EUROCODES
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Structural Design

Carlo Sigmund

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User's Guide

to Excel® spreadsheet file

Verification tests

EN 1991-1-3: Eurocode 1

Edited and published by:
Carlo Sigmund

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Eurocodes - Structural Design

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Location: Rotterdam, Netherlands
Length/ main span: 802 m/284 m
Pylon: 139 m
Designer: Architects Ben van Berkel, Freek Loos, UN Studio.

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Contents

Section 1 **Eurocode 1**
EN 1991-1-3

1.1 General

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 1500 m, unless otherwise specified. Advice for the treatment of snow loads for altitudes above 1500 m may be found in the National Annex.

Annex A gives information on design situations and load arrangements to be used for different locations. Annex B gives shape coefficients to be used for the treatment of exceptional snow drifts. Annex C gives characteristic values of snow load on the ground based on the results of work carried out under a contract specific to this Eurocode, to DGIII/D3 of the European Commission. Annex D gives guidance for adjusting the ground snow loads according to the return period. Annex E gives information on the bulk weight density of snow.

The statements and assumptions given in EN 1990:2002, 1.3 apply to EN 1991-1-3. The rules given in EN 1990:2002, 1.4 apply to EN 1991-1-3.

In some circumstances tests and proven and/or properly validated numerical methods may be used to obtain snow loads on the construction works. The circumstances are those agreed for an individual project, with the client and the relevant Authority.

1.2 Classification of actions

Snow loads shall be classified as variable, fixed actions (see also Section 5.2, EN 1991-1-3), 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, see EN 1990:2002, 4.1.1 (4). In accordance with EN 1990:2002, 4.1.1 (2), for the particular condition defined in 1.6.3, exceptional snow loads may be treated as accidental actions depending on geographical locations. In accordance with EN 1990:2002, 4.1.1 (2), for the particular condition defined in 1.6.10, loads due to exceptional snow drifts may be treated as accidental actions, depending on geographical locations.

> Snow loads are generally classified as variable, fixed actions. However certain drift loads (see Sections 5.4 and 5.6.3(b), EN 1991-1-3) are treated as accidental actions. See also Chapter 2.

1.3 Design situations

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 (EN 1991-1-3) the persistent/transient design situation should be used. The relevant snow loads are to be used for each identified design situation in accordance with Section 2.8.3 and/or Appendix B.

Important

UNDRIFTED SNOW LOAD ON THE ROOF. 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. 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.

NORMAL CONDITIONS. For locations where exceptional snow falls and exceptional snow drifts 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:

- 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, and
- the accidental design situation should be used for both the undrifted and the drifted snow load arrangements determined using 4.3, 5.2(3)P (b) and 5.3.

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

- 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, and
- the accidental design situation should be used for snow load cases determined using 5.2(3)P c) and Annex B.

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

— 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, and

— the accidental design situation should be used for both the undrifted and the drifted snow load arrangements determined using 4.3, 5.2(3)P(b), 5.3.

— the accidental design situation should be used for the snow load cases determined using 5.2(3)P c) and Annex B.

> When snow loads are derived using Annex B (as well as the other "accidental" design situations) no partial safety factor is applied to them. This is because they are considered to only occur in extreme cases and are therefore classified as accidental.

1.4 Characteristic values

The characteristic value of snow load on the ground (s_k) should be determined in accordance with EN 1990:2002, 4.1.2 (7)P, and the definition for characteristic snow load on the ground is given in Section 5.2 (EN 1991-1-3). 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. The characteristic ground snow loads s_k should be obtained from the maps shown in Annex C ("*European Ground Snow Load Maps*") and Table C.1 ("*Altitude - Snow Load Relationships*"). 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.

If the designer suspects that there are unusual local conditions that need to be taken into account, then the Meteorological Office should be consulted. Where a more refined characteristic ground snow load value s_k is required, the Meteorological Office should be consulted.

1.5 Other representative values

According to EN1990:2002, 4.1.3 the other representative values for snow load on the roof are as follows:

— combination value: $\psi_0 \cdot s$

— frequent value: $\psi_1 \cdot s$

— quasi-permanent value: $\psi_2 \cdot s$,

where "s" is the snow load over the roof: $s = s(s_k; C_i; \mu_i)$. The values of ψ_i may be set by the National Annex of EN 1990:2002. The recommended values of the coefficients ψ_0, ψ_1 and ψ_2 for buildings are dependent upon the location of the site being considered and should be taken from EN 1990:2002, Table A1.1 or Table 4.1 below (EN 1991-1-3), in which the information relating to snow loads is identical.

Regions	Ψ_0	Ψ_1	Ψ_2
Finland, Iceland, Norway, 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 $\leq$ 1000 m above sea level	0,50	0,20	0,00

Table 1.1 From Table 4.1 - Recommended values of coefficients ψ_i for different locations for building.

1.6 Treatment of exceptional snow loads on the ground

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

$$s_{Ad} = C_{esl} \cdot s_k \quad \textbf{(Eq. 1-1)}$$

where:

- 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. It may be set by the National Annex. The recommended value for C_{esl} is 2,0
- s_k is intended as the upper value of a random variable, for which a given statistical distribution function applies, with the annual probability of exceedence set to 0,02 (i.e. a probability of not being exceeded on the unfavourable side during a "reference period" of 50 years).(1)

1.7 Snow load on roofs

NATURE OF THE LOADS. Snow can be deposited on a roof in many different patterns. The properties of a roof or other factors causing different patterns include:

— the shape of the roof
— its thermal properties
— the roughness of its surface
— the amount of heat generated under the roof
— the proximity of nearby buildings

(1) The characteristic ground snow loads (s_k) are given by the National Annex for each CEN country. The snow load on the roof is derived from the snow load on the ground (s_k), multiplying by appropriate conversion factors (shape, thermal and exposure coefficients).

— 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. The two primary load arrangements to be taken into account are (see Section 5.2):

1. undrifted snow load on roofs
2. drifted snow load on roofs.

The load arrangements should be determined using 5.3; and Annex B, where specified in accordance with 3.3. The loads should be assumed to act vertically and refer to a horizontal projection of the roof area. Specialist advice should be sought where the consecutive melting and freezing of snow together with possible rainfall is likely to occur and block roof drainage.

Topography	C_e
Windswept[(a)]	0,8
Normal[(b)]	1,0
Sheltered[(c)]	1,2

Table 1.2 From Table 5.1 - Recommended values of C_e for different topographies.

(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.

Snow loads on roofs shall be determined as follows:

i. for the persistent/transient design situations:

$$s = \mu_i \cdot C_e \cdot C_i \cdot s_k \quad \text{(Eq. 1-2)}$$

ii. for the accidental design situations where exceptional snow load is the accidental action (except for the cases covered in 5.2 (3) P c):

$$s = \mu_i \cdot C_e \cdot C_i \cdot s_{Ad} \quad \text{(Eq. 1-3)}$$

iii. for the accidental design situations where exceptional snow drift is the accidental action and where Annex B applies:

$$s = \mu_i \cdot s_k \quad \text{(Eq. 1-4)}$$

where:

- μ_i is the snow load shape coefficient (see Section 5.3 and Annex B)
- 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 (see eq. 1-1 above).
- C_e is the exposure coefficient
- C_t is the thermal coefficient.

The exposure coefficient C_e should be used for determining the snow load on the roof. The choice for C_e should consider the future development around the site. C_e should be taken as 1,0 unless otherwise specified for different topographies. The National Annex may give the values of C_e for different topographies. The recommended values are given in Table 5.1 above. The thermal coefficient C_t should be used to account for the reduction of snow loads on roofs with high thermal transmittance $(> 1 \text{ W/m}^2\text{K})$, in particular for some glass covered roofs, because of melting caused by heat loss. For all other cases: $C_t = 1,0$.

1.8 Roof shape coefficients

This Section gives snow load shape coefficients for undrifted and drifted snow load arrangements for all types of roofs identified in this standard, with the exception of the consideration of exceptional snow drifts defined in Annex B, where its use is allowed. Special consideration should be given to the snow load shape coefficients to be used where the roof has an external geometry which may lead to increases in snow load that are considered significant in comparison with that of a roof with linear profile.

ROOF SNOW LOAD SHAPE COEFFICIENT. Ratio of the snow load on the roof to the undrifted snow load on the ground, without the influence of exposure and thermal effects.

MONOPITCH ROOFS. The snow load shape coefficient μ_1 that should be used for monopitch roofs is given in Table 5.2 and shown in Figure 5.2.

Angle of pitch of roof α:	$0° \leq \alpha \leq 30°$	$30° < \alpha < 60°$	$\alpha \geq 60°$
μ_1 =	0,8	$0,8 \cdot (60 - \alpha)/30$	0,0
μ_2 =	$0,8 + 0,8 \cdot \alpha/30$	1,6	--

Table 1.3 From Table 5.2 - Snow load shape coefficients.

The values given in Table 5.2 above 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 below should be used for both the undrifted and drifted load arrangements. The designer should give special consideration to large flat roofs which are treated as a monopitch roof with $\alpha = 0°$, where the value of μ_1 can be = 1,0.

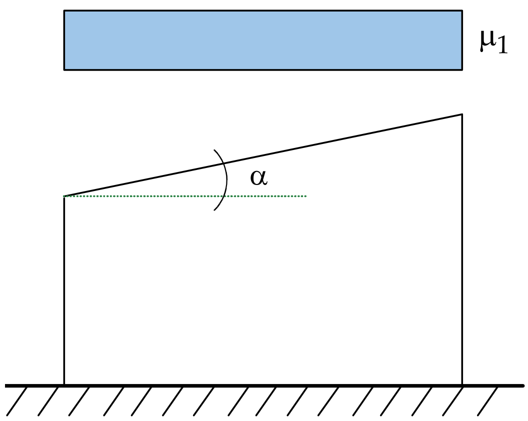

Figure 1.1 From Figure 5.2 - Snow load shape coefficient - monopitch roof.

There is research evidence that for larger roofs (e.g. square or almost square roofs with length about 40 m) the snow layer may be non uniform and the maximum value of the ratio between the roof and the ground snow loads reaches unity.

PITCHED ROOFS. The snow load shape coefficients that should be used for pitched roofs are given in Figure 5.3, where μ_1 is given in Table 5.2. The values given in Table 5.2 apply when 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.

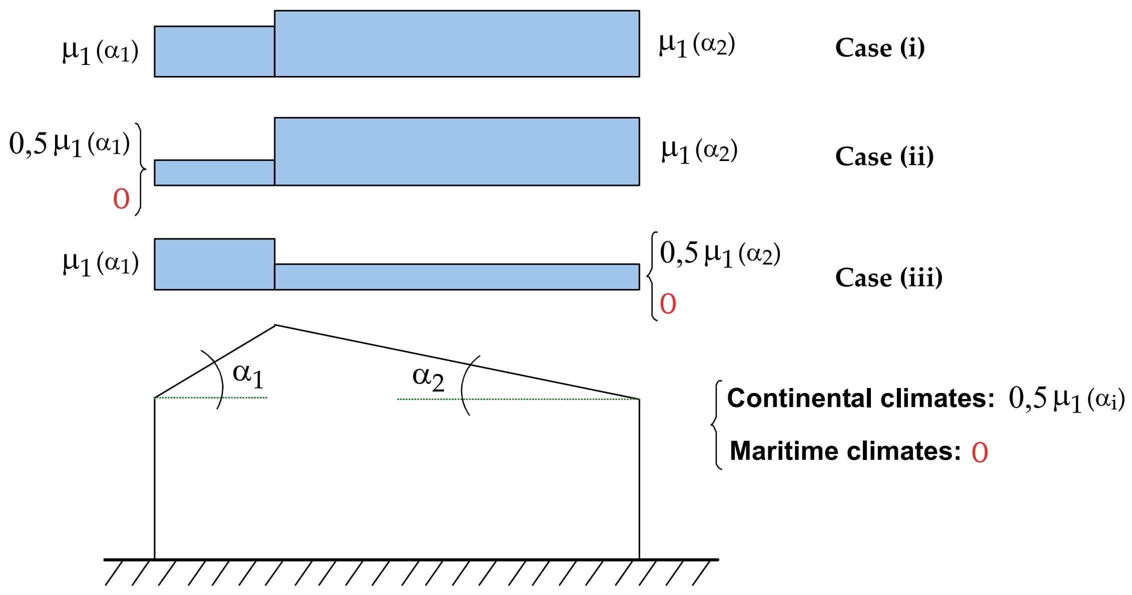

Figure 1.2 From Figure 5.3 - Snow load shape coefficients - pitched roofs.

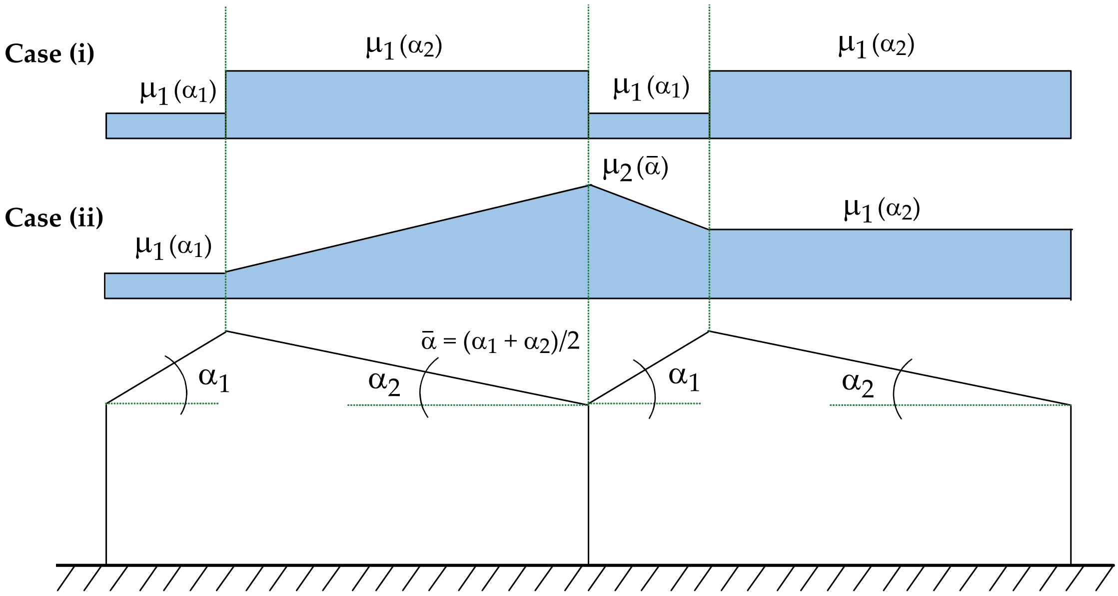

Figure 1.3 From Figure 5.4 - Snow load shape coefficients for multi-span roofs.

Important The undrifted load arrangement which should be used is shown in Figure 5.3, case (i). The drifted load arrangements which should be used are shown in Figure 5.3, cases (ii) and (iii), unless otherwise specified for local conditions. Based on local conditions, an alternative drifting load arrangement may be given in the National Annex.

MULTI-SPAN ROOFS. For multi-span roofs the snow load shape coefficients are given in Table 5.2. The undrifted load arrangement which should be used is shown in Figure 5.4 (above), case (i). The drifted load arrangement which should be used is shown in Figure 5.4, 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.

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°.

CYLINDRICAL ROOFS. The snow load shape coefficients that should be used for cylindrical roofs, in absence of snow fences, are given in the following expressions (see also Figure 5.6):

- for $\beta > 60°$, $\mu_3 = 0$
- for $\beta \le 60°$, $\mu_3 = 0,2 + 10 \cdot h/b$.

An upper value of μ_3 should be specified. The upper value of μ_3 may be specified in the National Annex. The recommended upper value for μ_3 is 2,0. Rules for considering the effect of snow fences for snow loads on cylindrical roofs may be given in the National Annex. The undrifted load arrangement which should be

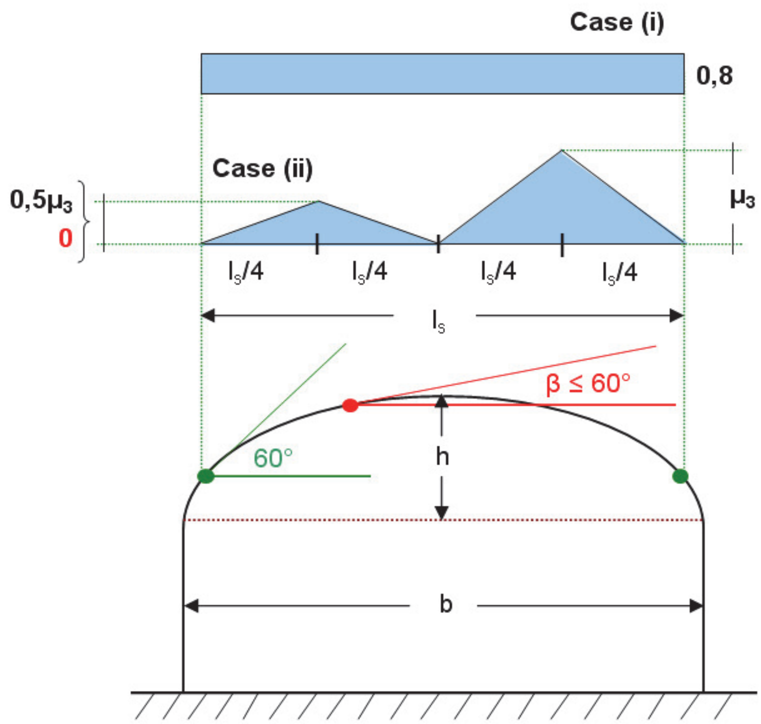

Figure 1.4 From Figure 5.6 - Snow load shape coefficients for cylindrical roof.

used is shown in Figure 5.6, case (i). The drifted load arrangement which should be used is shown in Figure 5.6, case (ii), unless specified for local conditions.

Based on local conditions an alternative drifting load arrangement may be given in the National Annex.

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 given in the following expressions and shown in Figure 5.7:

— $\mu_1 = 0,8$ assuming the lower roof is flat

— $\mu_2 = \mu_s + \mu_w$

where:

- μ_s is the snow load shape coefficient due to sliding of snow from the upper roof. For $\alpha \leq 15°$, $\mu_s = 0$. For $\alpha > 15°$, μ_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 according to 5.3.3
- μ_w is the snow load shape coefficient due to wind $\mu_w = (b_1 + b_2)/2h \leq \gamma h/s_k$, where $\gamma = 2\ kN/m^3$ is the weight density of snow. An upper and a lower value of μ_w should be specified. The range for μ_w may be fixed in the National Annex. The recommended range is $0,8 \leq \mu_w \leq 4$
- the drift length is determined as follows: $l_s = 2h$. A restriction for l_s may be given in the National Annex. The recommended restriction is $5 \leq l_s \leq 15\ m$.

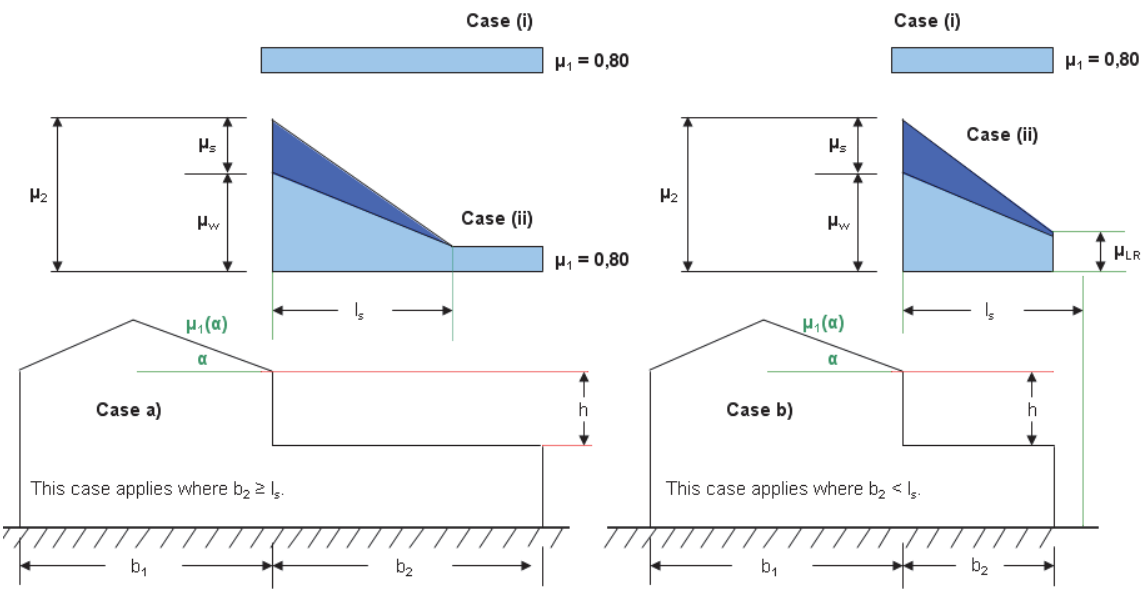

Figure 1.5 From Figure 5.7 - Snow load shape coefficients for roofs abutting to taller construction works.

Note If $b_2 < l_s$ the coefficient μ_{LR} at the end of the lower roof is determined by interpolation between μ_1 and μ_2 truncated at the end of the lower roof (see Figure 5.7, case b).

The undrifted load arrangement which should be used is shown in Figure 5.7, case (i). The drifted load arrangement which should be used is shown in Figure 5.7, 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.

1.9 Local effects

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: $\mu_1 = 0,8$, $\mu_2 = \gamma h / s_k$, where $\gamma = 2 \text{ kN/m}^3$ is the weight density of snow and $l_s = 2h$ with the restriction $5 \le l_s \le 15$ m. Where

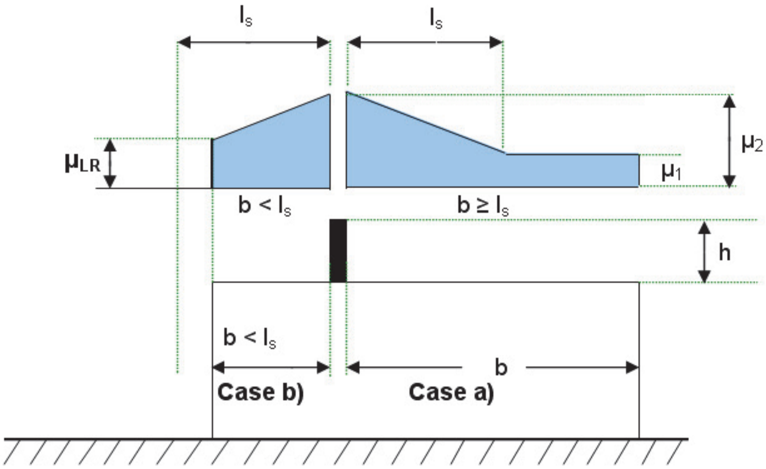

Figure 1.6 From Figure 6.1 - Snow load shape coefficients at projections and obstructions.

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

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:

$$s_e = \frac{ks^2}{\gamma} \qquad \textbf{(Eq. 1-5)}$$

where:

- s_e is snow load per metre length due to the overhang (see Figure 6.2)

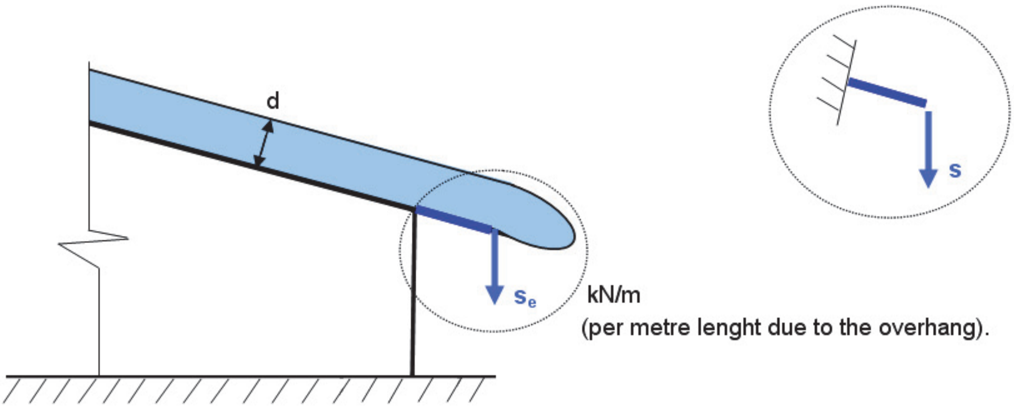

Figure 1.7 From Figure 6.2 - Snow overhanging the edge of a roof ("s_e" characteristic load).

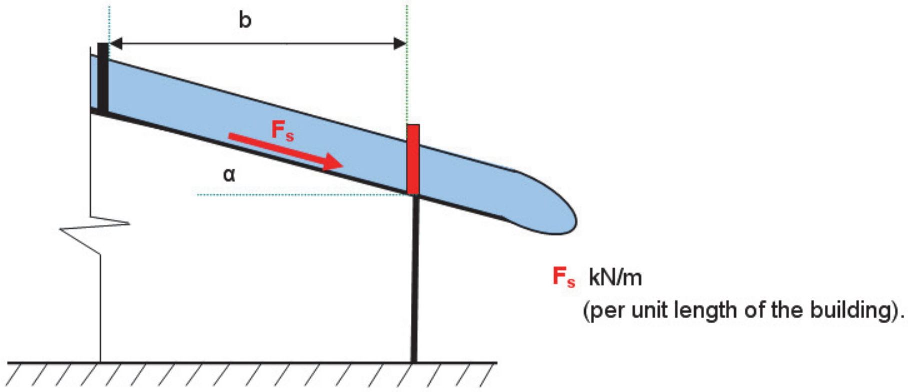

Figure 1.8 Snow loads on snowguards and other obstacles ("F_s" characteristic load).

- s is the most onerous undrifted load case appropriate for the roof under consideration (see Section 5.2)
- $\gamma = 3\ kN/m^3$ is the weight density of snow
- 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:

$$\begin{cases} k = \dfrac{3}{d} \\ k \le \gamma d \end{cases}$$

where d is the depth of the snow layer on the roof in meters.

SNOW LOADS ON SNOWGUARDS AND OTHER OBSTACLES. Under certain conditions snow may slide down a pitched or curved roof (see Figure above). 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:

$$F_s = s \cdot b \cdot \sin\alpha \qquad \textbf{(Eq. 1-6)}$$

where:

- s is the snow load on the roof relative to the most onerous undrifted load case appropriate for roof area from which snow could slide (see 5.2, 5.3)
- b is the width on plan (horizontal) from the guard or obstacle to the next guard or to the ridge
- α is the pitch of the roof, measured from the horizontal.

1.10 Verification tests

EN1991-1-3_(A).XLS. 6.00 MB. Created: 23 February 2013. Last/Rel.-date: 23 February 2013. Sheets:

— Splash
— CodeSec4-5
— CodeSec6.

EXAMPLE 1-A- Roof shape coefficients: Pitched roofs - **test 1**

Given: 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. Assuming a geographical location where exceptional snow falls are unlikely to occur but exceptional snow drifts may occur, find the roof shape coefficients using the data given in tables below for angles of pitch of roof equal to $\alpha_1 = 30°$ and $\alpha_2 = 40°$.

Angle of pitch of roof α:	$0° \leq \alpha \leq 15°$	$15° < \alpha \leq 30°$	$30° < \alpha < 60°$	$\alpha \geq 60°$
μ_1 =	0,8	0,8 + 0,4·(α – 15)/15	1,2·(60 – α)/30	0,0

Table 1.4 Drifted snow load shape coefficient for a duo-pitched roof[(a)].

(a). Manual for the design of building structures to Eurocode 1 and Basis of Structural Design April 2010. © 2010 The Institution of Structural Engineers.

Angle of pitch of roof α:	$0° \leq \alpha \leq 30°$	$30° < \alpha < 60°$	$\alpha \geq 60°$
μ_1 =	0,8	0,8·(60 – α)/30	0,0

Table 1.5 Undrifted snow load shape coefficient (from Table 5.2, EN 1991-1-3).

[*Reference sheet:* CodeSec4-5]-[*Cell-Range: A29:O29-A63:O63*].

Solution: The most unfavourable load situation has to be chosen for the design. The undrifted and drifted load arrangements which should be used are shown in Figure 1.9 below.

Using the given numerical data, we get:

(Case ii and iii) - Drifted load arrangement (see Table 1.4 above):

$\alpha_1 = 30°$, $\mu_1(\alpha_1) = 0,8 + 0,4 \cdot (\alpha_1 - 15)/15 = 0,8 + 0,4 \cdot (30 - 15)/15 = 1,20$; $\mu_1(\alpha_1) = 0$.

$\alpha_2 = 40°$, $\mu_1(\alpha_2) = 1,2 \cdot (60 - \alpha_2)/30 = 1,2 \cdot (60 - 40)/30 = 0,80$; $\mu_1(\alpha_2) = 0$.

(Case i) - Undrifted load arrangement (see Table 1.5 above):

$\alpha_1 = 30°$, $\mu_1(\alpha_1) = 0,80$.

$\alpha_2 = 40°$, $\mu_1(\alpha_2) = 0,8 \cdot (60 - \alpha_2)/30 = 0,8 \cdot (60 - 40)/30 = 0,53$.

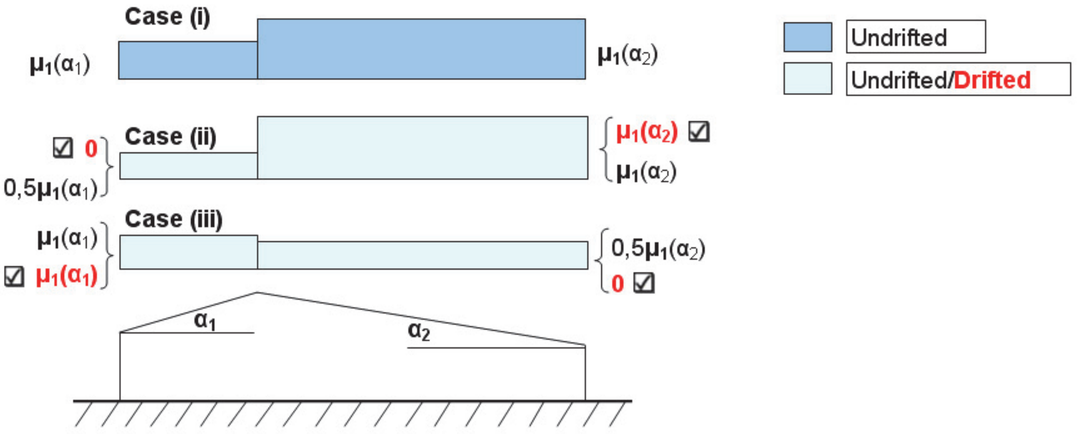

Figure 1.9 Snow load shape coefficient – pitched roofs.

These values lead to the two relevant load cases given in figure 1.10. In fact, from load arrangements in Figure 1.9 we get:

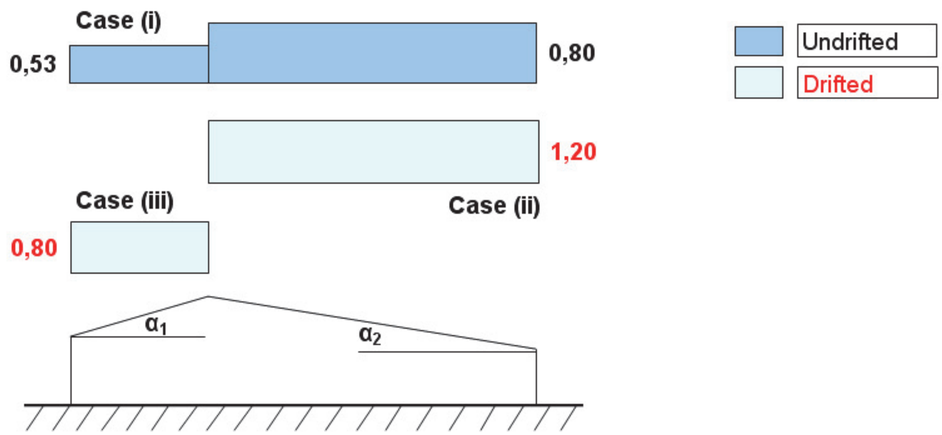

Figure 1.10 Snow load shape coefficient and load arrangements for calculations (summary sketch) – pitched roofs.

⚠ 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. If this case applies: $\mu_1(\alpha_1) = 0,53 \rightarrow 0,80$.

➡ *example-end*

EXAMPLE 1-B- Roof shape coefficients: Pitched roofs - **test 1b**

Given: Let us assume that exist the same assumptions as in the previous example. The characteristic value for the ground snow load on height 100 metres, where the building is located, is equal to (say): $s_k = 0,85\ kN/m^2$. The exposure factor is chosen as $C_e = 1,0$.

The thermal coefficient is also set to $C_t = 1,0$. Find the most unfavourable load situations that have to be chosen for the design.

[*Reference sheet:* CodeSec4-5]-[*Cell-Range: A29:O29-A63:O63*].

Solution: For locations where exceptional snow falls are unlikely to occur but exceptional snow drifts may 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, and the accidental design situation should be used for snow load cases determined using 5.2(3)P c) and Annex B. Therefore, for persistent/transient design situations (see Section 5.2(3)P a)):

$$s = \mu_i \cdot C_e \cdot C_i \cdot s_k = \mu_i \cdot 1,0 \cdot 1,0 \cdot (0,85\ \text{kN/m}^2) = \mu_i \cdot 0,85\ \text{kN/m}^2.$$

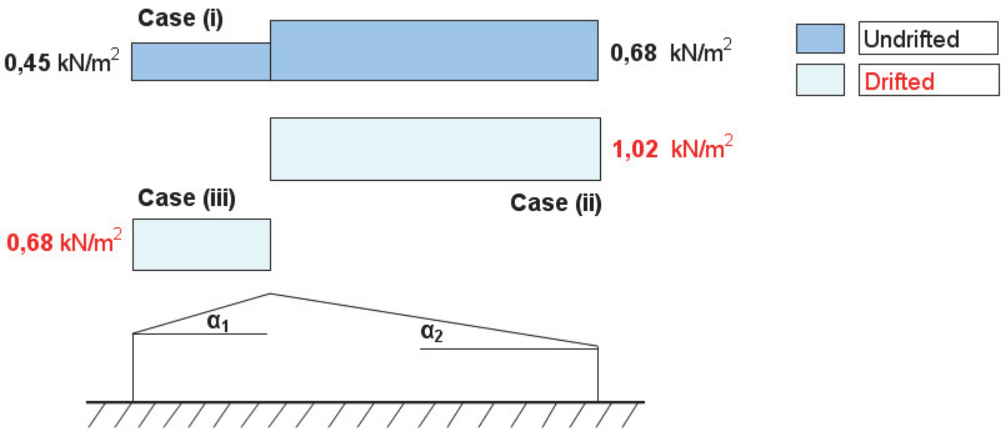

Figure 1.11 Snow load arrangements for calculations (summary sketch): characteristic value of snow loads.

Here the following values of shape coefficients and snow loads on the roof are obtained:

(Case ii and iii) - Drifted load arrangement (see Table 1.4 on page 17):

$\alpha_1 = 30°,\ \mu_1(\alpha_1) = 1,20;\ s = \mu_1 \cdot 0,85 = 1,20 \cdot 0,85 = 1,02\ \text{kN/m}^2$.

$\alpha_2 = 40°,\ \mu_1(\alpha_2) = 0,80;\ s = \mu_1 \cdot 0,85 = 0,80 \cdot 0,85 = 0,68\ \text{kN/m}^2$.

(Case i) - Undrifted load arrangement (see Table 1.5 on page 17):

$\alpha_1 = 30°,\ \mu_1(\alpha_1) = 0,80;\ s = \mu_1 \cdot 0,85 = 0,80 \cdot 0,85 = 0,68\ \text{kN/m}^2$.

$\alpha_2 = 40°,\ \mu_1(\alpha_2) = 0,53;\ s = \mu_1 \cdot 0,85 = 0,53 \cdot 0,85 = 0,45\ \text{kN/m}^2$.

These values lead to the three relevant load cases given in figure 1.11.

example-end

EXAMPLE 1-C- Snow load shape coefficients for multi-span roofs - **test 2**

Given: A building with shed roof is given. It is assumed that this building is located in Sweden, snow load zone 2, on a height above mean sea level of 300 m (with $s_k = 2,85\ \text{kN/m}^2$). The surroundings of the building represent normal conditions, so that the roof can not be denoted as "wind swept" or "wind sheltered" (see Table 1.2 on page 9). An effective heat insulation is applied on the roof and therefore the thermal coefficient $C_t = 1,0$ has to be used for the calculation. Assumption: $\alpha_1 = 40°$, $\alpha_2 = 30°$.

[*Reference sheet:* CodeSec4-5]-[*Cell-Range: A65:O65-A100:O100*].

Solution: For the determination of roof shape coefficients for shed roofs the more unfavourable case of two load cases has to be applied (see also Figure 1.3 on page 12):

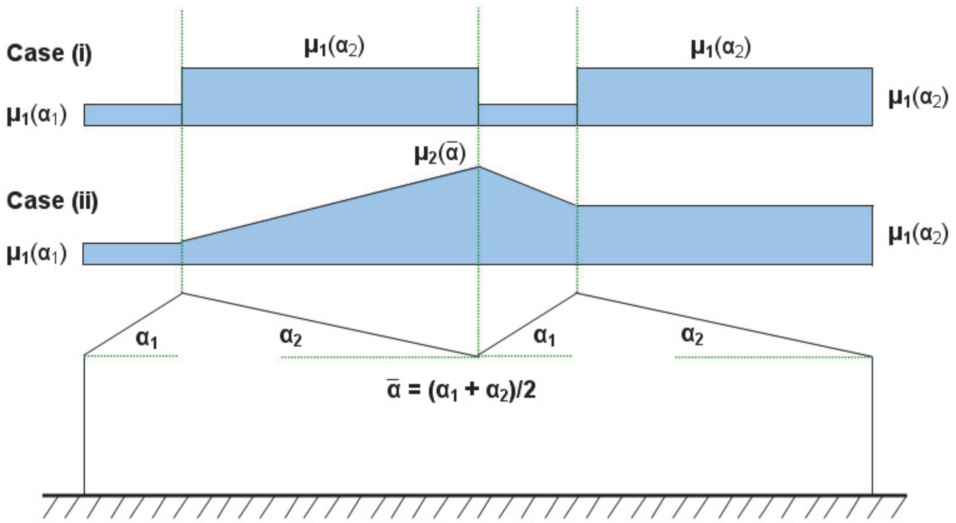

Figure 1.12 Determination of roof shape coefficients for shed roofs.

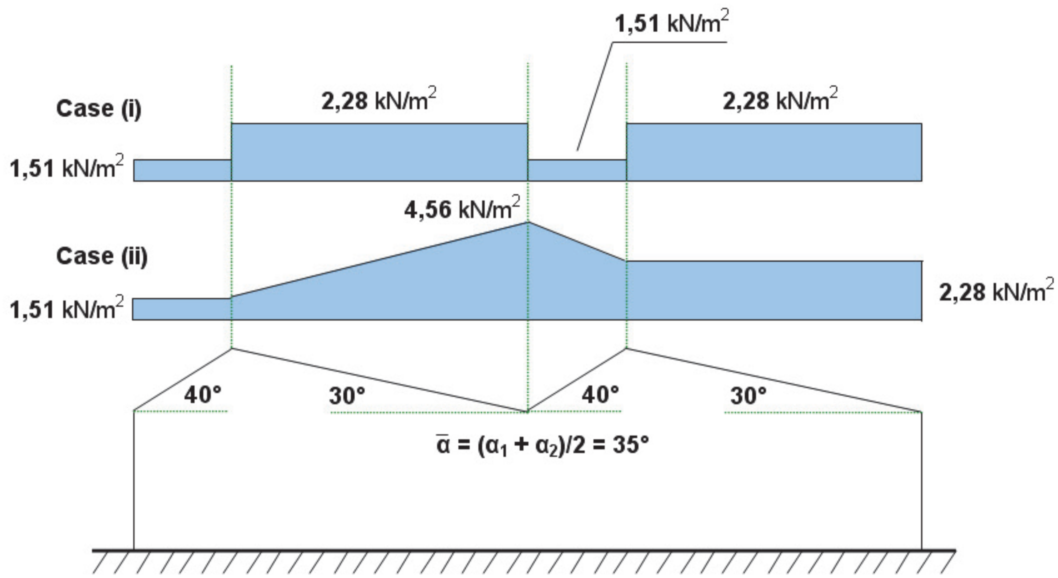

Figure 1.13 Load arrangements on the roof (summary sketch): characteristic value of snow loads. Partial factor for snow load in isolation (transient/persistent): 1,50.

Snow load on roof (see Section 5.2.(3)P a)):

$s = \mu_i \cdot C_e \cdot C_i \cdot s_k = \mu_i \cdot 1,0 \cdot 1,0 \cdot (2,85\ kN/m^2) = \mu_i \cdot 2,85\ kN/m^2$.

Values of shape coefficients and snow loads on the roof:

(Case i) - Undrifted load arrangement (see Table 1.5 on page 17):

$\alpha_1 = 30°$, $\mu_1(\alpha_1) = 0,80$; $s = \mu_1 \cdot 2,85 = 0,80 \cdot 2,85 = 2,28\ kN/m^2$.

$\alpha_2 = 40°$, $\mu_1(\alpha_2) = 0,8 \cdot (60 - \alpha_2)/30 = 0,8 \cdot (60 - 40)/30$; $\mu_1(\alpha_2) = 0,53$;

$s = \mu_1 \cdot 2,85 = 0,53 \cdot 2,85 = 1,51\ kN/m^2$.

(Case ii) - Drifted load arrangement (see Table 1.3 on page 10):

$\bar{\alpha} = 0,5 \cdot (\alpha_1 + \alpha_2) = 0,5 \cdot (30° + 40°) = 35°$, $\mu_2(\bar{\alpha}) = 1,60$;

$s = \mu_2 \cdot 2,85 = 1,60 \cdot 2,85 = 4,56\ kN/m^2$.

These values lead to the two relevant (characteristic) load cases given in figure 1.13 above.

example-end

EXAMPLE 1-D- Cylindrical roofs - **test 3**

Given: Find the snow load shape coefficients and the load arrangements for the case of drifted and undrifted snow that should be used for cylindrical roofs, in absence of snow fences. Assume: $b = 7,00\ m$, $h = 1,50\ m$, $l_s = 6,00\ m$ (see Figure 1.4 on page 13). The upper value for μ_3 is $2,0$.

[*Reference sheet:* CodeSec4-5]-[*Cell-Range: A103:O103-A130:O130*].

Solution: For $\beta > 60°$, $\mu_3 = 0$. For $\beta \leq 60°$, $\mu_3 \geq 0,2 + 10 \cdot h/b = 0,2 + 10 \cdot (1,50)/(7,00) = 2,34 > 2$.
Actual value for μ_3 assumed for the calculations: $\mu_3 = 2,00$. Therefore $0,5\mu_3 = 1,00$.

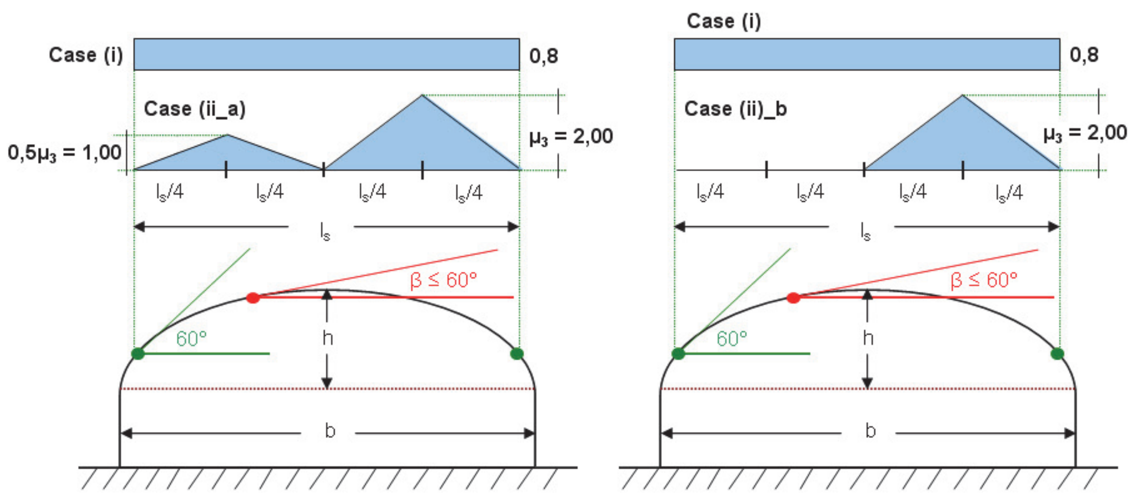

Figure 1.15 Load arrangements for the case of drifted and undrifted snow on cylindrical roof (summary sketch).

These values lead to the three relevant load cases given in the figure above. In particular, in the right part of the figure is represented a further possible case of arrangement of loads on the roof.

example-end

EXAMPLE 1-E- Roof abutting and close to taller construction works - **test 4**

Given: Find the snow load shape coefficients that should be used for roofs abutting to taller construction works. Assume (see Figure 1.5 on page 14): $\alpha = 18°$ (upper roof); $b_1 = 12,00$ m; $h = 3,20$ m; $b_2 = 7,50$ m. Characteristic value of snow load on the ground: $s_k = 1,50\ \text{kN/m}^2$, (see **Case a** on Figure 1.16).

[*Reference sheet:* CodeSec4-5]-[*Cell-Range: A182:O182-A214:O214*].

Solution: Assuming the lower roof is flat: $\mu_1 = 0,8$.

Snow load shape coefficient due to sliding of snow from the upper roof:

$0° \le \alpha \le 30°$ with $\mu_1(\alpha) = 0,80$ (see Table 1.3 on page 10) and $\alpha > 15°$ with $\mu_s = 0,5\mu_1 = 0,40$.

Drift length: $l_s = 2h = 2 \cdot (3,20\ \text{m}) = 6,40\ \text{m} \in [5\ ;15\ \text{m}]$ (ok).

Weight density of snow: $\gamma = 2,0\ \text{kN/m}^3$.

Snow load shape coefficient due to wind:

$$\mu_w = \frac{(b_1 + b_2)}{2h} = \frac{(12,00 + 7,50)}{2 \cdot (3,20)} = 3,05 \le \frac{\gamma h}{s_k} = \frac{(2,0) \cdot (3,20)}{1,50} = 4,27 \text{ with}$$

$\mu_w \in [0,80;\ 4,00]$ (ok).

Finally, we get (see details on the Figure below): $\mu_2 = \mu_s + \mu_w = 0,40 + 3,05 = 3,45$ [-], $\mu_1 = 0,80$ @ $l_s = 6,40\ \text{m} < b_2 = 7,50\ \text{m}$.

example-end

EXAMPLE 1-F- Roof abutting and close to taller construction works - **test 4b**

Given: Let assume the same assumptions set out in the previous example but with $b_2 = 4,00$ m. Find the snow load shape coefficients (see **Case b** on Figure 1.16).

[*Reference sheet:* CodeSec4-5]-[*Cell-Range: A182:O182-A214:O214*].

Solution: In this case, we have: $b_2 = 4,00\ \text{m} < l_s = 2h = 6,40\ \text{m}$. Therefore, the coefficient at the end of the lower roof is determined by linear interpolation between μ_1 and μ_2 truncated at the end of the lower roof.

Snow load shape coefficient due to wind:

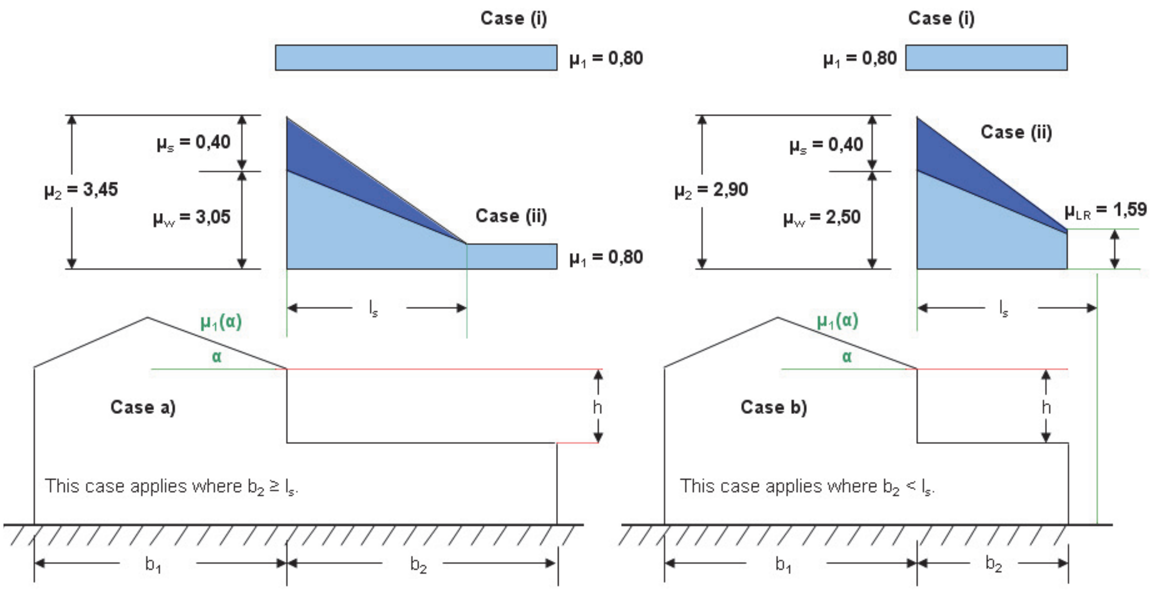

Figure 1.16 Snow load shape coefficients (summary sketch: example 1-E and 1-F).

$$\mu_w = \frac{(b_1 + b_2)}{2h} = \frac{(12,00 + 4,00)}{2 \cdot (3,20)} = 2,50 \le \frac{\gamma h}{s_k} = \frac{(2,0) \cdot (3,20)}{1,50} = 4,27 \text{ with}$$

$\mu_w \in [0,80; 4,00]$ (ok). We find:

$$\mu_2 = \mu_s + \mu_w = 0,40 + 2,50 = 2,90 \ [-],$$

$$\mu_{LR} = \frac{(\mu_2 - \mu_1) \cdot (l_s - b_2)}{l_s} + \mu_1 = \frac{(2,90 - 0,80) \cdot (6,40 - 4,00)}{6,40} + 0,80 = 1,59 \ [-].$$

The snow load shape coefficients are shown in figure above for both the latest two examples.

example-end

EXAMPLE 1-G- Local effects: drifting at projections and obstructions - **test 5**

Given: Wind-blown snow on flat roofs that are obstructed by walls/obstructions of taller sections of building causes wind drifts. Assume: drift height = obstruction height = $h = 2,00$ m; drift width: $l_s = 2h = 4,00 \text{ m} \notin [5; 15 \text{ m}]$; distances of the obstruction from the edges of the roof measured on the horizontal axis: $b_{sx} = 2,00$ m, $b_{dx} = 6,00$ m. Find the snow load shape coefficients if the characteristic value of snow load on the ground is equal to $s_k = 1,50 \text{ kN/m}^2$ and $\mu_{2,\max} = 2 \ [-]$.

[*Reference sheet:* CodeSec6]-[*Cell-Range: A1:O1-A49:O49*].

Solution: Actual value for the drift width that we must assume for the calculations:

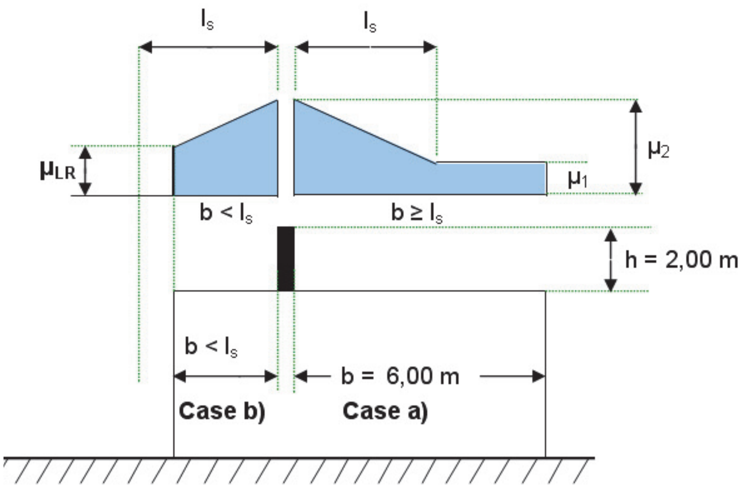

Figure 1.17 Snow load shape coefficients (summary sketch).

$l_s = l_{s,\,min} = 5,0\ \text{m}$.

Weight density of snow: $\gamma = 2,00\ \text{kN/m}^3$ with

$\mu_2 = \gamma h / s_k = (2,00) \cdot (2,00) / (1,50) = 2,67 > \mu_{2,\,max} = 2$.

Actual value assumed for the calculations: $\mu_2 = 2\ [-]$.

We have (see details on the figure below):

Case b): $b_{sx} = 2,00\ \text{m} < l_s = 4,00\ \text{m}$ and **Case a)**: $b_{dx} = 6,00\ \text{m} > l_s = 4,00\ \text{m}$.

Therefore, using the given numerical data, we get:

Case b): linear interpolation with $b_{sx} = 2,00\ \text{m}$:

$$\mu_{LR} = \frac{(\mu_2 - \mu_1) \cdot (l_s - b_{sx})}{l_s} + \mu_1 = \frac{(2,00 - 0,80) \cdot (5,00 - 2,00)}{5,00} + 0,80 = 1,52\ [-].$$

Case a): $\mu_2 = 2,00\ [-]$, $\mu_1 = 0,80\ [-]$.

example-end

EXAMPLE 1-H- Snow overhanging the edge of a roof - **test 6**

Given: A building is located at a height above mean sea level of 900 m. Find the characteristic value of the load due to the snow overhang acting at the edge of the roof. Let us assume that the most onerous undrifted load case for the roof under consideration is equal to $s = 4,00\ \text{kN/m}^2$. To take account of the irregular shape of the snow assume $k = 3,0$ irrespective of whether that the actual depth of the snow layer on the roof is $d = 0,90\ \text{m}$.

[*Reference sheet:* CodeSec6]-[*Cell-Range: A54:O54-A77:O77*].

Solution: Snow load per metre length due to the overhang:

$$s_e = \frac{ks^2}{\gamma} = \frac{3 \cdot (4,00)^2}{3,00} = 16,00 \ \mathrm{kN/m}$$

having taken the weight density of the snow as $3,00 \ \mathrm{kN/m^3}$.

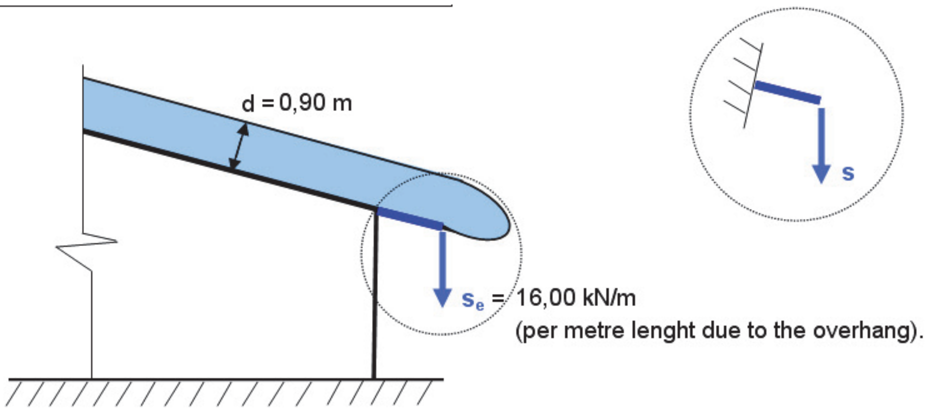

Figure 1.18 Snow overhanging the edge of the roof. Partial factor for snow load in isolation (transient/persistent): 1,50.

A summary sketch is shown in the figure above.

The design situation is to be considered as persistent/transient. Therefore, the design value of the load is:

$$s_{e,d} = \gamma_Q \cdot s_e = 1,50 \cdot (16,00 \ \mathrm{kN/m}) = 24,00 \ \mathrm{kN/m}.$$

example-end

EXAMPLE 1-I- Snow loads on snowguards and other obstacles - **test 7**

Given: Find the characteristic value of the force F_s (per unit length of the building) exerted by a sliding mass of snow with an angle of pitch of roof equal to $\alpha = 30°$. Assume that the horizontal width from the ridge to the guard is equal to $b = 4,00 \ \mathrm{m}$. The characteristic snow load on the roof, relative to the most onerous undrifted load case, is taken equal to $s_k = 2,50 \ \mathrm{kN/m^2}$.

[*Reference sheet:* CodeSec6]-[*Cell-Range: A95:O95-A112:O112*].

Solution: In the direction of the slide, we have:

$$F_s = s \cdot b \cdot \sin\alpha = (2,50) \cdot (4,00) \cdot \sin(30°) = 5,00 \ \mathrm{kN/m}.$$

F_s is to be considered per unit length of the building.

The design situation is to be considered as persistent/transient. Therefore, the design value of the load is:

$$F_{s,d} = \gamma_Q \cdot F_s = 1,50 \cdot (5,00 \ \mathrm{kN/m}) = 7,50 \ \mathrm{kN/m}.$$

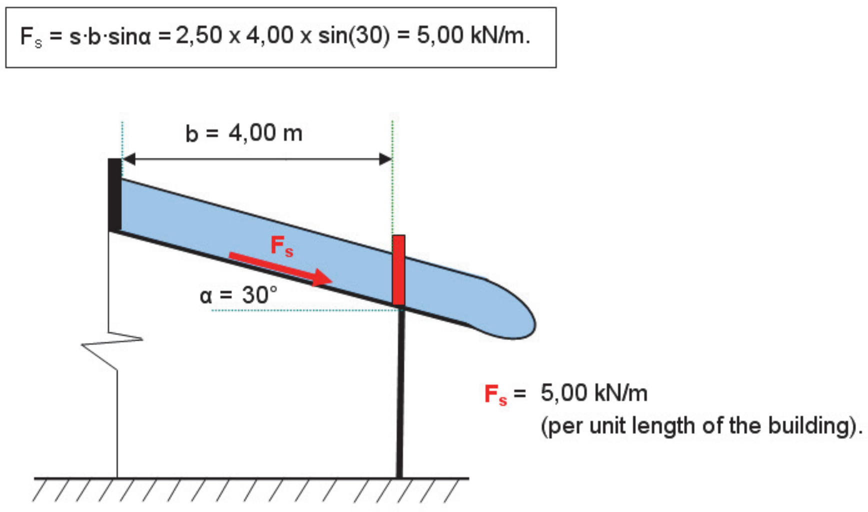

Figure 1.20 Snow overhanging the edge of a roof.

In the figure above is shown a summary sketch.

example-end

1.11 References [Section 1]

Derivation of snow load, Technical Guidance Note, TheStructuralEngineer, March 2012. Web resource: www.istructe.org/resources-centre/library.

EN 1991-1-3:2003/AC:2009. Eurocode 1: Actions on structures - Part 1-3: General actions - Snow loads. Brussels: CEN/TC 250 - Structural Eurocodes, March 2009.

EN 1991-1-3 (2003) (English): Eurocode 1: Actions on structures - Part 1-3: General actions - Snow loads [Authority: The European Union Per Regulation 305/2011, Directive 98/34/EC, Directive 2004/18/EC].

Manual for the design of building structures to Eurocode 1 and Basis of Structural Design April 2010. © 2010 The Institution of Structural Engineers.

Section 2 **Eurocode 1**
EN 1991-1-3: Annex A, Annex B

2.1 Design situations and load arrangements to be used for different locations

Table A.1 below (from Annex A, normative) summarises four cases A, B1, B2 and B3 (see 3.2, 3.3(1), 3.3(2) and 3.3(3) respectively) identifying the design situations and load arrangements to be used for each individual case.

Normal condition Case A	Exceptional condition Case B1	Exceptional condition Case B2	Exceptional condition Case B3
No exceptional falls No exceptional drift Reference Sec. **3.2(1)**	Exceptional falls No exceptional drift Reference Sec. **3.3(1)**	No exceptional falls Exceptional drift Reference Sec. **3.3(2)**	Exceptional falls Exceptional drift Reference Sec. **3.3(3)**
Persistent/transient design situation: [1], [2] [1] Undrifted: $\mu_i C_e C_t s_k$ [2] Drifted: $\mu_i C_e C_t s_k$	*Persistent/transient design situation: [1], [2]* [1] Undrifted: $\mu_i C_e C_t s_k$ [2] Drifted: $\mu_i C_e C_t s_k$	*Persistent/transient design situation: [1], [2]* [1] Undrifted: $\mu_i C_e C_t s_k$ [2] Drifted: $\mu_i C_e C_t s_k$ (a)	*Persistent/transient design situation: [1], [2]* [1] Undrifted: $\mu_i C_e C_t s_k$ [2] Drifted: $\mu_i C_e C_t s_k$
	Accidental(b) *design situation: [3], [4]* [3] Undrifted: $\mu_i C_e C_t C_{esl} s_k$ [4] Drifted: $\mu_i C_e C_t C_{esl} s_k$	*Accidental*(c) *design situation: [3], [4]* -- [3] Drifted: $\mu_i s_k$ (d)	*Accidental*(c) *design situation: [3], [4]* [3] Undrifted: $\mu_i C_e C_t C_{esl} s_k$ [4] Drifted: $\mu_i s_k$ (e)

Table 2.6 From Table A.1 - Design Situations and load arrangements to be used for different locations.

(a). Except for roof shapes in Annex B.
(b). Where snow is the accidental action.
(c). See table footnote above.
(d). For roof shapes in Annex B.
(e). For roof shapes in Annex B.

Exceptional conditions are defined according to the National Annex. For cases B1 and B3 the National Annex may define design situations which apply for the particular local effects described in section 6.

2.2 Annex B: Snow load shape coefficients for exceptional snow drifts

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

a. multi-span roofs
b. roofs abutting and close to taller construction works
c. roofs where drifting occurs at projections, obstructions and parapets
d. for all other load arrangements Section 5 and Section 6 should be used as appropriate.

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. In some circumstances more than one drift load case may be applicable for the same location on a roof in which case they should be treated as alternatives.

MULTI-SPAN ROOFS. The snow load shape coefficient for an exceptional snow drift that should be used for valleys of multi-span roofs is given in Figure B1 and B2(2). The shape coefficient given in figure below is determinated as:

$$\mu_1 = \min[2h/s_k;\ 2b_3/(l_{s1}+l_{s2});\ 5] \qquad \textbf{(Eq. 2-7)}$$

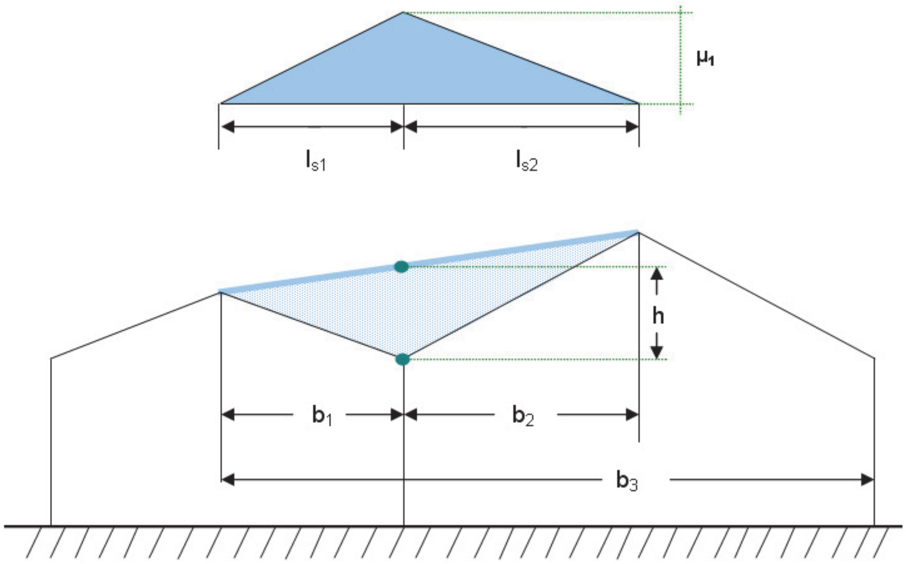

Figure 2.21 From Figure B1 - Shape coefficient and drift lengths for exceptional snow drifts – valleys of multi-span roofs.

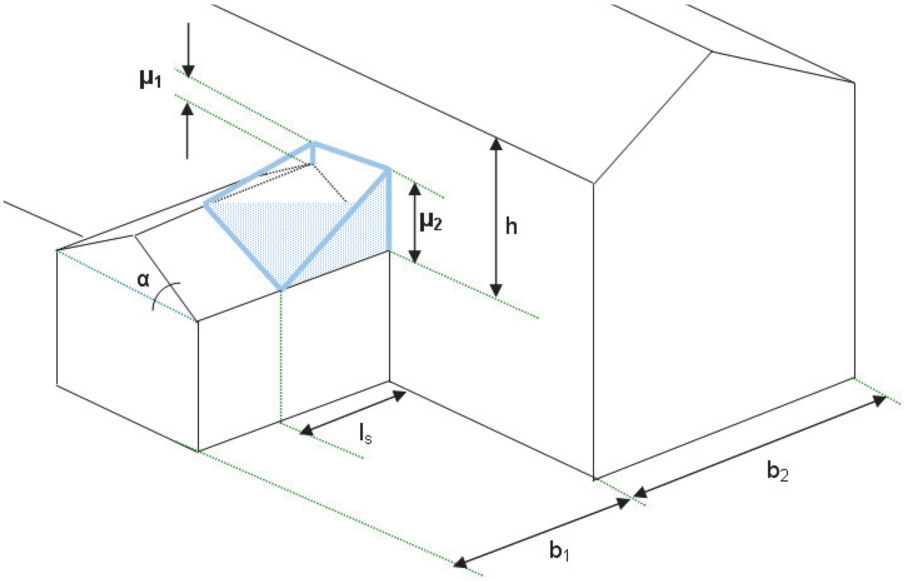

Figure 2.22 From Figure B2 - Shape coefficients and drift lengths for exceptional snow drifts - Roofs abutting and close to taller structures.

where s_k is the characteristic value of snow load on the ground and b_3 should be taken as the horizontal dimension of three slopes[1] (see details on Figure 2.21). The drift lengths are determined as follow:

$$\begin{cases} l_{s1} = b_1 \\ l_{s2} = b_2 \end{cases} \qquad \text{(Eq. 2-8)}$$

ROOFS ABUTTING AND CLOSE TO TALLER STRUCTURES. The snow load shape coefficients for exceptional snow drifts that should be used for roofs abutting a taller construction work are given in Figure B2 and Table B1. The snow load case given in Figure B2 is also applicable for roofs close to, but not abutting, taller buildings, with the exception that it is only necessary to consider the load actually on the lower roof, i.e. the load implied between the two buildings can be ignored.

> The effect of structures close to, but not abutting the lower roof will depend on the roof areas available from which snow can be blown into the drift and the difference in levels. However, as an approximate rule, it is only necessary to consider nearby structures when they are less than 1,50 m away.

(1) For roofs of more than two spans with approximately symmetrical and uniform geometry, b_3 should be taken as the horizontal dimension of three slopes (i.e. span x 1,5) and this snow load distribution should be considered applicable to every valley, although not necessarily simultaneously. Care should be taken when selecting b_3 for roofs with non-uniform geometry, significant differences in ridge height and/or span may act as obstructions to the free movement of snow across the roof and influence the amount of snow theoretically available to form the drift.

The drift length is the least value of $5h$, b_1 or $15\ m$: $l_s = \min[5h;\ b_1;\ 15\ m]$, where

Shape coefficient	Angle of roof pitch α_i:			
	$0° \le \alpha \le 15°$	$15° < \alpha \le 30°$	$30° < \alpha < 60°$	$\alpha \ge 60°$
$\mu_1 =$	μ_3	$\mu_3 \cdot (30 - \alpha)/15$	0	0
$\mu_2 =$	μ_3	μ_3	$\mu_3 \cdot (60 - \alpha)/30$	0

Table 2.7 From Table B1 - Shape coefficients for exceptional snow drifts for roofs abutting and close to taller structures.

μ_3 is equal to (see details on Figure 2.22 on page 29):

$$\mu_3 = \min\left[\frac{2h}{s_k};\ \frac{2 \cdot \max(b_1;\ b_2)}{\min(5h;\ b_1;\ 15\ m)};\ 8\right]. \quad \textbf{(Eq. 2-9)}$$

ROOFS WHERE DRIFTING OCCURS AT PROJECTIONS AND OBSTRUCTIONS. The snow load shape coefficients for exceptional snow drifts that should be used for roofs where drifting occurs at projections and obstructions, other than parapets, are given in B4(2) and Figure B3 below. Shape coefficients for drifting behind parapets are given in B4(4).

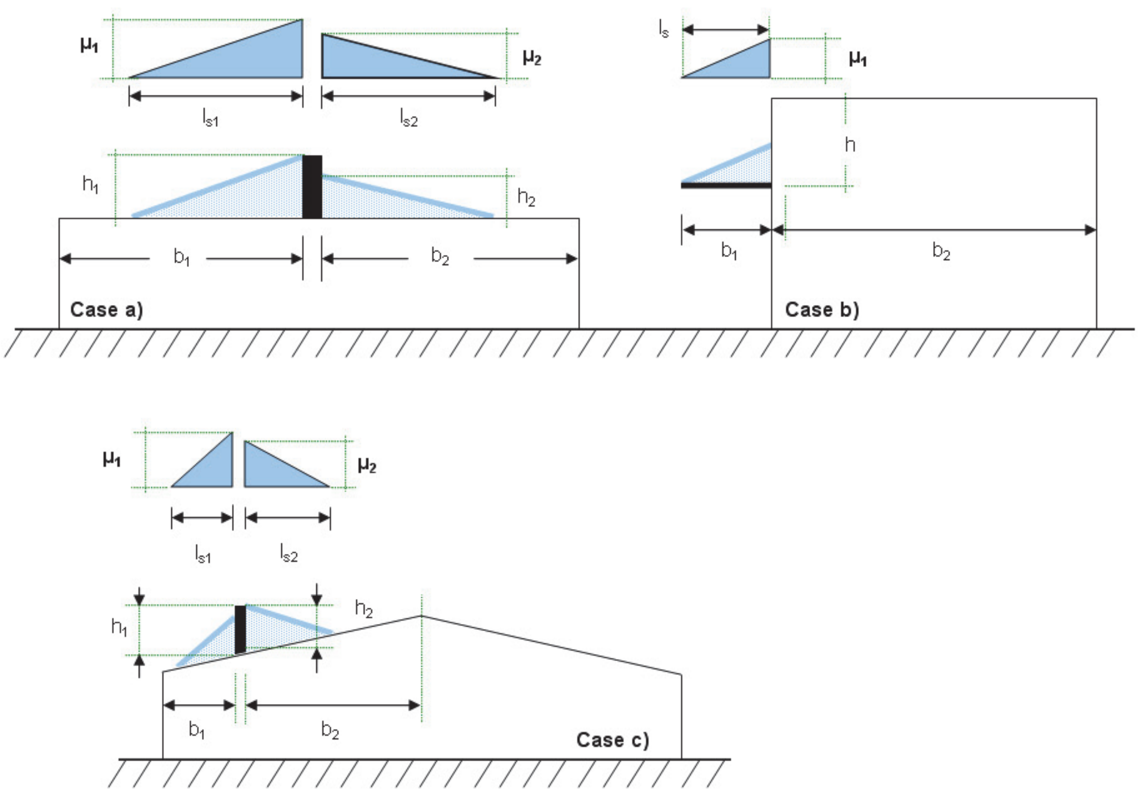

Figure 2.23 From Figure B3 - Shape coefficients for exceptional snow drifts for roofs where drifting occurs at projections and obstructions.

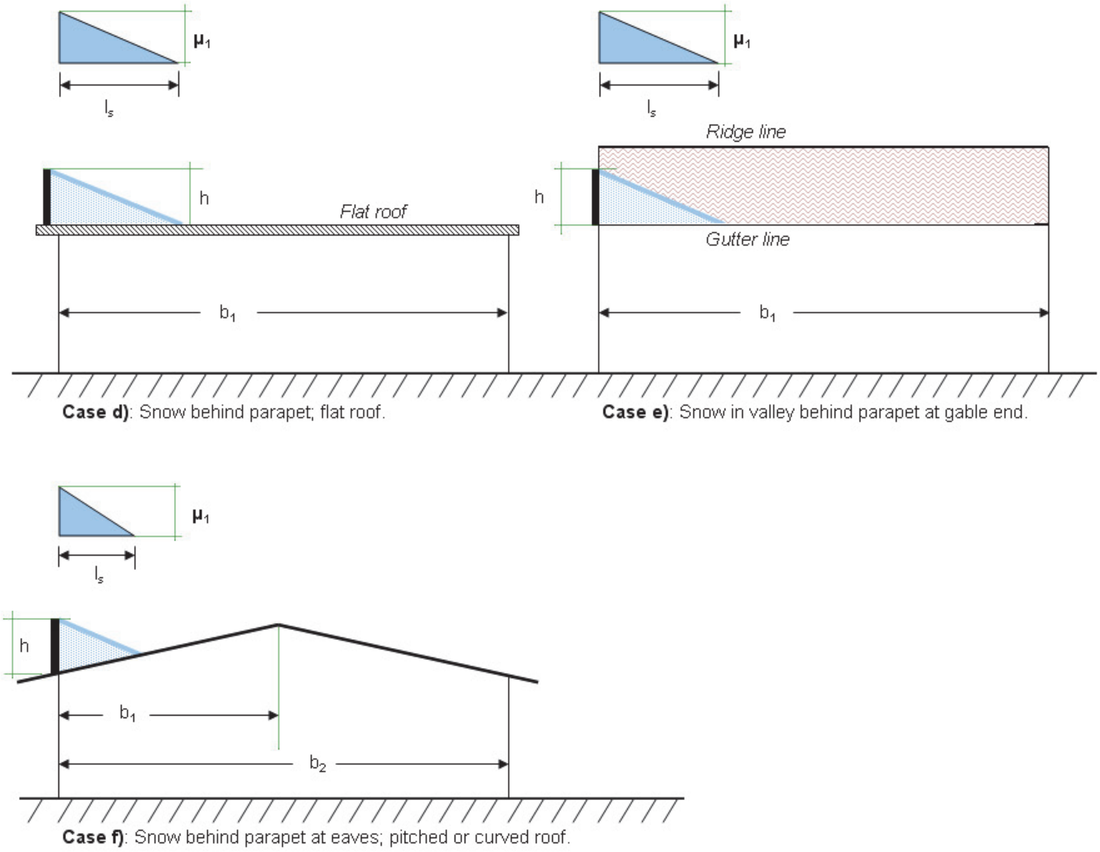

Figure 2.24 From Figure B4 - Shape coefficients for exceptional snow drifts - roofs where drifting occurs at parapets.

If the vertical elevation against which a drift could form is not greater than 1 m^2, the effect of drifting can be ignored.

This clause applies to:

— drifting against obstructions not exceeding 1 m in height.

— drifting on canopies, projecting not more than 5 m from the face of the building over doors and loading bays, irrespective of the height of the obstruction.

— slender obstructions over 1m high but not more than 2 m wide, may be considered as local projections. For this specific case h may be taken as the lesser of the projection height or width perpendicular to the direction of the wind.

The shape coefficient given in Figure B3 is determined as the least value of:

$$\mu_1 = \min[2h_1/s_k; 5]; \ \mu_2 = \min[2h_2/s_k; 5]. \quad \text{(Eq. 2-10)}$$

In addition, for door canopies projecting not more than 5 m from the building, μ_1 should not exceed:

$$\mu_{1,\,max} = \frac{2 \cdot max(b_1;\, b_2)}{min[b_1;\, min(5h;\, 5\ m)]} \quad \text{(Eq. 2-11)}$$

where the drift length (l_{si}) is taken as the least value of $5h_i$ or b_i (with i = 1 or 2) and $h_i \le 1\ m$:

$$l_{si} = min[b_i;\, min(5h_i;\, 5\ m)]\,. \quad \text{(Eq. 2-12)}$$

ROOFS WHERE DRIFTING OCCURS AT PARAPETS. The snow load shape coefficients for exceptional snow drifts that should be used for roofs where drifting occurs at parapets are given in Figure B4 (see Figure 2.24 on page 31).

The shape coefficient given in Figure B4 is determined as:

$$\mu_1 = min\left[\frac{2h}{s_k};\, \frac{2 \cdot b}{min[b_1;\, 5h;\, 15\ m]};\, 8\right] \quad \text{(Eq. 2-13)}$$

with $b = max(b_1;\, b_2)$ for the case "f" and $b = b_1$ for the cases "d" and "e" (see Figure 2.24 on page 31). The drift length l_s is taken as:

$$l_s = min[b_1;\, 5h;\, 15\ m]\,. \quad \text{(Eq. 2-14)}$$

For drifting in a valley behind a parapet at a gable end the snow load at the face of the parapet should be assumed to decrease linearly from its maximum value in the valley to zero at the adjacent ridges, providing the parapet does not project more than 300 mm above the ridge.

2.3 Verification tests

EN1991-1-3_(B).XLS. 5.95 MB. Created: 04 March 2013. Last/Rel.-date: 04 March 2013. Sheets:

— Splash
— Annex A
— Annex B.

EXAMPLE 2-J- Multi-span roofs - **test 1**

Given: A building with shed roof is given. It is assumed that this building is located 1 km south of Inverness city centre and is 90 m above mean sea level (with $s_k \approx 0,60\ kN/m^2$). Calculate the design snow load for an exceptional snow drift with an height of build up snow within the valley of the multi-span roof equal to $h = 1,50\ m$. Assume: $b_1 = 3,00\ m$ and $b_2 = 5,00\ m$. Horizontal dimension of three slopes: $b_3 = 13,00\ m$. (All of the variables mentioned herein are defined in Figure 2.21 on page 28).

[*Reference sheet:* Annex B]-[*Cell-Range: A20:O20-A50:O50*].

Solution: Drift lengths: $l_{s1} = b_1 = 3,00\ m$, $l_{s2} = b_2 = 5,00\ m$.

With the given numerical data, we get:

$$\frac{2h}{s_k} = \frac{2 \cdot (1,50)}{0,60} = 5,00\ [-];\ \frac{2b_3}{l_{s1} + l_{s2}} = \frac{2 \cdot (13,00)}{3,00 + 5,00} = 3,25\ [-].$$

The shape coefficient is determined as the lowest value from the following (5; 3,25; 5):

$\mu_1 = \min[2h/s_k;\ 2b_3/(l_{s1} + l_{s2});\ 5] = \min[5,00;\ 3,25;\ 5] = 3,25\ [-]$.

The snow drift (design) load is defined by Clause 5.2(3)Pc) in Eurocode 1-1-3 thus:

$s = \mu_1 \cdot s_k = 3,25 \cdot 0,60 = 1,95\ kN/m^2$.

⚠ This is considered to be an accidental action as it is classified as an extreme condition. Therefore in Ultimate Limit State (ULS) and Equilibrium (EQU) analyses, no partial factor would be applied to this load.

EXAMPLE 2-K- Roofs abutting and close to taller structures - **test 2**

Given: Find the snow load shape coefficients and design loads for exceptional snow drifts that should be used for roofs abutting a taller building. Figure 2.22 on page 29 explains how the extent of the snowdrift is defined. Assume: $s_k = 0,60\ kN/m^2$; $h = 5,00\ m$; $b_1 = 7,00\ m$; $b_2 = 12,00\ m$; $\alpha = 18°$.

[*Reference sheet:* Annex B]-[*Cell-Range: A79:O79-A125:O125*].

Solution: Drift length: $l_s = \min[5h;\ b_1;\ 15\ m] = \min[(5 \cdot 5);\ 7,00;\ 15\ m] = 7,00\ m$.

$b = \max(b_1;\ b_2) = \max(7,00;\ 12,00) = 12,00\ m$.

$$\mu_3 = \min\left[\frac{2h}{s_k};\ \frac{2 \cdot \max(b_1;\ b_2)}{\min(5h;\ b_1;\ 15\ m)};\ 8\right] = \min\left[\frac{2 \cdot 5,00}{0,60};\ \frac{2 \cdot 12,00}{7,00};\ 8\right]$$

$\mu_3 = \min[16,7;\ 3,43;\ 8] = 3,43\ [-]$. From Table B1 with $15° < \alpha \le 30°$:

$\mu_1 = \mu_3 \cdot (30 - \alpha)/15 = \mu_3 \cdot (30 - 18°)/15 = 3,43 \cdot 0,8 = 2,74\ [-]$, $\mu_2 = \mu_3 = 3,43\ [-]$.

Therefore, we find: $s_1 = \mu_1 \cdot s_k = 2,74 \cdot 0,60 = 1,64\ kN/m^2$

$s_2 = \mu_2 \cdot s_k = 3,43 \cdot 0,60 = 2,06\ kN/m^2$.

⚠ Each snow drift load is considered to be an accidental action as it is classified as an extreme condition (see Annex A). Therefore in Ultimate Limit State (ULS) and Equilibrium (EQU) analyses, no partial factor would be applied to this load.

example-end

EXAMPLE 2-L- Roofs where drifting occurs at projections and obstructions - **test 3**

Given: Referring to the details shown in the Figure 2.24 on page 31, assume:

Case a: $h_1 = 1,00\ m$; $h_2 = 1,00\ m$; $b_1 = 3,00\ m$; $b_2 = 7,00\ m$.

Case b: $h = 3,00\ m$; $b_1 = 2,00\ m$; $b_2 = 75,00\ m$.

Case c: $h_1 = 1,00\ m$; $h_2 = 0,80\ m$; $b_1 = 3,00\ m$; $b_2 = 6,00\ m$.

Calculate the exceptional snow drift loads for the three cases mentioned above.

[*Reference sheet:* Annex B]-[*Cell-Range: A146:O146-A247:O247*].

Solution: Drift lengths $l_{si} = \min[b_i; \min(5h_i; 5\ m)]$:

Case a: $l_{s1} = \min[b_1; \min(5h_1; 5\ m)] = \min[3,00; \min(5; 5\ m)] = 3,00\ m$.

$l_{s2} = \min[b_2; \min(5h_2; 5\ m)] = \min[7,00; \min(5; 5\ m)] = 5,00\ m$.

Case b: $l_{s1} = \min[b_1; \min(5h; 5\ m)] = \min[2,00; \min((5 \cdot 3); 5\ m)] = 2,00\ m$.

Case c: $l_{s1} = \min[b_1; \min(5h_1; 5\ m)] = \min[3,00; \min(15; 5\ m)] = 3,00\ m$.

$l_{s2} = \min[b_2; \min(5h_2; 5\ m)] = \min[6,00; \min((5 \cdot 0,80); 5\ m)] = 4,00\ m$.

Shape coefficients given in figure B3:

Case a: $\mu_2 = \mu_1 = \min[2h_1/s_k; 5] = \min[(2 \cdot 1,00)/(0,60); 5] = \min[3,33; 5] = 3,33\ [-]$.

Case b: $\mu_1 = \min[2h_1/s_k; 5] = \min[(2 \cdot 3,00)/(0,60); 5] = \min[10\ ; 5] = 5,00\ [-]$

with the limit:

$$\mu_{1,\,max} = \frac{2 \cdot \max(b_1; b_2)}{\min[b_1; \min(5h; 5\ m)]} = \frac{2 \cdot 75,00}{\min[2,00; 5,00]} = 75,00\ [-]\ \text{(ok)}.$$

Case c: $\mu_1 = \min[2h_1/s_k; 5] = \min[(2 \cdot 1,00)/(0,60); 5] = \min[3,33\ ; 5] = 3,33\ [-]$.

$\mu_2 = \min[2h_2/s_k; 5] = \min[(2 \cdot 0,80)/(0,60); 5] = \min[2,67\ ; 5] = 2,67\ [-]$.

Exceptional snow drift loads:

Case a: $\mu_1 \cdot s_k = \mu_2 \cdot s_k = 3,33 \cdot 0,60 = 2,00\ kN/m^2$.

Case b: $\mu_1 \cdot s_k = 5,00 \cdot 0,60 = 3,00\ kN/m^2$.

Case c: $\mu_1 \cdot s_k = 3,33 \cdot 0,60 = 2,00\ kN/m^2$; $\mu_2 \cdot s_k = 2,67 \cdot 0,60 = 1,60\ kN/m^2$.

⚠ Each snow drift load is considered to be an accidental action as it is classified as an extreme condition (see Annex A). Therefore in Ultimate Limit State (ULS) and Equilibrium (EQU) analyses, no partial factor would be applied to this load.

example-end

EXAMPLE 2-M- Shape coefficients for exceptional snow drifts - roofs where drifting occurs at parapets or adjacent structures - **test 3b**

Given: An indoor sports hall is to be constructed adjacent to an existing further education college. It is located 1 km south of Inverness city centre and is 90 m above mean sea level (with $s_k = 0,60\ kN/m^2$). Calculate the characteristic snow load on the roof of the new sports hall. The roof pitch angle α to the sports hall is 8°.

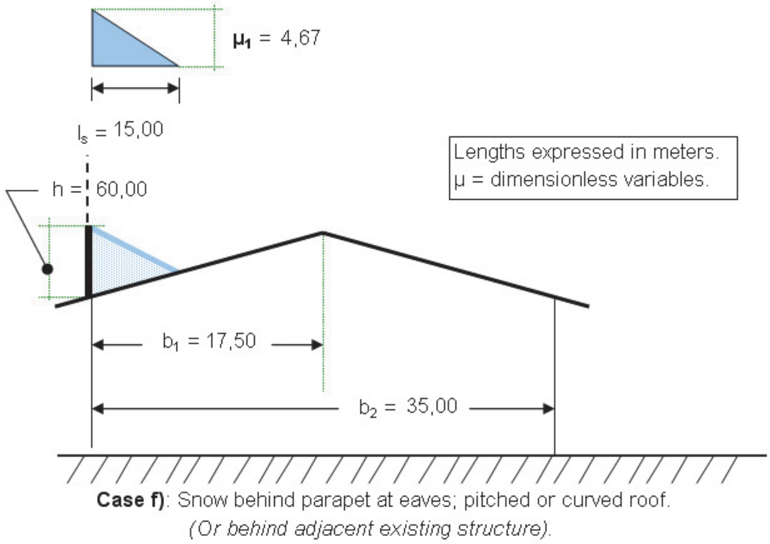

Figure 2.25 Snowdrift load onto the main roof due to the adjacent existing structure: the adjacent building is h = 60 meters high.

(Worked example taken from: www.thestructuralengineer.org).
[*Reference sheet:* Annex B]-[*Cell-Range: A251:O251-A322:O322*].

Solution: Initially, the basic snow load was calculated equal to $s_k = 0,60\ kN/m^2$. The shape factor for the overall snow load on the duo-pitch roof for the new sports hall is then determined and the corresponding snow load is calculated. With (see EN 1991-1-3, Table 5.2 - "*Snow load shape coefficients*"):

$\alpha = 8° \quad \Rightarrow \quad \mu_1 = 0,8\ [-]$

the snow load onto sports hall roof is calculated as follow:

$s = \mu_1 \cdot s_k = 0,8 \cdot 0,60 = 0,48 \approx 0,5\ kN/m^2$.

Note that this load is a variable static action and therefore would have a partial factor of $1,5 \cdot Q_k$ if it were being considered in isolation to other loads.

Finally, we consider the snowdrift load onto the main roof due to the adjacent existing structure, which is significantly taller than the sports hall. See Figure 2.24 on page 31 (case f) and figure above.

Drift length: $l_s = \min[b_1; 5h; 15\ m] = \min[17,50; (5 \cdot 60); 15\ m] = 15,00\ m$.

Shape coefficients given in figure B4:

$$\mu_1 = \min\left[\frac{2h}{s_k}; \frac{2 \cdot \max(b_1; b_2)}{\min[b_1; 5h; 15\ m]}; 8\right] = \min\left[\frac{120}{0,60}; \frac{2 \cdot 35,00}{15,00}; 8\right] = \min[200;(4,67; 8)],$$

$\mu_1 = 4,67\ [-]$.

Therefore, the snow drift load is calculated as follow:

$$s = \mu_1 \cdot s_k = 4,67 \cdot 0,60 = 2,80 \text{ kN/m}^2 .$$

⚠ This load is deemed to be an accidental action and therefore no partial factors are applied to it within ULS and EQU analyses.

example-end

2.4 References [Section 2]

Derivation of snow load, Technical Guidance Note, TheStructuralEngineer, March 2012. Web resource: www.istructe.org/resources-centre/library.

EN 1991-1-3:2003/AC:2009. Eurocode 1: Actions on structures - Part 1-3: General actions - Snow loads. Brussels: CEN/TC 250 - Structural Eurocodes, March 2009.

EN 1991-1-3 (2003) (English): Eurocode 1: Actions on structures - Part 1-3: General actions - Snow loads [Authority: The European Union Per Regulation 305/2011, Directive 98/34/EC, Directive 2004/18/EC].

Manual for the design of building structures to Eurocode 1 and Basis of Structural Design April 2010. © 2010 The Institution of Structural Engineers.

Section 3 **Eurocode 1**
EN 1991-1-3: Annex C, Annex D

3.1 Annex C: European Ground Snow Load Maps

This Annex presents the European snow maps which are the result of scientific work carried out under contract to DGIII/D-3 of the European Commission, by a specifically formed research Group. The objectives of this Annex, defined in 1.1(5), are:

— to help National Competent Authorities to redraft their national maps

— to establish harmonised procedures to produce the maps.

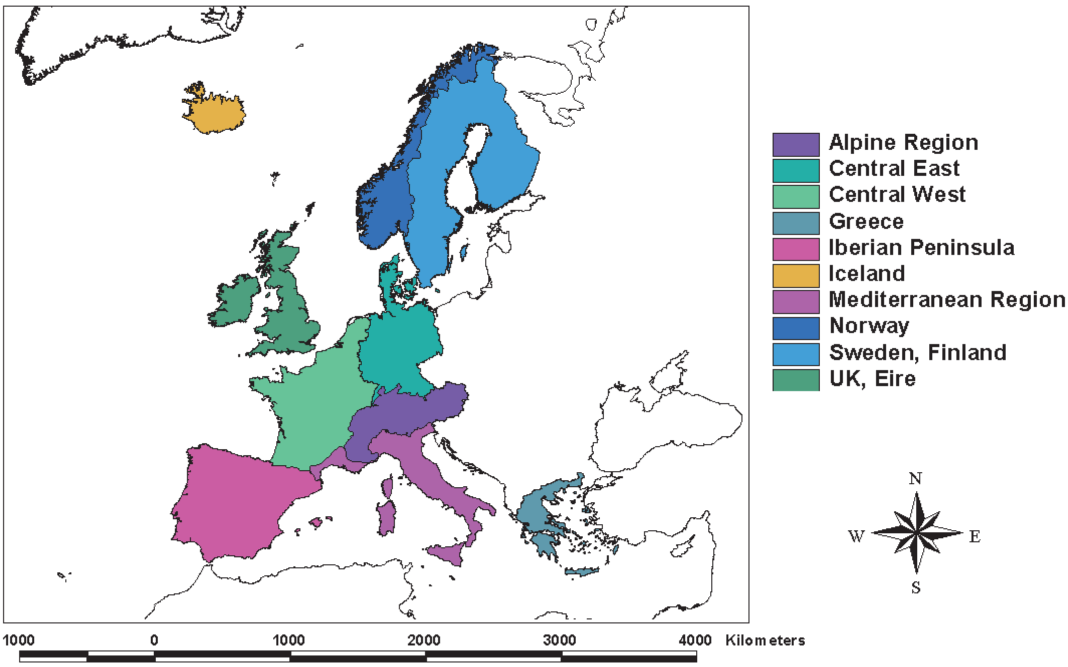

Figure 3.26 From Figure C.1 - European Climatic regions.

This will eliminate or reduce the inconsistencies of snow load values in CEN member states and at borderlines between countries. The European snow map developed by the Research Group are divided into 9 different homogeneous climatic regions, as shown in Figures C.1 to C.10.

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:	$s_k = 0,140Z - 0,1 + \frac{A}{501}$

Table 3.8 From Table C.1 - Altitude - Snow Load Relationships.

In each climatic region a given load-altitude correlation formula applies and this is given in Table C.1 above where:

- s_k is the characteristic snow load on the ground [kN/m^2]
- A is the site altitude above Sea Level [m]
- Z is the zone number given on the map (1; 2; 3; 4; 4,5).

3.2 Annex D: Adjustment of the ground snow load according to return period

Ground level snow loads for any mean recurrence interval different to that for the characteristic snow load, s_k, (which by definition is based on annual probability of exceedence of 0,02) may be adjusted to correspond to characteristic values by application of Sections D(2) to D(4). If the available data show that the annual maximum snow load can be assumed to follow a Gumbel probability distribution, then the relationship between the characteristic value of the snow load on the ground and the snow load on the ground for a mean recurrence interval of n years is given by the formula (D.1):[1]

$$\frac{s_n}{s_k} = \left\{ \frac{1 - V\frac{\sqrt{6}}{\pi} \cdot [\ln(-\ln(1 - P_n)) + 0,57722]}{1 + 2,5923V} \right\}$$

where:

- s_k is the characteristic snow load on the ground (with a return period of 50 years, in accordance with EN 1990:2002)
- s_n is the ground snow load with a return period of n years
- P_n is the annual probability of exceedence (equivalent to approximately $1/n$, where n is the corresponding recurrence interval (years))
- V is the coefficient of variation of annual maximum snow load[2].

However, expression (D.1) should not be applied for annual probabilities of exceedence greater than 0,2 (i.e. return period less than approximately 5 years). Where permitted by the relevant national Authority expression (D.1) may also be adapted to calculate snow loads on the ground for other probabilities of exceedence. For example for:

a. structures where a higher risk of exceedence is deemed acceptable
b. structures where greater than normal safety is required.

3.3 Verification tests

EN1991-1-3_(C).XLS. 8.40 MB. Created: 09 March 2013. Last/Rel.-date: 09 March 2013. Sheets:

— Splash
— Annex C
— Annex D.

EXAMPLE 3-N- European Ground Snow Load Maps - **test 1**

Given: Assuming $A = 100$ mamsl (*meters above mean sea level*) and zone number $Z = 2$, find the characteristic snow load on the ground s_k for all the climatic regions on Table C.1 "*Altitude - Snow Load Relationship*".

[*Reference sheet:* Annex C]-[*Cell-Range: A53:O53-A100:O100*].

(1) Where appropriate another distribution function for the adjustment of return period of ground snow load may be defined by the relevant national Authority.

(2) Information on the coefficient of variation may be given by the relevant national Authority.

Solution: Alpine Region:

$$s_k = (0,642Z + 0,009)\left[1 + \left(\frac{A}{728}\right)^2\right] = (0,642 \cdot 2 + 0,009)\left[1 + \left(\frac{100}{728}\right)^2\right] = 1,32 \ \text{kN/m}^2 .$$

Central East:

$$s_k = (0,264Z - 0,002)\left[1 + \left(\frac{A}{256}\right)^2\right] = (0,264 \cdot 2 - 0,002)\left[1 + \left(\frac{100}{256}\right)^2\right] = 0,61 \ \text{kN/m}^2 .$$

Greece:

$$s_k = (0,420Z - 0,030)\left[1 + \left(\frac{A}{917}\right)^2\right] = (0,420 \cdot 2 - 0,030)\left[1 + \left(\frac{100}{917}\right)^2\right] = 0,82 \ \text{kN/m}^2 .$$

Iberian Peninsula:

$$s_k = (0,190Z - 0,095)\left[1 + \left(\frac{A}{524}\right)^2\right] = (0,190 \cdot 2 - 0,095)\left[1 + \left(\frac{100}{524}\right)^2\right] = 0,30 \ \text{kN/m}^2 .$$

Mediterranean Region:

$$s_k = (0,498Z - 0,209)\left[1 + \left(\frac{A}{452}\right)^2\right] = (0,498 \cdot 2 - 0,209)\left[1 + \left(\frac{100}{452}\right)^2\right] = 0,83 \ \text{kN/m}^2 .$$

Central West:

$$s_k = 0,164Z - 0,082 + \frac{A}{966} = 0,164 \cdot 2 - 0,082 + \frac{100}{966} = 0,35 \ \text{kN/m}^2 .$$

Sweden, Finland:

$$s_k = 0,790Z + 0,375 + \frac{A}{336} = 0,790 \cdot 2 + 0,375 + \frac{100}{336} = 2,25 \ \text{kN/m}^2 .$$

UK, Republic of Ireland:

$$s_k = 0,140Z - 0,1 + \frac{A}{501} = 0,140 \cdot 2 - 0,1 + \frac{100}{501} = 0,38 \ \text{kN/m}^2 .$$

example-end

EXAMPLE 3-O- European Ground Snow Load Maps - **test 2**

Given: Assuming $A = 200$ mamsl, $Z = 2$, $C_e = 1$, $C_t = 1$ find for the UK:

1) the characteristic ground snow load s_k

2) the design value of exceptional snow load on the ground for locations where exceptional snow loads on the ground can occur

3) the snow load on roofs for the persistent/transient design situations

4) the snow load on roofs for the accidental design situations where exceptional snow load is the accidental action

5) the snow load on roofs for the accidental design situations where exceptional snow drift is the accidental action and where Annex B applies.

[*Reference sheet:* Annex C]-[*Cell-Range: A102:O102-A150:O150*].

Plot: s_k = 0,140·Z – 0,1 + A/501 = f(A; Z = 2)

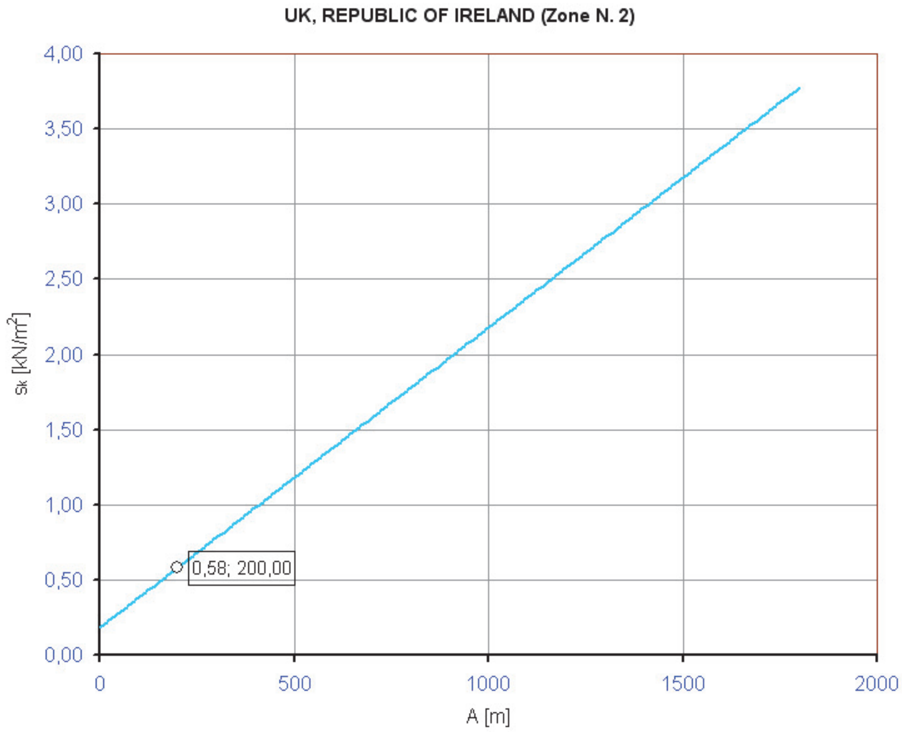

Figure 3.27 Characteristic ground snow load for UK and Republic of Ireland (zone N. 2).

Solution: **1)** UK, Republic of Ireland:

$$s_k = 0,140Z - 0,1 + \frac{A}{501} = 0,140 \cdot 2 - 0,1 + \frac{200}{501} = 0,58\ \text{kN/m}^2.$$

2) With a coefficient for exceptional snow loads equal to $C_{esl} = 2$:

$s_{Ad} = C_{esl} \cdot s_k = 2 \cdot 0,58 = 1,16\ \text{kN/m}^2$.

3) With $C_e = 1$, $C_t = 1$: $s = \mu_1 \cdot C_2 \cdot C_t \cdot s_k = \mu_1 \cdot 1 \cdot 1 \cdot 0,58 = \mu_1 \cdot 0,58\ \text{kN/m}^2$.

4) With $s_{Ad} = 1,16\ \text{kN/m}^2$: $s = \mu_1 \cdot C_e \cdot C_1 \cdot s_{Ad} = \mu_1 \cdot 1,16\ \text{kN/m}^2$.

5) $s = \mu_1 \cdot s_k = \mu_1 \cdot 0,58\ \text{kN/m}^2$.

example-end

EXAMPLE 3-P- Adjustment of the ground snow load according to return period - **test 3**

Given: According to Annex D, find the ratio s_n/s_k for a coefficient of variation of annual maximum snow load $V = 0,5$ and a recurrence interval equal to $n = 90$ years.

[*Reference sheet:* Annex D]-[*Cell-Range: A15:O15-A31:O31*].

Solution: From eq. D.1 with $P_n = 1/n = 1/90 \approx 0,0111$:

$$\frac{s_n}{s_k} = \left\{\frac{1 - V\frac{\sqrt{6}}{\pi}\cdot[\ln(-\ln(1-P_n)) + 0,57722]}{1 + 2,5923V}\right\} = \left\{\frac{1 - 0,5\frac{\sqrt{6}}{\pi}\cdot\left[\ln\left(-\ln\left(1-\frac{1}{90}\right)\right) + 0,57722\right]}{1 + 2,5923\cdot 0,5}\right\},$$

$$\frac{s_n}{s_k} = \frac{2,527}{2,296} \approx 1,10.$$

Graph of eq. (D.1) with V = 0,5.

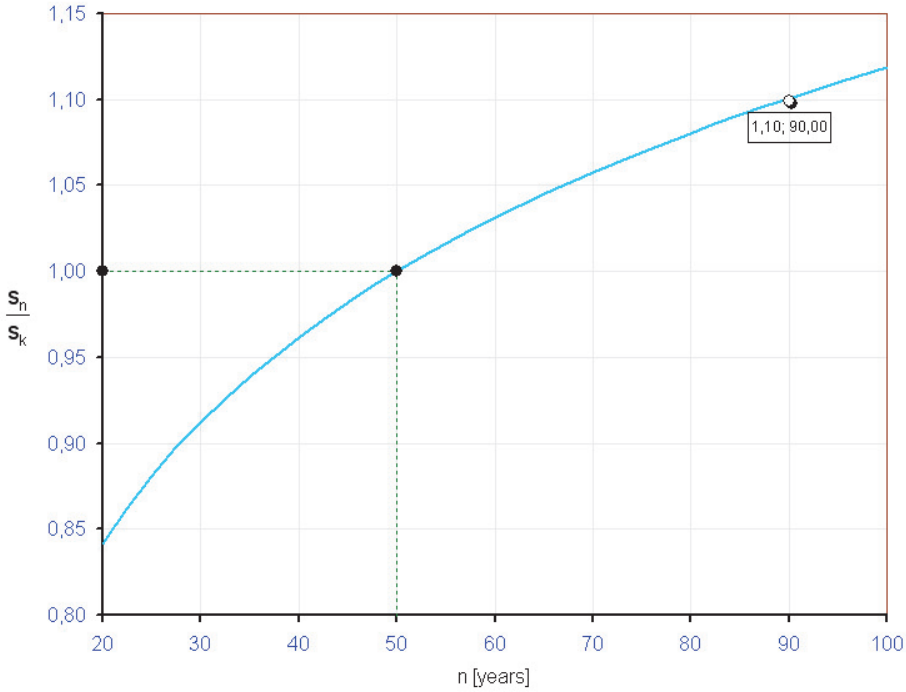

Figure 3.28 Ratio s_n/s_k with V = 0,5 plotted against "n" (years).

For a characteristic snow load on the ground equal to $s_k = 0,58$ kN/m² (return period of 50 years), we get (n = 90 years):

$s_n = 1,10 \cdot s_k = 1,10 \cdot 0,58 = 0,64$ kN/m².

example-end

3.4 References [Section 3]

Derivation of snow load, Technical Guidance Note, TheStructuralEngineer, March 2012. Web resource: www.istructe.org/resources-centre/library.

EN 1991-1-3:2003/AC:2009. Eurocode 1: Actions on structures - Part 1-3: General actions - Snow loads. Brussels: CEN/TC 250 - Structural Eurocodes, March 2009.

EN 1991-1-3:2003. Eurocode 1 - Actions on structures - Part 1-3: General actions - Snow loads. Brussels: CEN/TC 250 - Structural Eurocodes, July 2003 (DAV).

EN 1991-1-3 (2003) (English): Eurocode 1: Actions on structures - Part 1-3: General actions - Snow loads [Authority: The European Union Per Regulation 305/2011, Directive 98/34/EC, Directive 2004/18/EC].

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