,1}$ | $c_{pe,10}$ | $c_{pe,1}$ | $c_{pe,10}$ | $c_{pe,1}$ |
| 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 | |

**Table 7.1 — Recommended values of external pressure coefficients for vertical walls**

## Flat roofs

Flat roofs are defined as having a slope ($\alpha$) of $-5° < \alpha < 5°$

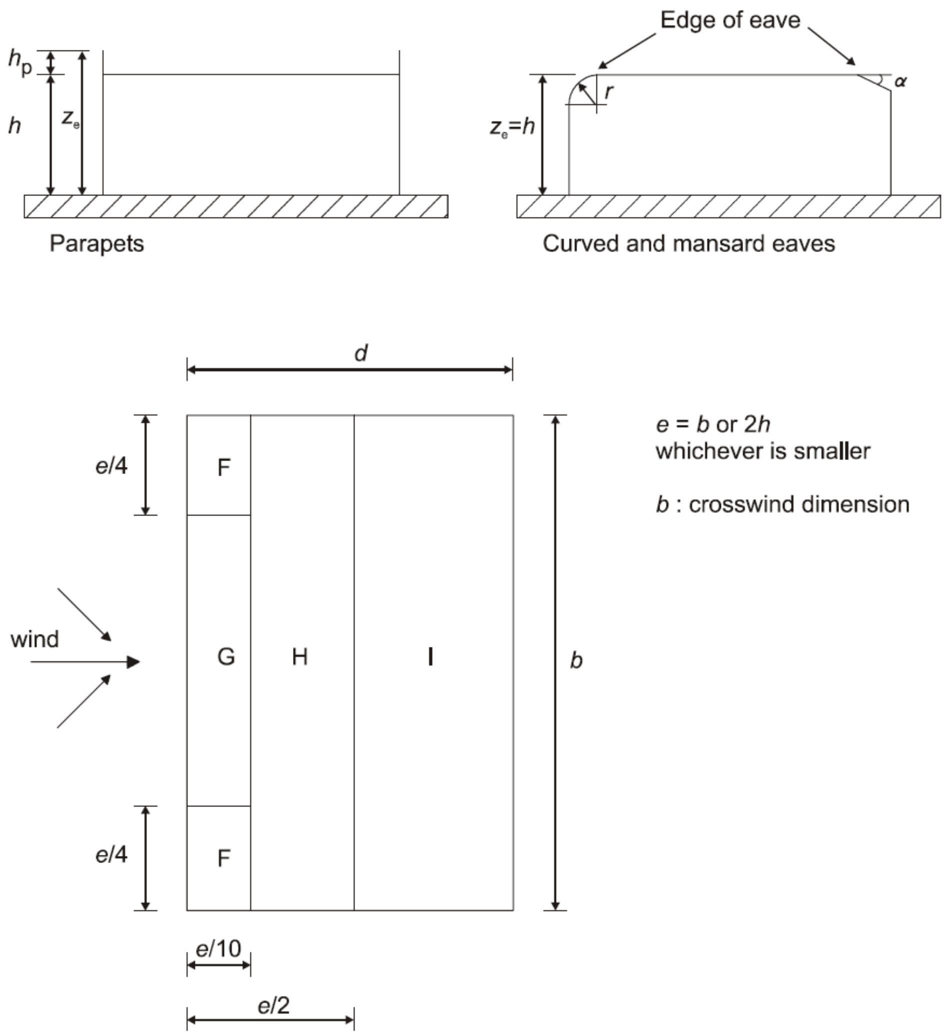



**Figure 7.6 — Key for flat roofs**

| Roof type | | Zone | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | F | | G | | H | | I | |
| | | $c_{pe,10}$ | $c_{pe,1}$ | $c_{pe,10}$ | $c_{pe,1}$ | $c_{pe,10}$ | $c_{pe,1}$ | $c_{pe,10}$ | $c_{pe,1}$ |
| Sharp eaves | | -1,8 | -2,5 | -1,2 | -2,0 | -0,7 | -1,2 | +0,2<br>-0,2 | |
| With Parapets | $h_p/h$=0,025 | -1,6 | -2,2 | -1,1 | -1,8 | -0,7 | -1,2 | +0,2<br>-0,2 | |
| | $h_p/h$=0,05 | -1,4 | -2,0 | -0,9 | -1,6 | -0,7 | -1,2 | +0,2<br>-0,2 | |
| | $h_p/h$=0,10 | -1,2 | -1,8 | -0,8 | -1,4 | -0,7 | -1,2 | +0,2<br>-0,2 | |
| Curved Eaves | $r/h$ = 0,05 | -1,0 | -1,5 | -1,2 | -1,8 | -0,4 | | +0,2<br>-0,2 | |
| | $r/h$ = 0,10 | -0,7 | -1,2 | -0,8 | -1,4 | -0,3 | | +0,2<br>-0,2 | |
| | $r/h$ = 0,20 | -0,5 | -0,8 | -0,5 | -0,8 | -0,3 | | +0,2<br>-0,2 | |
| Mansard Eaves | $\alpha$ = 30° | -1,0 | -1,5 | -1,0 | -1,5 | -0,3 | | +0,2<br>-0,2 | |
| | $\alpha$ = 45° | -1,2 | -1,8 | -1,3 | -1,9 | -0,4 | | +0,2<br>-0,2 | |
| | $\alpha$ = 60° | -1,3 | -1,9 | -1,3 | -1,9 | -0,5 | | +0,2<br>-0,2 | |

NOTE 1 For roofs with parapets or curved eaves, linear interpolation may be used for intermediate values of $h_p/h$ and $r/h$.

NOTE 2 For roofs with mansard eaves, linear interpolation between $\alpha$ = 30°, 45° and $\alpha$ = 60° may be used. For $\alpha$ > 60° linear interpolation between the values for $\alpha$ = 60° and the values for flat roofs with sharp eaves may be used.

NOTE 3 In Zone I, where positive and negative values are given, both values shall be considered.

NOTE 4 For the mansard eave itself, the external pressure coefficients are given in Table 7.4 "External pressure coefficients for duopitch roofs: wind direction 0° ", Zone F and G, depending on the pitch angle of the mansard eave.

NOTE 5 For the curved eave itself, the external pressure coefficients are given by linear interpolation along the curve, between values on the wall and on the roof.

**Table 7.2 — External pressure coefficients for flat roofs**

**<u>Monopitch roofs</u>**

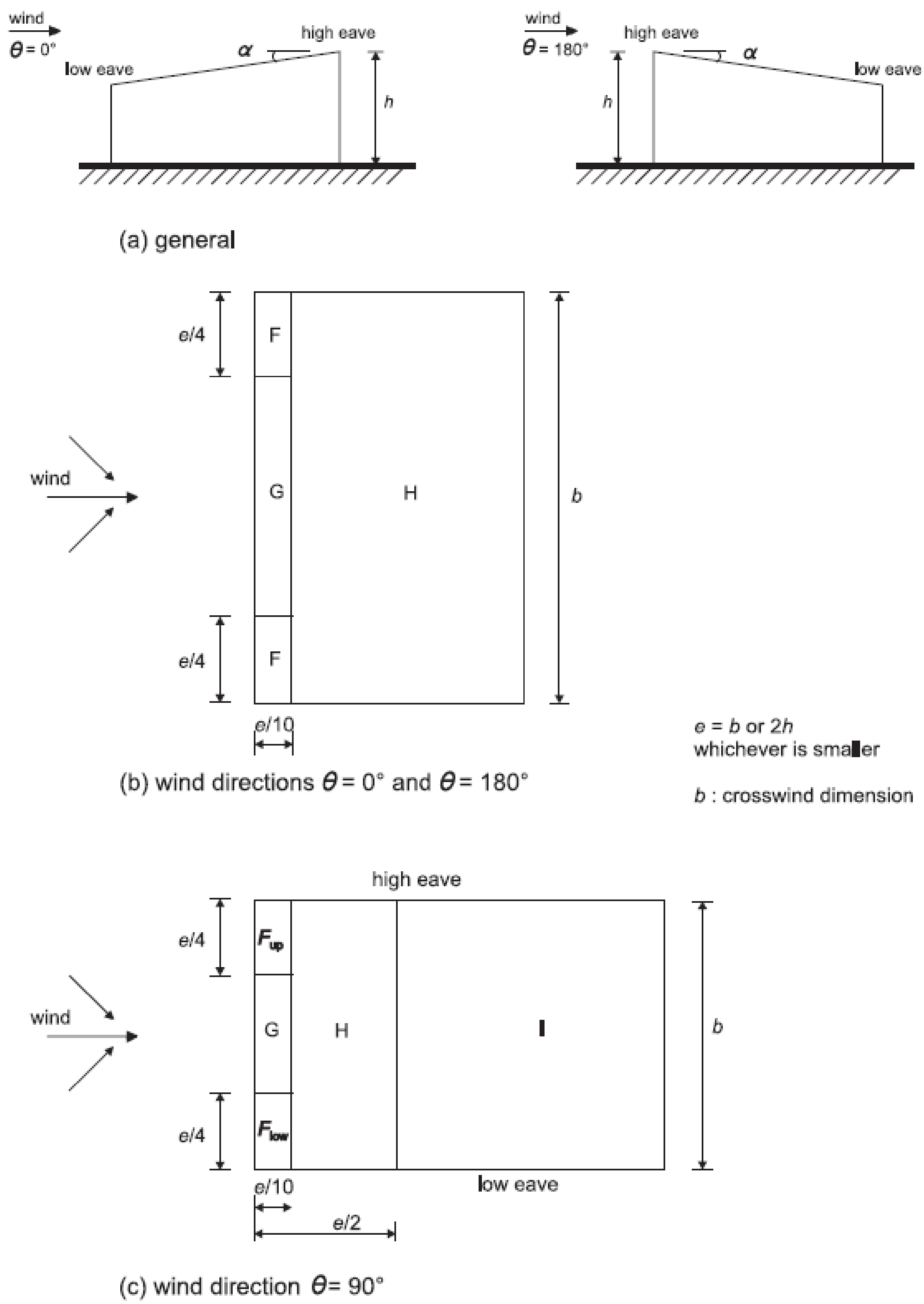



**Figure 7.7 — Key for monopitch roofs**

| Pitch Angle $\alpha$ | Zone for wind direction $\Theta = 0°$ | | | | | | Zone for wind direction $\Theta = 180°$ | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | F | | G | | H | | F | | G | | H | |
| | $c_{pe,10}$ | $c_{pe,1}$ | $c_{pe,10}$ | $c_{pe,1}$ | $c_{pe,10}$ | $c_{pe,1}$ | $c_{pe,10}$ | $c_{pe,1}$ | $c_{pe,10}$ | $c_{pe,1}$ | $c_{pe,10}$ | $c_{pe,1}$ |
| 5° | -1,7 | -2,5 | -1,2 | -2,0 | -0,6 | -1,2 | -2,3 | -2,5 | -1,3 | -2,0 | -0,8 | -1,2 |
| | +0,0 | | +0,0 | | +0,0 | | | | | | | |
| 15° | -0,9 | -2,0 | -0,8 | -1,5 | -0,3 | | -2,5 | -2,8 | -1,3 | -2,0 | -0,9 | -1,2 |
| | +0,2 | | +0,2 | | + 0,2 | | | | | | | |
| 30° | -0,5 | -1,5 | -0,5 | -1,5 | -0,2 | | -1,1 | -2,3 | -0,8 | -1,5 | -0,8 | |
| | +0,7 | | +0,7 | | +0,4 | | | | | | | |
| 45° | -0,0 | | -0,0 | | -0,0 | | -0,6 | -1,3 | -0,5 | | -0,7 | |
| | +0,7 | | +0,7 | | +0,6 | | | | | | | |
| 60° | +0,7 | | +0,7 | | +0,7 | | -0,5 | -1,0 | -0,5 | | -0,5 | |
| 75° | +0,8 | | +0,8 | | +0,8 | | -0,5 | -1,0 | -0,5 | | -0,5 | |

**Table 7.3a — External pressure coefficients for monopitch roofs**

| Pitch Angle $\alpha$ | Zone for wind direction $\Theta = 90°$ | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $F_{up}$ | | $F_{low}$ | | G | | H | | I | |
| | $c_{pe,10}$ | $c_{pe,1}$ | $c_{pe,10}$ | $c_{pe,1}$ | $c_{pe,10}$ | $c_{pe,1}$ | $c_{pe,10}$ | $c_{pe,1}$ | $c_{pe,10}$ | $c_{pe,1}$ |
| 5° | -2,1 | -2,6 | -2,1 | -2,4 | -1,8 | -2,0 | -0,6 | -1,2 | -0,5 | |
| 15° | -2,4 | -2,9 | -1,6 | -2,4 | -1,9 | -2,5 | -0,8 | -1,2 | -0,7 | -1,2 |
| 30° | -2,1 | -2,9 | -1,3 | -2,0 | -1,5 | -2,0 | -1,0 | -1,3 | -0,8 | -1,2 |
| 45° | -1,5 | -2,4 | -1,3 | -2,0 | -1,4 | -2,0 | -1,0 | -1,3 | -0,9 | -1,2 |
| 60° | -1,2 | -2,0 | -1,2 | -2,0 | -1,2 | -2,0 | -1,0 | -1,3 | -0,7 | -1,2 |
| 75° | -1,2 | -2,0 | -1,2 | -2,0 | -1,2 | -2,0 | -1,0 | -1,3 | -0,5 | |

NOTE 1 At $\Theta = 0°$ (see table a)) the pressure changes rapidly between positive and negative values around a pitch angle of $\alpha = +5°$ to $+45°$, so both positive and negative values are given. For those roofs, two cases should be considered: one with all positive values, and one with all negative values. No mixing of positive and negative values is allowed on the same face.

NOTE 2 Linear interpolation for intermediate pitch angles may be used between values of the same sign. The values equal to 0.0 are given for interpolation purposes

**Table 7.3b — External pressure coefficients for monopitch roofs**

**Duopitch roofs**

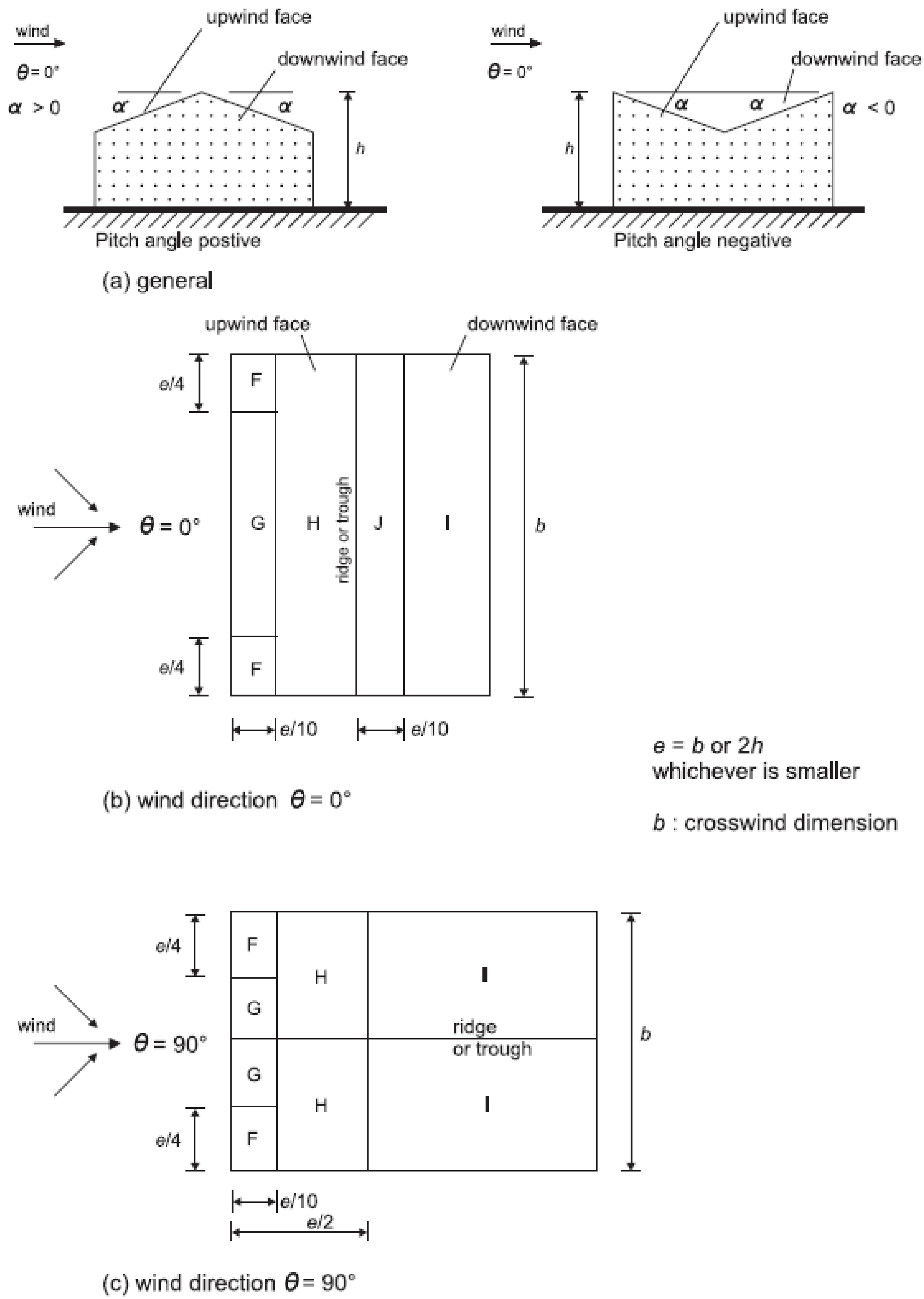



**Figure 7.8 — Key for duopitch roofs**

| Pitch Angle $\alpha$ | Zone for wind direction $\Theta = 0°$ | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | F | | G | | H | | I | | J | |
| | $c_{pe,10}$ | $c_{pe,1}$ | $c_{pe,10}$ | $c_{pe,1}$ | $c_{pe,10}$ | $c_{pe,1}$ | $c_{pe,10}$ | $c_{pe,1}$ | $c_{pe,10}$ | $c_{pe,1}$ |
| -45° | -0,6 | | -0,6 | | -0,8 | | -0,7 | | -1,0 | -1,5 |
| -30° | -1,1 | -2,0 | -0,8 | -1,5 | -0,8 | | -0,6 | | -0,8 | -1,4 |
| -15° | -2,5 | -2,8 | -1,3 | -2,0 | -0,9 | -1,2 | -0,5 | | -0,7 | -1,2 |
| -5° | -2,3 | -2,5 | -1,2 | -2,0 | -0,8 | -1,2 | +0,2 | | +0,2 | |
| | | | | | | | -0,6 | | -0,6 | |
| 5° | -1,7 | -2,5 | -1,2 | -2,0 | -0,6 | -1,2 | -0,6 | | +0,2 | |
| | +0,0 | | +0,0 | | +0,0 | | | | -0,6 | |
| 15° | -0,9 | -2,0 | -0,8 | -1,5 | -0,3 | | -0,4 | | -1,0 | -1,5 |
| | +0,2 | | +0,2 | | +0,2 | | +0,0 | | +0,0 | +0,0 |
| 30° | -0,5 | -1,5 | -0,5 | -1,5 | -0,2 | | -0,4 | | -0,5 | |
| | +0,7 | | +0,7 | | +0,4 | | +0,0 | | +0,0 | |
| 45° | -0,0 | | -0,0 | | -0,0 | | -0,2 | | -0,3 | |
| | +0,7 | | +0,7 | | +0,6 | | +0,0 | | +0,0 | |
| 60° | +0,7 | | +0,7 | | +0,7 | | -0,2 | | -0,3 | |
| 75° | +0,8 | | +0,8 | | +0,8 | | -0,2 | | -0,3 | |

NOTE 1 At $\Theta = 0°$ the pressure changes rapidly between positive and negative values on the windward face around a pitch angle of $\alpha = -5°$ to $+45°$, so both positive and negative values are given. For those roofs, four cases should be considered where the largest or smallest values of all areas F, G and H are combined with the largest or smallest values in areas I and J. No mixing of positive and negative values is allowed on the same face.

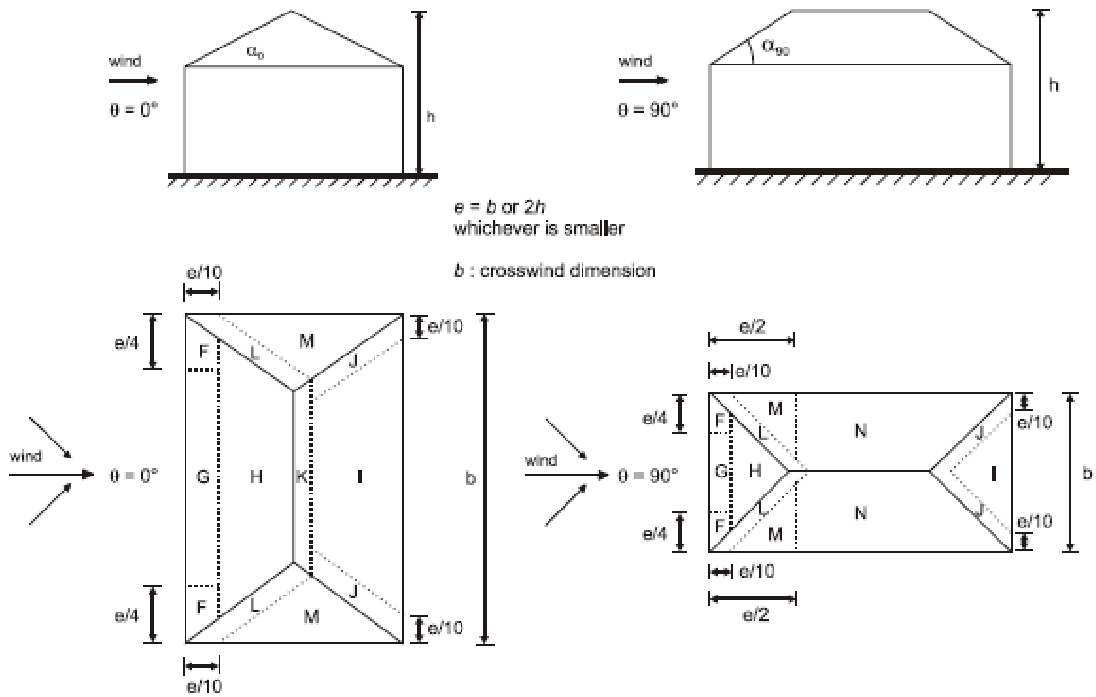
NOTE 2 Linear interpolation for intermediate pitch angles of the same sign may be used between values of the same sign. (Do not interpolate between $\alpha = +5°$ and $\alpha = -5°$, but use the data for flat roofs in 7.2.3). The values equal to 0,0 are given for interpolation purposes

**Table 7.4a — External pressure coefficients for duopitch roofs**

| Pitch angle $\alpha$ | Zone for wind direction $\Theta = 90°$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | F | | G | | H | | I | |
| | $c_{pe,10}$ | $c_{pe,1}$ | $c_{pe,10}$ | $c_{pe,1}$ | $c_{pe,10}$ | $c_{pe,1}$ | $c_{pe,10}$ | $c_{pe,1}$ |
| -45° | -1,4 | -2,0 | -1,2 | -2,0 | -1,0 | -1,3 | -0,9 | -1,2 |
| -30° | -1,5 | -2,1 | -1,2 | -2,0 | -1,0 | -1,3 | -0,9 | -1,2 |
| -15° | -1,9 | -2,5 | -1,2 | -2,0 | -0,8 | -1,2 | -0,8 | -1,2 |
| -5° | -1,8 | -2,5 | -1,2 | -2,0 | -0,7 | -1,2 | -0,6 | -1,2 |
| 5° | -1,6 | -2,2 | -1,3 | -2,0 | -0,7 | -1,2 | -0,6 | |
| 15° | -1,3 | -2,0 | -1,3 | -2,0 | -0,6 | -1,2 | -0,5 | |
| 30° | -1,1 | -1,5 | -1,4 | -2,0 | -0,8 | -1,2 | -0,5 | |
| 45° | -1,1 | -1,5 | -1,4 | -2,0 | -0,9 | -1,2 | -0,5 | |
| 60° | -1,1 | -1,5 | -1,2 | -2,0 | -0,8 | -1,0 | -0,5 | |
| 75° | -1,1 | -1,5 | -1,2 | -2,0 | -0,8 | -1,0 | -0,5 | |

**Table 7.4b — External pressure coefficients for duopitch roofs**

## Hipped roofs




(a) wind direction =0° (b) wind direction =90°

**Figure 7.9 — Key for hipped roofs**

| Pitch angle $\alpha_0$ for $\theta$=0° $\alpha_{90}$ for $\theta$=90° | Zone for wind direction $\theta$= 0° and $\theta$= 90° | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | F | | G | | H | | I | | J | | K | | L | | M | | N | |
| | $c_{pe,10}$ | $c_{pe,1}$ | $c_{pe,10}$ | $c_{pe,1}$ | $c_{pe,10}$ | $c_{pe,1}$ | $c_{pe,10}$ | $c_{pe,1}$ | $c_{pe,10}$ | $c_{pe,1}$ | $c_{pe,10}$ | $c_{pe,1}$ | $c_{pe,10}$ | $c_{pe,1}$ | $c_{pe,10}$ | $c_{pe,1}$ | $c_{pe,10}$ | $c_{pe,1}$ |
| 5° | -1,7 | -2,5 | -1,2 | -2,0 | -0,6 | -1,2 | -0,3 | | -0,6 | | -0,6 | | -1,2 | -2,0 | -0,6 | -1,2 | -0,4 | |
| | +0,0 | | +0,0 | | +0,0 | | | | | | | | | | | | | |
| 15° | -0,9 | -2,0 | -0,8 | -1,5 | -0,3 | | -0,5 | | -1,0 | -1,5 | -1,2 | -2,0 | -1,4 | -2,0 | -0,6 | -1,2 | -0,3 | |
| | +0,2 | | +0,2 | | +0,2 | | | | | | | | | | | | | |
| 30° | -0,5 | -1,5 | -0,5 | -1,5 | -0,2 | | -0,4 | | -0,7 | -1,2 | -0,5 | | -1,4 | -2,0 | -0,8 | -1,2 | -0,2 | |
| | +0,5 | | +0,7 | | +0,4 | | | | | | | | | | | | | |
| 45° | -0,0 | | -0,0 | | -0,0 | | -0,3 | | -0,6 | | -0,3 | | -1,3 | -2,0 | -0,8 | -1,2 | -0,2 | |
| | +0,7 | | +0,7 | | +0,6 | | | | | | | | | | | | | |
| 60° | +0,7 | | +0,7 | | +0,7 | | -0,3 | | -0,6 | | -0,3 | | -1,2 | -2,0 | -0,4 | | -0,2 | |
| 75° | +0,8 | | +0,8 | | +0,8 | | -0,3 | | -0,6 | | -0,3 | | -1,2 | -2,0 | -0,4 | | -0,2 | |

NOTE 1 At $\theta$ = 0° the pressures changes rapidly between positive and negative values on the windward face at pitch angle of $\alpha$ = +5° to +45°, so both positive and negative values are given. For those roofs, two cases should be considered: one with all positive values, and one with all negative values. No mixing of positive and negative values are allowed.

NOTE 2 Linear interpolation for intermediate pitch angles of the same sign may be used between values of the same sign. The values equal to 0,0 are given for interpolation purposes

NOTE 3 The pitch angle of the windward face always will govern the pressure coefficients.

**Table 7.5 — External pressure coefficients for hipped roofs of buildings**

EN 1991-1-4 also gives guidance to determine external pressure coefficients for:

- **Multispan roofs**
- **Vaulted roofs and domes**

**Internal pressure**

Internal and external pressures shall be considered to act at the same time. The worst combination of external and internal pressures shall be considered for every combination of possible openings and other leakage paths.

The internal pressure coefficient, $c_{pi}$, depends on the size and distribution of the openings in the building envelope. When in at least two sides of the buildings (facades or roof) the total area of openings in each side is more than 30 % of the area of that side, the actions on the structure should not be calculated from the rules given in this section but the rules for canopy roofs and Free-standing walls should be used.

The openings of a building include small openings such as: open windows, ventilators, chimneys, etc. as well as background permeability such as air leakage around doors, windows, services and through the building envelope. The background permeability is typically in the range 0,01% to 0,1% of the face area. Additional information may be given in a National Annex.

Where an external opening, such as a door or a window, would be dominant when open but is considered to be closed in the ultimate limit state, during severe windstorms, the condition with the door or window open should be considered as an accidental design situation in accordance with EN 1990.
Checking of the accidental design situation is important for tall internal walls (with high risk of hazard) when the wall has to carry the full external wind action because of openings in the building envelope.

A face of a building should be regarded as dominant when the area of openings at that face is at least twice the area of openings and leakages in the remaining faces of the building considered.

**For a building with a dominant face,** the internal pressure should be taken as a fraction of the external pressure at the openings of the dominant face.

- When the area of the openings at the dominant face is twice the area of the openings in the remaining faces:

$$c_{pi} = 0{,}75 \cdot c_{pe}$$

When the area of the openings at the dominant face is at least 3 times the area of the openings in the remaining faces:

$$c_{pi} = 0{,}90 \cdot c_{pe}$$

where $c_{pe}$ is the value for the external pressure coefficient at the openings in the dominant face. When these openings are located in zones with different values of external pressures an area weighted average value of $c_{pe}$ should be used.

When the area of the openings at the dominant face is between 2 and 3 times the area of the openings in the remaining faces linear interpolation for calculating $c_{pi}$ may be used.

**For a building without a dominant face,** the internal pressure coefficient $c_{pi}$ should be determined from Figure 7.13, and is a function of the ratio of the height and the depth of the building, *h*/*d*, and the opening ratio $\mu$ for each wind direction θ, which should be determined from the following expression:

$$\mu = \frac{\sum area\ of\ openings\ where\ c_{pe}\ is\ negative\ or\ 0}{\sum area\ all\ of\ openings}$$

This applies to façades and roof of buildings with and without internal partitions.

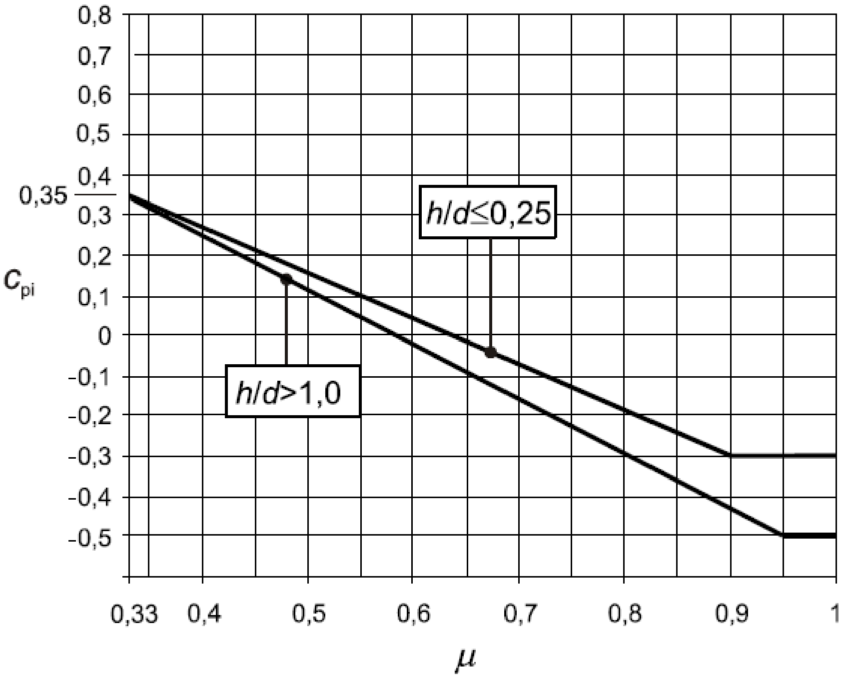



**Figure 7.13 - Internal pressure coefficients for uniformly distributed openings**

Where it is not possible, or not considered justified, to estimate $\mu$ for a particular case then $c_{pi}$ should be taken as the more onerous of +0,2 and -0,3.

The reference height $z_i$ for the internal pressures should be equal to the reference height $z_e$ for the external pressures on the faces which contribute by their openings to the creation of the internal pressure. If there are several openings the largest value of $z_e$ should be used to determine $z_i$.

The internal pressure coefficient of open silos and chimneys should be equal to -0.60
The internal pressure coefficient of vented tanks with small openings should be equal to -0.40
The reference height $z_i$ is equal to the height of the structure.

**Canopy roofs**

**Free-standing walls, parapets, fences and signboards**

**Friction coefficients**

**Structural elements with rectangular sections**

**Structural elements with sharp edged sections**

**Structural elements with regular polygonal sections**

**Circular cylinders**

**Spheres**

**Lattice structures and scaffoldings**

**Flags**

**Effective slenderness $\lambda$ and end-effect factor $\psi_{\lambda}$**

# Section 8: Wind actions on bridges

## General

## Choice of the response calculation procedure

## Force coefficients

## Bridge Piers

# Annexes

## Annex A (informative)

Annex A gives illustrations of the terrain categories and provides rules for the effects of orography including displacement height, roughness change, influence of landscape and influence of neighbouring structures.

## Annex B (informative)

Annex B gives a procedure for calculating the structural factor $c_s c_d$.

## Annex C (informative)

Annex C gives an alternative procedure for calculating the structural factor $c_s c_d$.

## Annex D (informative)

Annex D gives $c_s c_d$ factors for different types of structures.

## Annex E (informative)

Annex E gives rules for vortex induced response and some guidance on other aeroelastic effects.

## Annex F (informative)

Annex F gives dynamic characteristics of structures with linear behavior.

# References


[1] EN 1991-1-1: 2002, Eurocode 1: Action on structures – Part 1-1: General actions – Densities, self - weight, imposed loads for buildings

[2] EN 1991-1-1: 2002, Eurocode 1: Action on structures – Part 1-3: General actions – Snow loads

[3] EN 1991-1-1: 2002, Eurocode 1: Action on structures – Part 1-4: General actions – Wind actions

[4] Development of skills facilitating implementation of Eurocodes:
Handbook 3: Action Effects For Buildings
Leonardo da Vinci pilot project CZ/02/B/F/PP-134007

[5] NBN EN 1991-1-3 ANB, Eurocode 1 : Belastingen op constructies – Deel 1-3: Algemene belastingen – Sneeuwbelasting – Nationale bijlage

[6] NEN-EN 1991-1-3/NB, National Annex to NEN-EN 1991-1-3, Eurocode 1 : Actions of structures – Part 1-3 : General actions – Snow loads

[7] NF EN 1991-1-3/NA, Eurocode 1 – Actions sur les structures – Partie 1-3 : Actions générales – Charges de neige ; Annexe nationale à la NF EN 1991-1-3 :2004.

[8] Eurocodes – Background and Applications. Eurocode example: Actions on a six storey building.
18-20 February 2008
*Kristine Bak-Kristensen and Sven Ole Hansen*