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Bases for design of structures — Determination of snow loads on roofs

Bases du calcul des constructions — Détermination de la charge de neige sur les toitures

Reference number
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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 98, *Bases for design of structures*, Subcommittee SC 3, *Loads, forces and other actions*.

This third edition cancels and replaces the second edition (ISO 4355: 1998), which has been technically revised.

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Introduction

The intensity and distribution of snow load on roofs can be described as functions of climate, topography, shape of building, roof surface material, heat flow through the roof, and time. Only limited and local data describing some of these functions are available. Consequently, for this International Standard it was decided to treat the problem in a semi-probabilistic way.

The characteristic snow load on a roof area, or any other area above ground which is subject to snow accumulation, is in this International Standard defined as a function of the characteristic snow load on the ground, s_0, specified for the region considered, and a shape coefficient which is defined as a product function, in which the various physical parameters are introduced as nominal coefficients.

The shape coefficients will depend on climate, especially the duration of the snow season, wind, local topography, geometry of the building and surrounding buildings, roof surface material, building insulation, etc. The snow can be redistributed as a result of wind action; melted water can flow into local areas and refreeze; snow can slide or can be removed.

In order to apply this International Standard, each country will have to establish maps and/or other information concerning the geographical distribution of snow load on ground in that country. Procedures for a statistical treatment of meteorological data are described in Annex A.

Bases for design of structures — Determination of snow loads on roofs

1 Scope

This International Standard specifies methods for the determination of snow load on roofs.

It can serve as a basis for the development of national codes for the determination of snow load on roofs.

National codes should supply statistical data of the snow load on ground in the form of zone maps, tables, or formulae.

The shape coefficients presented in this International Standard are prepared for design application, and can thus be directly adopted for use in national codes, unless justification for other values is available.

For determining the snow loads on roofs of unusual shapes or shapes not covered by this International Standard or in national standards, it is advised that special studies be undertaken. These can include testing of scale models in a wind tunnel or water flume, especially equipped for reproducing accumulation phenomena, and should include methods of accounting for the local meteorological statistics. Examples of numerical methods, scale model studies, and accompanying statistical analysis methods are described in Annex G.

The annexes describing methods for determining the characteristic snow load on the ground, exposure coefficient, thermal coefficient, and loads on snow fences are for information only as a consequence of the limited amount of documentation and available scientific results.

In some regions, single winters with unusual weather conditions can cause severe load conditions not taken into account by this International Standard.

Specification of standard procedures and instrumentation for measurements is not dealt with in this International Standard.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 2394[1], *General principles on reliability for structures*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
characteristic value of snow load on the ground
s_0
load with a specified annual exceedance probability

Note 1 to entry: It is expressed in kilonewton per square metre (kN/m^2).

Note 2 to entry: In meteorology, the term “weight of the ground snow cover” is also used.

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1) In process of revision.

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3.2
shape coefficient

μ

coefficient which defines the amount and distribution of the snow load on the roof over a cross section of the building complex and primarily depends on the geometrical properties of the roof

3.3
value of snow load on roofs

s

function of the characteristic snow load on the ground, s_0, and appropriate shape coefficients

Note 1 to entry: The value of s is also dependent on the exposure of the roof and the thermal conditions of the building.

Note 2 to entry: It refers to a horizontal projection of the area of the roof.

Note 3 to entry: It is expressed in kilonewton per square metre (kN/m^2).

3.4
basic load coefficient

μ_b

coefficient defining the reduction of the snow load on the roof due to a slope of the roof, β, and the surface material coefficient, C_m

3.5
drift load coefficient

μ_d

coefficient which defines the amount and redistribution of additional load on a leeward side or part of a roof, depending on the exposure of the roof to wind, C_e, and the geometrical configurations of the roof

3.6
slide load coefficient

μ_s

coefficient defining the amount and distribution of the slide load on a lower part of a roof, or a lower level roof

3.7
exposure coefficient

C_e

coefficient which accounts for the effects of the roof's exposure to wind

3.8
exposure coefficient for small roofs

C_e0

exposure coefficient for small roofs with effective roof length shorter than 50 m

3.9
effective roof length

l_c

length of the roof influenced by exposure coefficient given as a function of roof dimensions

3.10
thermal coefficient

C_t

coefficient defining the change in snow load on the roof as a function of the heat flux through the roof

Note 1 to entry: C_t, in some cases, can be greater than 1,0. Further guidance is given in 6.2 and Annex D.

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3.11
surface material coefficient

C_m

coefficient defining a reduction of the snow load on sloped roofs made of surface materials with low surface roughness

3.12
equivalent snow density

ρ_e

density for calculating the annual maximum snow load from annual maximum snow depth

3.13
snow density

ρ

ratio between snow load and snow depth

4 Snow loads on roofs

4.1 General function describing intensity and distribution of the snow load on roofs

Formally, the snow load on roofs can be defined as a function, F, of several parameters:

$$s = F\left(s_0, C_e, C_t, C_m, \mu_b, \mu_d, \mu_s\right) \tag{1}$$

where the symbols are as defined in Clause 3.

While C_e, C_t, and C_m are assumed constant for a roof or a roof surface, μ_b, μ_d, and μ_s generally vary throughout the roof.

4.2 Approximate formats for the determination of the snow load on roofs

This International Standard defines the snow load on the roof as a combination of a basic load part, s_b, a drift load part, s_d, and a slide load part, s_s. Thus, for the most unfavourable condition (lower roof on leeward side):

$$s = s_b \text{"+"} s_d \text{"+"} s_s \tag{2}$$

where "+" implies "to be combined with".

Effects of the various parameters are simplified by the introduction of product functions.

$$s_b = 0{,}8 s_0 C_e C_t \mu_b \tag{3}$$

$$s_d = s_0 \mu_b \mu_d \tag{4}$$

$$s_s = s_0 \mu_s \tag{5}$$

The basic roof snow load, s_b, is uniformly distributed in all cases, [1] [2] except for curved roofs, where the distribution varies with the slope, β (see B.4).

The basic load defines the load on a horizontal roof, and the load on the windward side of a pitched roof. Since any direction can be the wind direction, the basic load is treated as a symmetrical load on a symmetrical roof, thus defining a major part of the total load on the leeward side as well.

The drift load is the additional load that can accumulate on the leeward side due to drifting.

The slide load is the load that can slide from an upper roof onto a lower roof, or a lower part of a roof.

4.3 Partial loading due to melting, sliding, snow redistribution, and snow removal

A load corresponding to severe imbalances resulting from snow removal, redistribution, sliding, melting, etc. (e.g. zero snow load on specific parts of the roof) should always be considered.

Such considerations are particularly important for structures which are sensitive to unbalanced loading (e.g. curved roofs, arches, domes, collar beam roofs, continuous beam systems) which are addressed in other clauses of this International Standard.

4.4 Ponding instability

Roofs shall be designed to preclude ponding instability. For flat roofs (or with a small slope), roof deflections caused by snow loads shall be investigated when determining the likelihood of ponding instability from rain-on-snow or from snow meltwater.

5 Characteristic snow load on the ground

The characteristic snow load on the ground, s_0, is determined by statistical treatment of snow data.

Snow load measurements on the ground should be taken in an undisturbed area not subject to localized drifting.

Methods for the determination of the characteristic snow load on the ground, s_0, are described in Annex A.

For practical application, the characteristic snow load on the ground will be defined in standard step values, which will yield basic values for the preparation of zone maps as described in Annex A.

6 Snow load coefficients

6.1 Exposure coefficient

The exposure coefficient, C_e, should be used for determining the snow load on the roof. The choice of C_e should consider the future development around the site. For regions where there are no sufficient winter climatological data available, it is recommended to set $C_e = 1{,}0$.

For most cases, the exposure coefficient, C_e, is equal to the exposure coefficient for small roofs, C_{e0}. However, for very large flat roofs, wind is less effective in removing snow from the whole roof. To compensate for this, the exposure coefficient for large roofs is higher than for smaller roofs.

$$C_e = \begin{cases} C_{e0} & l_c \le 50\ \mathrm{m} \\ 1{,}25 - \left(1{,}25 - C_{e0}\right) e^{-(l_c - 50)/200} & l_c > 50\ \mathrm{m} \end{cases} \tag{6}$$

where

l_c is the effective roof length equal to $2W - \dfrac{W^2}{L}$ in metres;

C_{e0} is the exposure coefficient for small roofs.

Methods for the determination of C_{e0} are given in Annex C.

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In the expression for l_c, W is the length of the shorter side of the roof and L is the length of the longer side (see Figure 1).

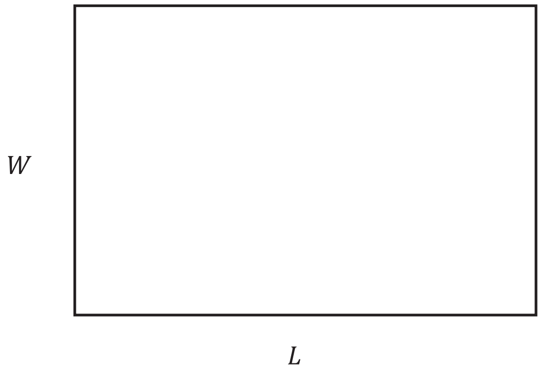

Figure 1 — Rectangular roof dimensions

For non-rectangular roofs, W and L can be taken as the shorter and longer side of the roof's major dimensions along two orthogonal axes. For example, for an elliptical shape, W is measured along the short axis and L along the long axis.

An overview of the exposure coefficient is shown in Figure 2.

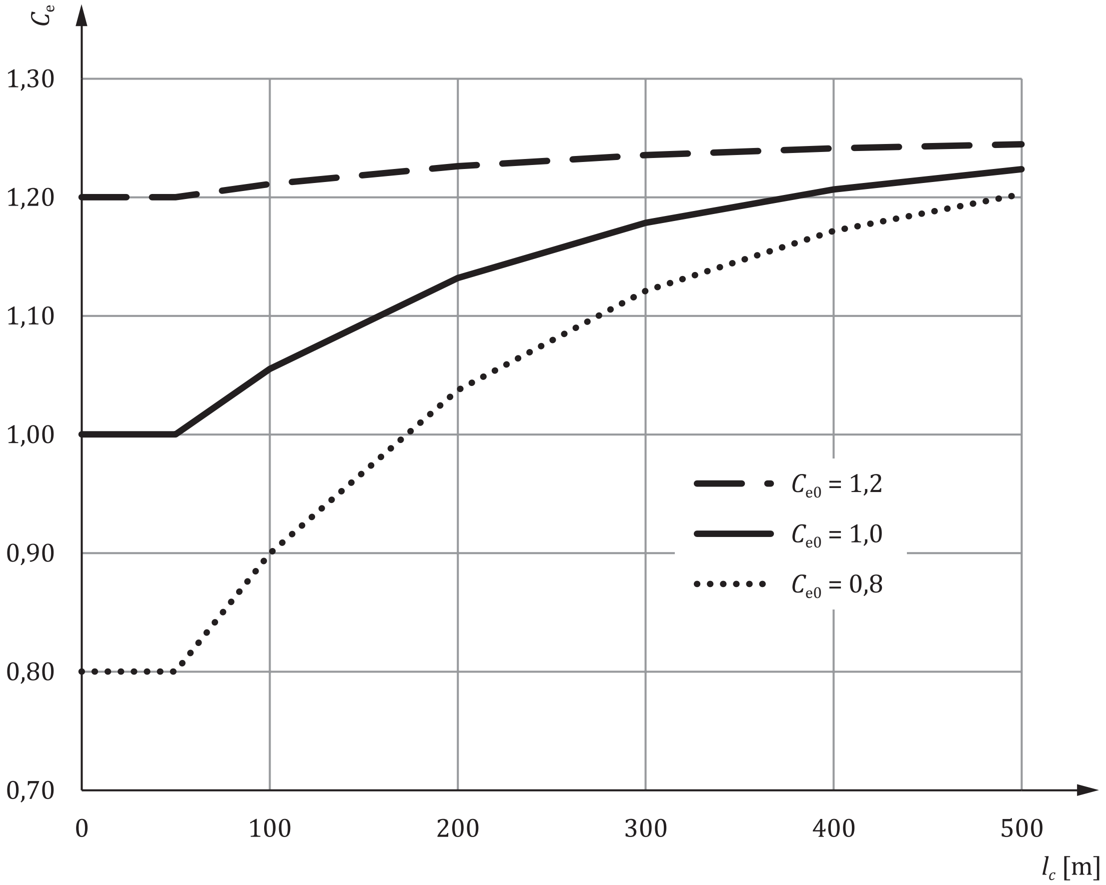

Figure 2 — Exposure coefficient, C_e, as a function of effective roof length, l_c

6.2 Thermal coefficient

The thermal coefficient, C_t (see 3.10), is introduced to account for effect of thermal transmittance of the roof.

The snow load is reduced on roofs with high thermal transmittance because of melting caused by heat loss through the roof. For such cases and for glass-covered roofs in particular, C_t, can take values less than unity.

For buildings where the internal temperature is intentionally kept below 0 °C (e.g. freezer buildings, ice skating arenas), C_t, can be taken as 1,2. For all other cases, $C_t = 1{,}0$ applies.

Bases for the determination of C_t are the thermal transmittance of the roof, U, and the lowest temperature, θ, to be expected for the space under the roof, and the snow load on the ground, s_0.

Methods for the determination of C_t for roofs with high thermal transmittance are described in Annex D.

NOTE The intensity of snowfall for short periods, approximately 1 d to 5 d, is often a more relevant parameter than s_0 for roofs with considerable heat loss, since the melting is too rapid to allow accumulation throughout the winter. Since only s_0, however, is available, it has been used with the modifications given in Annex D.

6.3 Surface material coefficient

The amount of snow which slides off the roof will, to some extent, depend on the surface material of the roofing; see 6.4.2.

The surface material coefficient, C_m (see 3.11), is defined to vary between unity and 1,333, and takes the following fixed values:

— $C_m = 1{,}333$ for slippery, unobstructed surfaces for which the thermal coefficient $C_t < 0{,}9$ (e.g. glass roofs);

— $C_m = 1{,}2$ for slippery, unobstructed surfaces for which the thermal coefficient $C_t > 0{,}9$ (e.g. glass roofs over partially climatic conditioned space, metal roofs, etc.);

— $C_m = 1{,}0$ corresponds to all other surfaces.

NOTE $C_m = 1{,}2$ could also be applied for $C_t < 0{,}9$ if this is assumed to be more reasonable.

6.4 Shape coefficients

6.4.1 General principles

The shape coefficients define distribution of the snow load over a cross section of the building complex and depend primarily on the geometrical properties of the roof.

For buildings of rectangular plan form, the distribution of the snow load in the direction parallel to the eaves is assumed to be uniform, corresponding to an assumed wind direction normal to the eaves.

The shape coefficients presented for selected types of roof (see Annex B), are illustrated for one specific wind direction. Since prevailing wind directions can not correspond to the wind directions during heavy snow falls, the condition that the wind during snow fall can have any direction with reference to the roof location should be considered when designing roofs.

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6.4.2 Basic load coefficient

When snow on sloped roofs can slide off unobstructed, snow load on the roof will be reduced. The reduction of the snow load on the roof due to the slope, β, of the roof and the surface material coefficient, C_m, is defined by the shape coefficient, μ_b (see 3.4), which is given by Formula (7):

$$\mu_b = \begin{cases} 1 & \beta < 30(1/C_m) \\ (60 - C_m\beta)/30 & 30(1/C_m) < \beta < 60(1/C_m) \\ 0 & \beta > 60(1/C_m) \end{cases} \quad (7)$$

An overview of the basic load coefficient is shown in Figure 3.

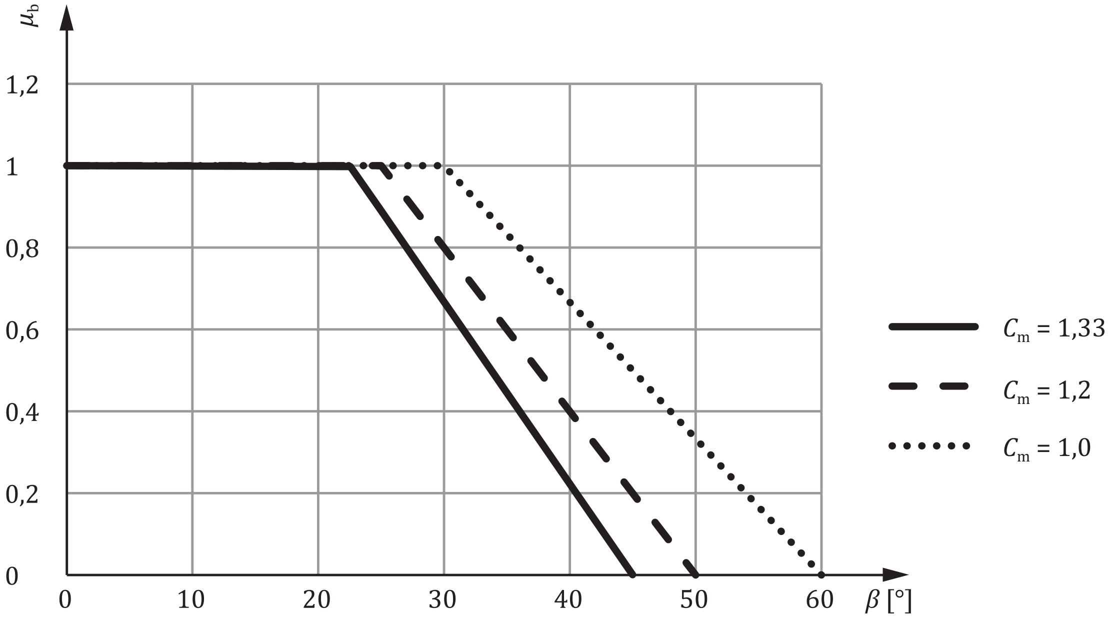

Figure 3 — Basic load coefficient, μ_b, as a function of surface material coefficient, C_m

6.4.3 Drift load coefficient

The drift load coefficient, μ_d (see 3.5), is dependent on the roof geometry and the exposure coefficient, C_e, and is described in Annex B.

6.4.4 Slide load coefficient

Slide load from an upper part of a roof onto a lower part of a roof, or onto a lower roof of a multilevel roof, will depend on the amount of snow that can slide down, and on the geometrical configuration of the roof.

The distribution of the slide load and the spreading out of the load will, in addition to the geometrical shape of the roof, depend on the properties of the sliding snow and on the friction on the upper roof from which the snow is sliding.

The slide load magnitude and distribution is incorporated in the slide load coefficient, μ_s (see 3.6).

In the cases when slide load should be considered, the slide load coefficient for different roof types is described in Annex B.

The impact loading due to slide load should be considered.

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Annex A
(informative)

Background on the determination of some snow parameters

A.1 Snow zones and maps

The characteristic snow load on the ground, s_0, with an annual exceedance probability of 0,02 or other values taking into account the importance of the building and the limit state considered, should be available in national standards.

Due to the nature of the variation of snow load, a snow zone mapping with basic values throughout the zones, often related to a fixed altitude, is preferred rather than a continuous field with isolines. This approach is recommended since a specific snow load variation with altitude can often be developed within climatologically defined zones.

Investigations have shown that near the coasts, not only the altitude but also the distance from the coast can influence the snow load.

NOTE 1 When more appropriate, an annual exceedance probability of less than 0,02 can apply.

NOTE 2 Important studies on defining the characteristic snow load on load the ground have been carried out and are discussed in References [3],[4],[5],[6], and [7]. On the treatment of statistical values, see A.3.

A subdivision of a country into zones of basic s_0 values should be constructed in a logical set of steps. Recommended interval values, in kN/m^2, are: 0,25 – 0,5 – 0,75 – 1,0 – 1,5 – 2,0 – 2,5 – 3,5 – 4,5 – [...].

A.2 Use of basic meteorological data

To determine snow load on the ground, s_0, a sequence of maximum yearly snow loads is used. This parameter can be determined on the basis of recordings of water equivalents, snow depths, precipitation, etc. For areas where there is snow every year, the recommended recording length is 20 years. For areas with larger variability, a longer recording length is recommended. Snow sampling equipment and the observation procedure should be in accordance with WMO recommendations.[8] Preferably, snow courses with records of water equivalents should be used. However, if water equivalent data are scarce, available data on snow depth can be used.

A.2.1 Snow load on the ground related to snow depth

In the USA[9], the following relationship between snow load and snow depth is used:

$$s_{50} = 1{,}97 d_{50}^{1{,}36} \tag{A.1}$$

where

s_{50} is the snow load on the ground (kN/m^2) with a return period of 50 years;

d_{50} is the snow depth on the ground (m) with a return period of 50 years.

Formula (A.1) takes into account that the maximum ground load does not necessarily occur on the same day as the maximum ground snow depth.

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A.2.2 Density of snow

The average density of snow layer is an important parameter for determining snow load, since the snow depth has more recordings than the water equivalent at many stations.

When determining annual maximum snow load by means of snow depth and density, it should be considered that these two parameters usually have a significant positive correlation before the occurrence of a year's snow depth maximum, and negative afterwards. In heavy snow regions, there is usually a time lag between the annual maximum snow depth and the annual maximum snow load. This difference is due to densification of snow layers. Therefore, an equivalent density of snow needs to be used for determining s_0 when based on the annual maximum snow depth.[11]

Many formulae have been proposed due to different climates in different countries. A snow density of 300 kg/m^3 should be used if no other information is given.

In Russia, former USSR[10], Formula (A.2) has been proposed:

$$\rho = \left(90 + 130\sqrt{d}\right)\left(1{,}5 + 0{,}17\sqrt[3]{T}\right)\left(1 + 0{,}1\sqrt{v}\right) \tag{A.2}$$

where

ρ is the snow density (kg/m^3);

d is the snow depth (m);

T is the average temperature (°C) over the period of snow accumulation (assumed to be not below −25 °C);

v is the average wind speed (m/s) over the same period.

Another formula for equivalent snow density on the ground with a return period of 100 years used in Japan[11] is

$$\rho_e = 73\sqrt{{}^{d}\!/_{d_{\mathrm{ref}}}} + 240 \tag{A.3}$$

where

ρ_e is the equivalent snow density (kg/m^3);

d is the snow depth (m);

d_{ref} is the reference snow depth of 1 m.

Formula (A.4) is for snow density in the USA. It relates the snow density at one point in time to the snow load at the same point in time:

$$\rho = 43{,}5\, s_0 + 224 \leq 480 \tag{A.4}$$

where

ρ is the snow density (kg/m^3);

s_0 is the snow load on the ground (kN/m^2).

Formula (A.4), written in terms of snow depth, is

$$\rho = \begin{cases} 270/(1{,}2 - 0{,}51d) & d < 1{,}25\ \mathrm{m} \\ 480 & d \geq 1{,}25\ \mathrm{m} \end{cases} \tag{A.5}$$

where

ρ is the snow density (kg/m^3);

d is the snow depth (m).

Based on observations of the German Weather Service (Deutscher Wetterdienst DWD)[12] [13] the following approach has been developed:

$$\rho = \frac{\rho_\infty d_{\mathrm{ref}}}{d} \ln\left[1 + \frac{\rho_0}{\rho_\infty}\left(\exp\left(\frac{d}{d_{\mathrm{ref}}}\right) - 1\right)\right] \tag{A.6}$$

where

d is the snow depth (m);

ρ_0 is the density of snow at the surface (kg/m^3);

ρ_∞ is the upper limiting value of the snow density;

d_{ref} is the reference snow depth of 1 m.

For Germany, the snow density at the surface usually is in the range from 170 kg/m^3 to 190 kg/m^3, and the upper limiting value ranges from 400 kg/m^3 to 600 kg/m^3. The latter value is valid for wet climates.

Figure A.1 shows a comparison of Formulae (A.1), (A.2), (A.3), (A.5), and (A.6) for snow density.[14]

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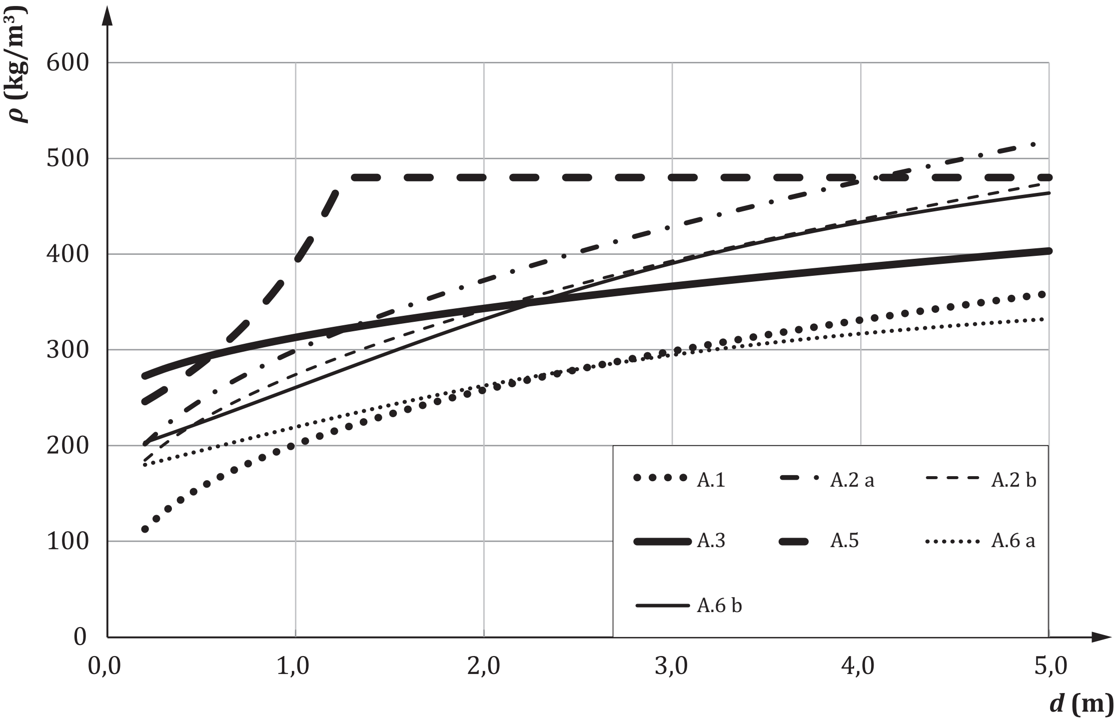

NOTE 1 For Formula (A.2), two alternatives are shown: a) average temperature T = −10 °C and average wind speed v = 4 m/s and b) average temperature T = −20 °C and average wind speed v = 4 m/s.

NOTE 2 For Formula (A.6): a) dry climate with surface density 170 kg/m^3 and upper limit density 400 kg/m^3, b) wet climate with surface density 190 kg/m^3 and upper limit density 600 kg/m^3.

Figure A.1 — Snow density, *ρ*, as a function of snow depth, *d*, according to Formulae (A.1), (A.2), (A.3), (A.5), and (A.6)

A.2.3 Snow intensities for short periods of time

For roofs with high values of heat loss, the snow fall intensity for short periods of time, 24 h or even shorter, can be of particular interest of design.

Normally, only recordings from various kinds of rain gauges can be obtained for this purpose. Such data on snow fall should never be used without corrections. The data shall be corrected for errors caused by wind effects at the gauge. Recommendations on such adjustments of the data, based on observations in Nordic countries, are available in Reference [15].

A.2.4 Rain on snow surcharge load

For locations where $0 < s_0 < 1$ kN/m^2, all roofs with slopes less than W/15,2 (in degrees) shall have 0,25 kN/m^2 rain-on-snow surcharge. This rain-on-snow-augmented design load applies only to the basic load case and need not be used in combination with drift, sliding, unbalanced, or partial loads.

NOTE Formulation from ASCE 7–10.

A.2.5 Climate change

When developing national or regional maps for ground snow loads, it is important to note that confined ensembles of annual extremes or peaks over a specific threshold can contain random positive or negative trends. The evaluation of possible climate change effects has to consider this randomness. Climate change scenarios can provide information on the basic shape of trends which should be considered in the analysis.

A.3 Statistical treatment of basic data

When applying statistical methods to basic snow measurement data, it should generally be noted that the regional significance of such data is highly dependent on the method of observation and the sheltering of the observation area. Whether or not a meteorological station typifies a region shall therefore be carefully considered in snow load calculations.

A.3.1 Statistical distributions

For snow climates with a permanent snow cover over the complete winter season in every winter, the annual maximum snow loads provide the appropriate basis for extreme value statistics. For those snow climates which have more than one independent period of permanent snow cover over the winter season, the statistical stability of the estimated parameters can be increased by using peaks over a specific threshold. Since confined ensembles inevitably contain random information, it is extremely difficult to identify the “true” probability distribution and the corresponding “true” parameters. Therefore, it is recommended to use the Type I extreme value distribution for the annual non-exceedance probabilities. For snow climates not having snow every year, the fitting of data should only use non-zero snow load amplitudes. Special care has to be taken if the observations include unusual large values in terms of outliers.

A.3.2 Possible climatic dependence in choice of distribution

Research indicates that the best fit of local data to the Lognormal or the Type 1 distribution is governed by certain climatic conditions of the region.[4]

If detailed analyses comparing different distributions are not available, it is recommended that in regions with an annual extreme snow load resulting from accumulation during a long part of the winter season, the Type 1 should be selected. In other regions with extreme load as a result of only one, or a few, snowfalls, the Lognormal distribution applies.

The conservatism of the two distributions depends on the magnitude of the coefficient of variation, i.e. for low values, Type 1 is more conservative, and for high values, Lognormal is most conservative when calculating long return period loads.

The standard error of estimate for the return period considered can be used in comparing different parameter estimation methods.

Often the return period considered is greater than the number of maximum snow load recordings available. The degree of goodness of fit for a theoretical distribution to the sample data cannot always be relied upon for extrapolated values corresponding to long return periods. It is recommended also to consider climatic conditions in the decision making.

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Annex B
(normative)

Snow load distribution on selected types of roof

B.1 Simple pitched roofs

Snow load distribution for simple pitched roofs is described in Figure B.1. For asymmetrical simple pitched roofs, each side of the roof shall be treated as one-half of a corresponding symmetrical roof.

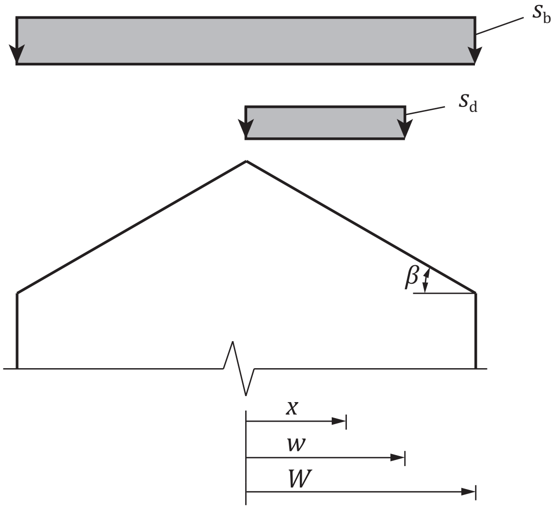

Figure B.1 — Snow load distribution on simple pitched roof

Basic load case:

— Windward side: $s = s_b$

— Leeward side: $s = s_b$

Drifted load case:

— Windward side: $s = 0$

— Leeward side: $s = s_b + s_d$

Basic load part:

$$s_b = 0{,}8 s_0 C_e C_t \mu_b \tag{B.1}$$

Drifted load part:

$$s_d = s_0 \mu_d \mu_b \tag{B.2}$$

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$$\mu_d = \left(0,12\,\frac{\beta}{42,5} + 0,05\right)\left(-5C_e + 6\right) \tag{B.3}$$

where

$$5^\circ < \beta < 60^\circ$$

$$w = \begin{cases} W & W \le 20\,\text{m} \\ 20\,\text{m} & W > 20\,\text{m} \end{cases}$$

$$s_d = \begin{cases} s_0 \mu_d \mu_b & x \le w \\ 0 & x > w \end{cases}$$

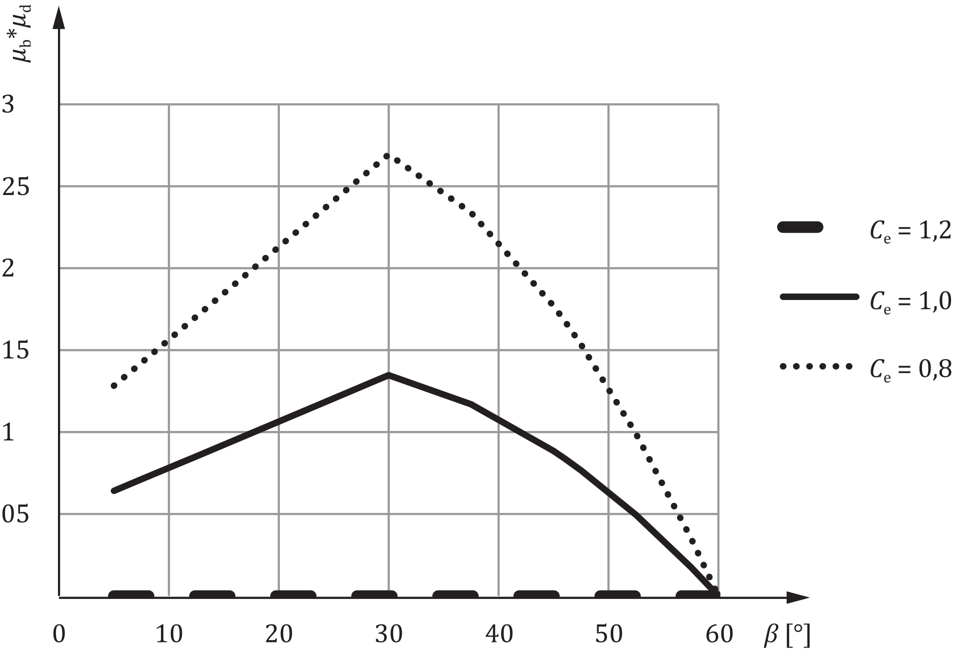

Figure B.2 — $\mu_b\mu_d$ as a function of roof slope β in case of C_m = 1,0

B.2 Simple flat and monopitched roofs

For this roof shape only the basic roof snow load, s_b, need to be considered.

$$s = s_b$$

$$s_b = 0,8 s_0 C_e C_t \mu_b \tag{B.4}$$

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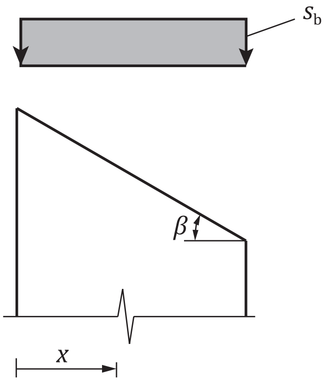

Figure B.3 — Snow load distribution on monopitched roof

B.3 Multipitched roofs

For a simple pitched roof, one expects snow to slide off the roof when the slope is steep. However, for a multipitched roof, the snow slides and results in a redistribution of load on the same roof. This is covered by separate basic and sliding load cases as shown in Figure B.4. The sliding load case accounts for the potential for sliding snow and possible drifted snow. It is recommended to set ρ = 300 kg/m^3. External slopes of multipitched roofs is according to B.1.

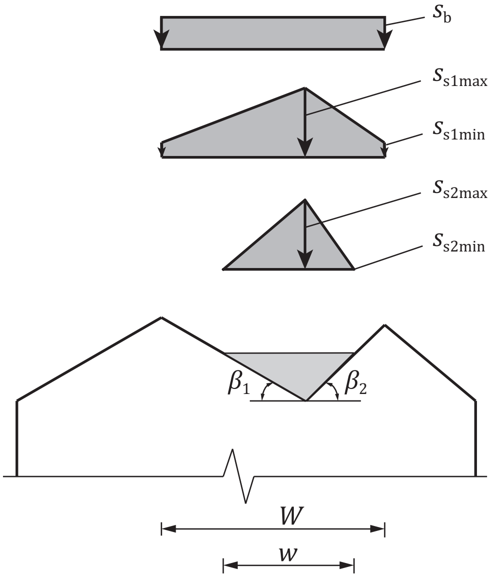

Figure B.4 — Snow load distribution — multipitched roof

Basic load case:

$$s_b = 0{,}8 s_0 C_e C_t \mu_b \tag{B.5}$$

Sliding load case 1:

$$h < \left[\frac{0{,}8 s_0 C_e C_t W}{\rho\left(\tan\left(90\text{-}\beta_1\right) + \tan\left(90\text{-}\beta_2\right)\right)} \right]^{1/2} \tag{B.6}$$

$$d = \frac{0{,}4 s_0 C_e C_t}{\rho} + \frac{h}{2} \tag{B.7}$$

$$s_{s1\text{min}} = 2\rho\left(\frac{0{,}4 s_0 C_e C_t}{\rho} - \frac{h}{2}\right) \tag{B.8}$$

$$s_{s1\text{max}} = 2\rho d \tag{B.9}$$

Sliding load case 2:

$$h \geq \left[\frac{0{,}8 s_0 C_e C_t W}{\rho\left(\tan\left(90\text{-}\beta_1\right) + \tan\left(90\text{-}\beta_2\right)\right)}\right]^{1/2} \tag{B.10}$$

$$d = \left[\frac{0{,}8 s_0 C_e C_t W}{\rho\left(\tan\left(90\text{-}\beta_1\right) + \tan\left(90\text{-}\beta_2\right)\right)}\right]^{1/2} \tag{B.11}$$

$$s_{s2\text{min}} = 0 \tag{B.12}$$

$$s_{s2\text{max}} = 2\rho d \tag{B.13}$$

B.4 Simple curved roofs, pointed arches, and domes

For curved and pointed arch roofs with $h/b \geq 0{,}05$, the basic load and drifted load distributions are determined according to Figure B.5. For $h/b < 0{,}05$, the snow loads are determined according to B.2. Pointed arches with $\beta \geq 5°$ at the ridge line ($x = 0$) should be treated as pitched roofs, see B.1.

For domes of circular plan form, the basic load is that in Figure B.6 applied in an axially symmetric manner. The drifted load along the central axis parallel to the wind is the same as for an arch and μ_d varies as shown in Figure B.5 with distance y from this axis.

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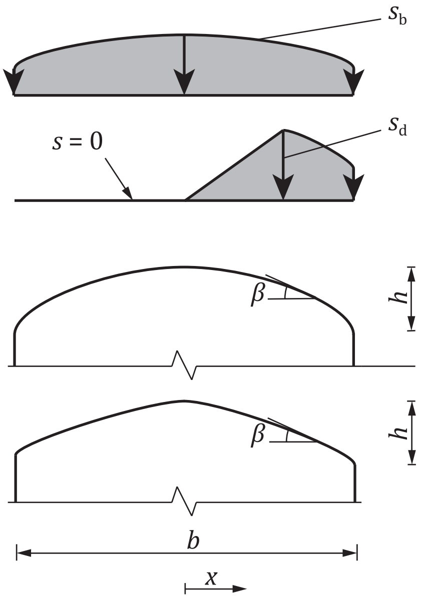


Figure B.5 — Basic and drifted snow load distribution on curved roofs

Basic load case:

$$s_b = 0{,}8 s_0 C_e C_t \mu_b \tag{B.14}$$

Drifted load case:

$$s_b = 0 \tag{B.15}$$

$$s_d = s_0 \mu_b \mu_d(x) \tag{B.16}$$

$$\left.\begin{array}{ll} \mu_d = 2x/x_{30} & x \le x_{30} \\ \mu_d = 2 & x \ge x_{30} \end{array}\right\} \frac{h}{b} > 0{,}12 \tag{B.17}$$

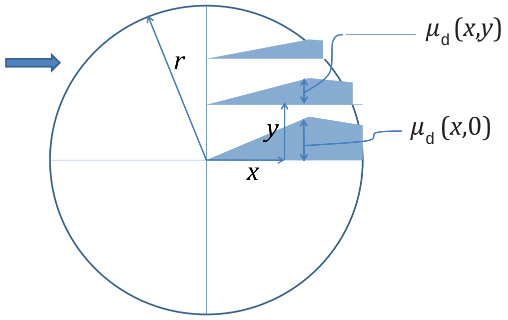
$$\left.\begin{array}{ll} \mu_d = 16{,}7(x/x_{30})(h/b) & x \le x_{30} \\ \mu_d = 16{,}7(h/b) & x \ge x_{30} \end{array}\right\} 0{,}05 \le \frac{h}{b} \le 0{,}12 \tag{B.18}$$

where

$$x_{30} \equiv x \text{ at } \beta = 30^\circ \text{ and } x_{30} \le b/2$$

Drift load coefficient on domes (see Figure B.6):

$$\mu_d(x,y) = \mu_d(x,0)\left(1 - \frac{y}{r}\right) \tag{B.19}$$



NOTE The arrow indicates wind direction.

Figure B.6 — Plan view of drift load coefficient on dome

B.5 Multilevel roofs (lower roofs with slope β_l)

For lower roofs, Figure B.7, the basic part of the load is determined from

$$s_b = 0{,}8 s_0 C_e C_t \mu_b \tag{B.20}$$

$$C_e \geq 1{,}0 \text{ for } x < 10h \tag{B.21}$$

where

x is the horizontal distance from the step;

h is the height of step.

The drift part of the snow load, $s_d(x)$, is determined as the most severe of three possible cases, illustrated in Figure B.8:

Case a: Step faces in the downwind direction and snow drifts off the upper roof into the sheltered zone at the step.

Case b: Step faces into the wind and snow drifts over the lower roof into the step region.

Case c: End region of a step that faces in the downwind direction where snow drifts into the sheltered step region from around the corner.

$s_d(x)$ is a triangular function of x, being a maximum at x = 0 and decreases linearly to zero at the tail of the drift, at $x = l_d$. Where the tail of the drift would extend beyond the edge of the lower roof, the drift is truncated to a trapezoidal form.

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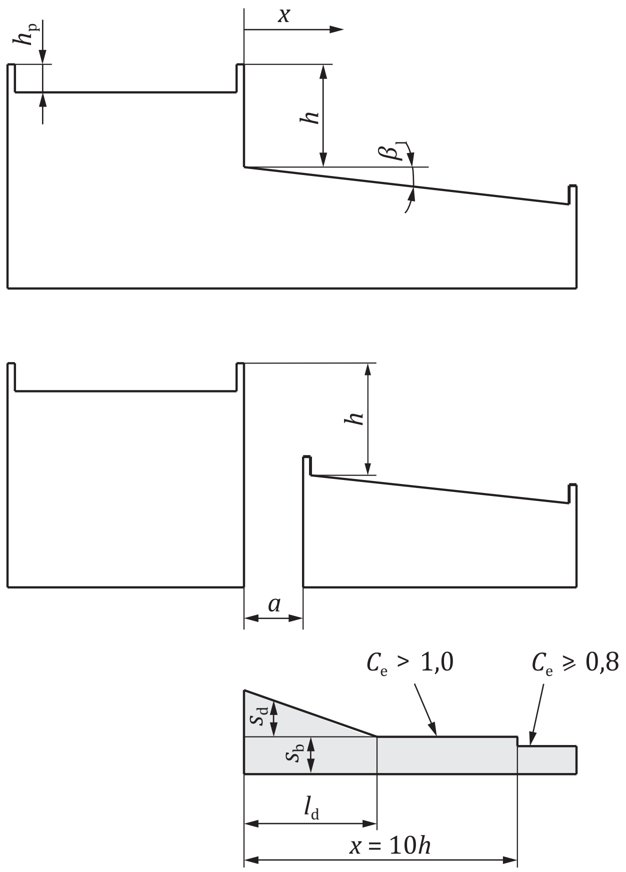

Figure B.7 — Snow distribution and snow load coefficients for lower level adjacent roofs

The length of the drift is as follows:

$$l_d = 5\frac{s_d(0)}{\rho g} \tag{B.22}$$

The maximum of the drift load is given by the following formulae:

$$s_d(0) = s_0 \mu_b \mu_d(0) \tag{B.23}$$

$$\mu_d(0) = 0{,}35\xi\sqrt{\frac{\left(l_c - 5h_p'\right)\rho g}{s_0}} \tag{B.24}$$

$$0 < \mu_d \le \frac{\xi \rho g h - s_0}{s_0 \mu_b} \tag{B.25}$$

$$\mu_d \le \frac{4\xi}{C_e^{2,5}} \tag{B.26}$$

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$$h_p^{'} = h_p - \frac{s_{bs}}{\rho g} \tag{B.27}$$

where

h_p is the height of the roof perimeter parapet of the source area.

s_{bs} is the basic snow load of the source area.

ρ is the snow density.

g is the acceleration due to gravity.

h_p shall be taken as zero unless all the roof edges of the source area have parapets.

It is recommended to set ρ = 300 kg/m^3. Alternatively, see Annex A for density formulae.

Table B.1 — Coefficients C_e and μ_d

x	C_e	μ_d
0	$C_e \geq 1{,}0$	$\mu_d(0)$
$0 < x \leq l_d$	$C_e \geq 1{,}0$	$\mu_d(0)(1 - \frac{x}{l_d})$
$l_d < x \leq 10h$	$C_e \geq 1{,}0$	0
$x > 10h$	$C_e \geq 0{,}8$	0

The appropriate values of the parameter ξ for each of cases a), b), and c) are tabulated in Table B.2. l_{cs} is the representative length of the appropriate source area for snow drifting for each of the three cases shown in Figure B.8.

$$l_{cs} = 2W - \frac{W^2}{L} \tag{B.28}$$

where

L is the longer dimension of the source area.

If the upper roof is pitched, the dimensions W and L are based on the overall dimensions of the upper roof for case a).

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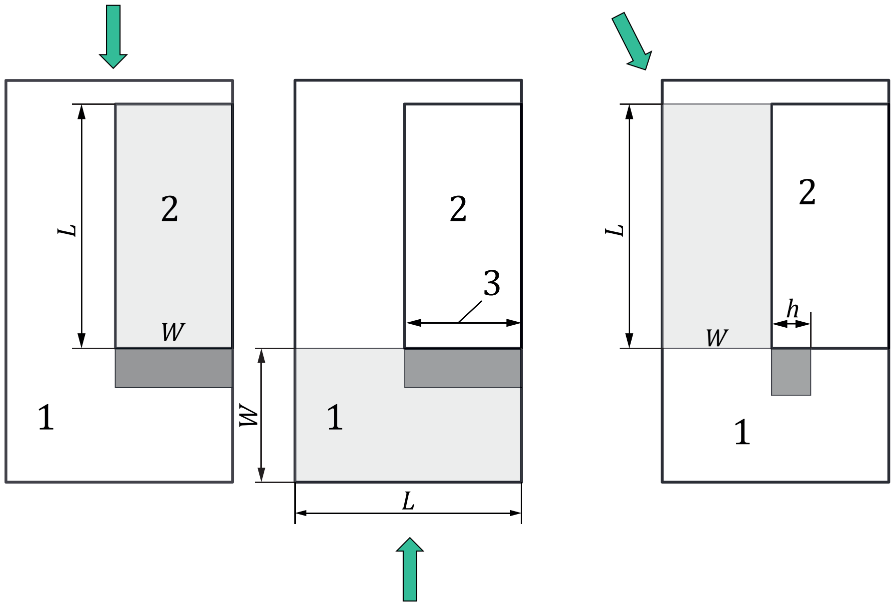


(a) (b) (c)

Key

1	lower roof
2	upper roof
3	length of step
□	source area for snow in drift
■	snow drift
➡	wind direction

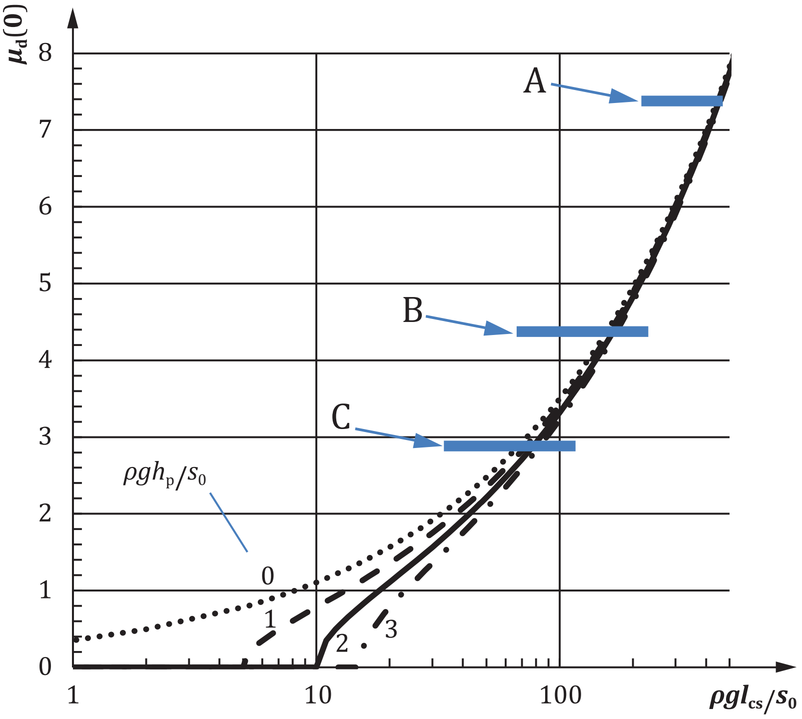
NOTE The directions of the dimensions *L* and *W* shown in the diagrams will interchange depending on which is larger.

Figure B.8 — Snowdrift cases and parameters for lower level roofs

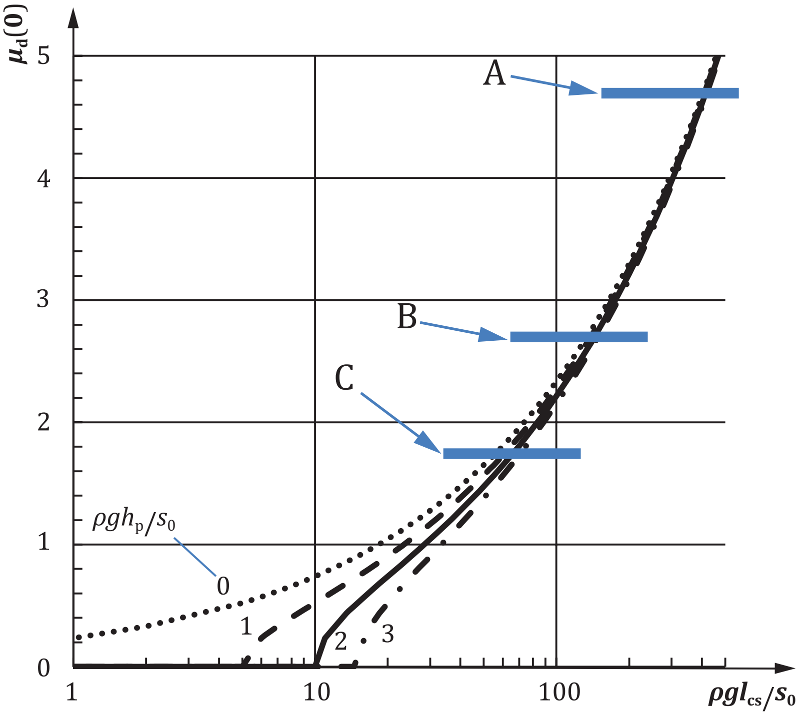
Table B.2 — Values of the parameter ξ for each of cases a), b), and c)

Parameter	Case a)	Case b)	Case c)
ξ	1,0	0,67	0,67
h_p	Parapet height of upper roof	Parapet height of lower roof	Parapet height of lower roof
l_{cs}	*W* and *L* taken as the shorter and longer dimensions, respectively, of the upper roof	*W* and *L* taken as the shorter and longer dimensions, respectively, of the source area on the lower roof for upwind-facing step	*W* and *L* taken as the shorter and longer dimensions, respectively, of the source area on the lower roof for downwind-facing step

Figure B.9 shows $\mu_d(0)$ plotted as a function of $\rho g l_{cs}/s_0$ for cases a) and b) for several values of $\rho g h_p/s_0$. For case c) the plot for case b) with $\rho g h_p/s_0 = 0$ applies.



(a)



(b)

Key

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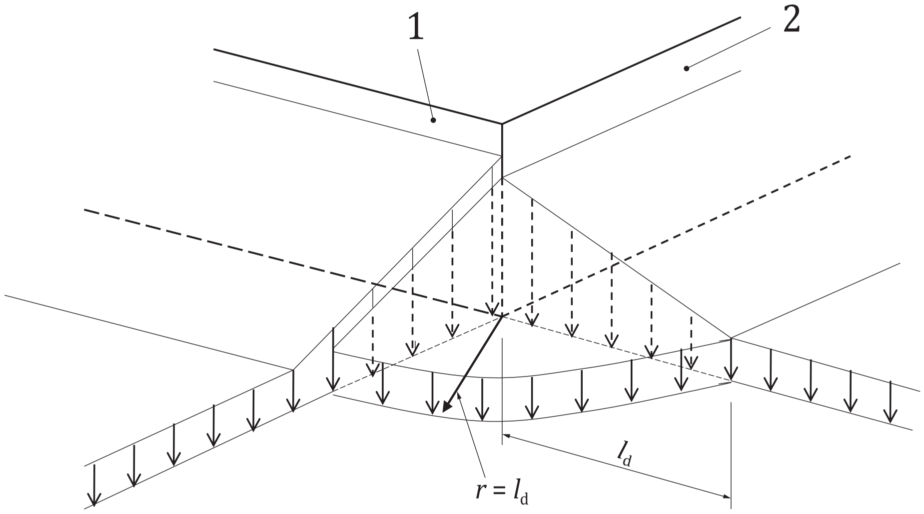
A upper limit for $C_e = 0{,}8$
B upper limit for $C_e = 1{,}0$
C upper limit for $C_e = 1{,}2$

NOTE For case (c), the plot for case (b) applies with $\rho g h_p / s_0 = 0$.

Figure B.9 — Variation of $\mu_d(0)$ with $\rho g l_{cs}/s_0$ for cases a) and b)

At an outside corner where two step faces meet (see Figure B.10) the triangular drift load from the more lightly loaded step region shall be assumed to extend radially from the corner. At an inside corner the drift loads calculated for each step face shall be applied as far as the bisector of the corner angle, as shown in Figure B.11.

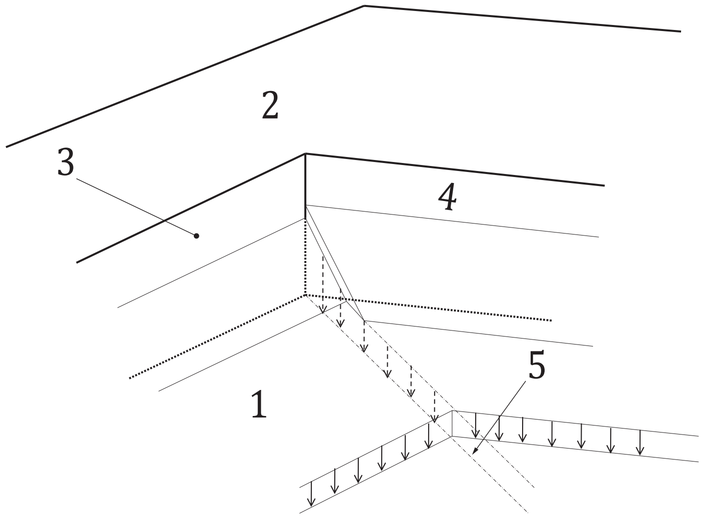


Key

1 step face with higher $\mu_d(0)$
2 step face with lower μ_d (0)

NOTE Radius of drift surcharge, r, is equal to l_d.

Figure B.10 — Drift loading at outside corner



Key

1 lower roof
2 upper roof
3 step face 1
4 step face 2
5 bisector of angle between two step faces

Figure B.11 — Drift loading at inside corner

When a building roof is closer than 5 m to a higher level roof of an adjacent building, it shall be designed for the tail portion of the triangular drift load, as shown in Figure B.7.

If the upper roof is sloped greater than 5° and has no edge parapet or snow fence to prevent sliding, the additional sliding snow load, $s_\mathrm{s}(x)$, on the lower roof shall be assumed to take a triangular form (see Figure B.11) and is calculated as follows:

$$s_\mathrm{s}(x)=s_0\mu_\mathrm{b}\mu_\mathrm{s}(x) \tag{B.29}$$

$$\mu_\mathrm{s}(0)=\frac{h_\mathrm{u}}{l_\mathrm{s}\tan\beta_\mathrm{u}} \tag{B.30}$$

$$\mu_\mathrm{s}(0)\le\frac{\rho gh}{s_0\mu_\mathrm{b}}-\mu_\mathrm{d}(0) \tag{B.31}$$

$$l_\mathrm{s}=2h_\mathrm{u}\cos\beta_\mathrm{u}\left(\sqrt{\frac{h}{h_\mathrm{u}}+p^2}-p\right) \tag{B.32}$$

where

$$p=\sin\beta_\mathrm{u}-\tan\beta_\mathrm{l}\cos\beta_\mathrm{u} \tag{B.33}$$

$$h<3s_0/\rho g \quad \text{for } \mu_\mathrm{s}(0)=1 \tag{B.34}$$

$$\mu_\mathrm{s}(x)=\mu_\mathrm{s}(0)\left(1-\frac{x}{l_\mathrm{s}}\right) \text{for } 0\le x\le l_\mathrm{s} \tag{B.35}$$

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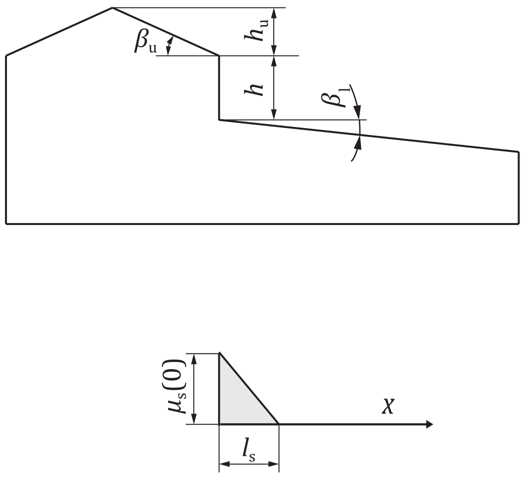

Figure B.12 — Sliding snow load factor

The sliding snow load should be considered as simultaneous with the basic load and 50 % of the drift load. Note that the sliding snow load defined above does not include the effect of the impact of the snow as it lands on the lower roof.

B.6 Additional drift load and sliding load on ground or on lower level roof, acting against the upper arch or pitched roof

A lower level roof should be checked for the sliding load as an alternative load case as compared with the load cases of B.5. Impact effects shall be considered (see Figure B.13).

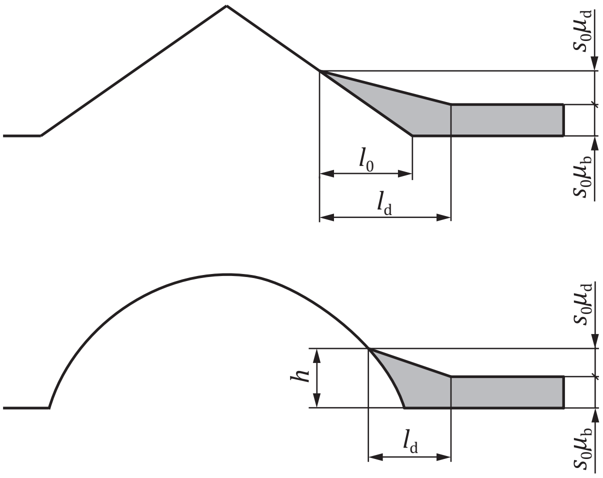

Figure B.13 — Additional drift load and sliding load acting on upper arch or pitched roof

$$s = s_0(\mu_d + \mu_b) \tag{B.36}$$

$$l_d = \frac{6s_0}{\rho g} \tag{B.37}$$

$$l_0 = \frac{(\mu_b + \mu_d)s_0}{\rho g \tan\beta} \tag{B.38}$$

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$$h = \frac{(\mu_b + \mu_d) s_0}{\rho g} \tag{B.39}$$

$$\mu_b = 1{,}0 \tag{B.40}$$

$$\mu_d = 3{,}0 \tag{B.41}$$

where

β is the roof angle;

ρ is the snow density;

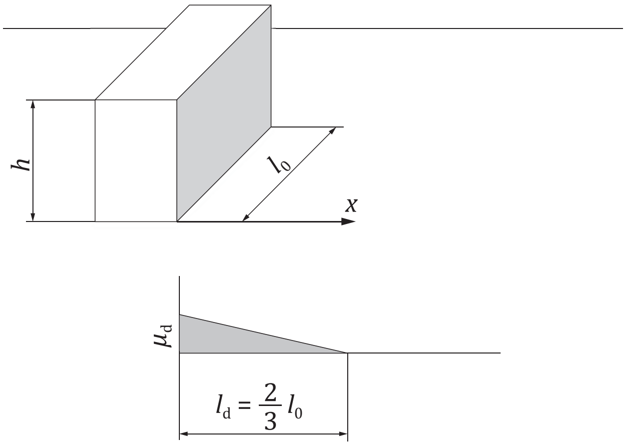
g is the acceleration due to gravity.

B.7 Roofs with local obstructions

The basic part of the load, s_b, for roofs with local obstructions, such as elevator, air-conditioning and fan housings, small penthouses, and wide chimneys, is determined in the same way as for lower roofs (see B.5). The drift load, s_d *(x)*, in areas adjacent to the obstructions is determined as a triangular function of distance x from the obstruction, being a maximum at x = 0 and decreasing linearly to zero at the tail of the drift, at $x = l_d$.

$$l_d = \frac{2}{3} l_0 \tag{B.42}$$

where



l_0 is the longest horizontal dimension of the obstruction (see Figure B.14).

Figure B.14 — Drift load coefficient for local obstructions

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$$\mu_{\mathrm{d}}(x) = \mu_{\mathrm{d}}(0)\left(1 - \frac{x}{l_{\mathrm{d}}}\right) \tag{B.43}$$

The drift load shall extend from all sides of the obstruction and in a radial manner from the corners (see Figure B.10). Drift loads need not be considered when $l_0 < 3$ m. Note that, as the horizontal dimension l_0 of the obstruction increases, the drift load from Formula (B.43) can surpass that for a lower level roof as determined in B.5. At this point it will be preferable to treat the projection or obstruction as an upper level roof and use B.5 to determine the drift loads adjacent to it.

Annex C
(informative)

Determination of the exposure coefficient for small roofs

C.1 General

The exposure coefficient for small roofs, C_{e0}, is a general coefficient reflecting the effect of snow removal at a roof location independent of the roof shape. The definition of C_{e0} is given in 3.8.

In this Annex, C_{e0} is determined as described in C.4, after the characteristics of the regional wind category, temperature climate and terrain roughness category have been considered. These characteristics are outlined under C.2 and C.3, respectively.

Wind during a snow fall can cause a reduction in the uniformly distributed snow load on a roof as compared to the snow load on the ground. However, the local maximum of a non-uniform snow load caused by wind can be considerably higher than the ground load.

Strong wind, in the absence of snow fall, can also cause a uniform decrease or a redistribution of existing snow on the roof. This is highly dependent on the air temperature and the temperature history of the snow layer. Beneath a threshold wind speed, no transport occurs. This threshold wind speed increases with the air temperature, as the cohesion forces between snow particles are observed to increase with the temperature.

The above described effects are well known both from observations and analytical studies. Important physical studies in this field are described in Reference [16] and analyses of observational projects concerning snow loads on buildings have been carried out by several researchers (References [17] to [19]). Water flume and wind tunnel studies of drifting are described in References [20], [21],[22], and [23]. Mixed wind tunnel and computational studies are described in References [24] and [25].

Because C_{e0} is highly sensitive to the local wind and temperature regime, the building shape, and the configuration of surrounding obstacles such as nearby buildings, trees, and topography, there is significant uncertainty in its determination unless special detailed model and computational studies are undertaken for the specific building to take all these factors into account. Therefore, the values of C_{e0} given by the analytical methods of this Annex should be regarded as nominal. The range of C_{e0} in this Annex is from 0,8 to 1,2. The set of rounded values C_{e0} = 1,2, 1,0, and 0,8 are used for the various climatic regimes as a consequence of the limited accuracy in the practical determination of exposure coefficient by simple methods.

For very large roofs, it is expected that C_e will approach 1,25, regardless of the wind and temperature regime, since at a sufficiently large size the roof becomes no different from the ground from a snow drifting point of view. Therefore, the calculation of C_e in B.5 assumes a basic value of $C_e = C_{e0}$ for small roofs, with dimensions less than about 50 m, and then increases C_e as the roof size increases so that it approaches 1,25 asymptotically (see 6.1).

C.2 Winter wind exposure

The mean frequency of wind speed above a threshold value (5 m/s) is used rather than the monthly mean of wind speed as the main parameter for drifting. This is due to the fact that the effectiveness of drifting of both falling and old snow depends on the occurrence of relatively strong wind during snow falls, and snow falls are often accompanied by strong winds.

The normal terrain is suburban, urban or wooded areas. Sheltered terrain is for sites with completely sheltered by other higher buildings or trees in all directions.

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The winter wind climates given in Table C.1 should be considered, normally by using the average values of the three coldest months of the year.

Table C.1 — Winter wind categories

Average number of monthly days, N, with an occurrence of at least one 10 min averaged mean wind speed exceeding 5 m/s	Terrain roughness category		
	Open	**Normal**	**Sheltered**
$N < 1$	II	I	I
$1 \leq N \leq 10$	III	II	I
$10 < N$	III	III	II

Data on the wind frequency are available for meteorological stations recording the wind speed in open terrain 10 m above ground level.

C.3 Winter temperature climate

In regions with a relatively warm winter climate, only drifting of falling snow is usually possible. In such regions snow falls are accompanied by the lowest temperature of the winter. This is normally not the case in cold regions. A common variable reflecting the temperature during snow falls for different climates is therefore difficult to obtain. For practical reasons, the parameter used in this Annex is the lowest monthly mean temperature of the year. Note that this parameter has lower values than the winter mean temperature being referred to in C.5.

The monthly mean temperatures, θ, for the coldest month of the year given in Table C.2 should be considered.

Table C.2 — Winter temperature categories

Monthly mean temperature, θ, for the coldest month of the year °C	Winter temperature category
$\theta > 2,5$	A
$-2,5 \leq \theta \leq 2,5$	B
$\theta < -2,5$	C

C.4 Exposure coefficient

When winter wind and temperature categories have been determined from Tables C.1 and C.2, respectively, and adjusted due to local topography, the exposure coefficient can be determined from Table C.3.

Table C.3 — Exposure coefficient for small roofs, C_{e0}

Winter temperature category	Winter wind category		
	I	**II**	**III**
A	1,2	1,1	1,0
B	1,1	1,0	0,9
C	1,0	0,9	0,8

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C.5 Alternative determination of the exposure coefficient

In Russia[17], formulae for the exposure coefficient for different wind regimes have been derived for regions having mean winter temperature (average temperature for the three coldest months of the year) less than −5 °C (winter temperature category C). Based on that system, the expressions for C_{e0} replacing the values in Table C.3 would be as follows:

$$C_{e0} = 1{,}0 \qquad \text{for } v \le 2 \text{ m/s}; \tag{C.1}$$

$$C_{e0} = 1{,}2 - 0{,}1v \text{ for } 2 \text{ m/s} < v < 8 \text{ m/s}; \tag{C.2}$$

$$C_{e0} = 0{,}4 \qquad \text{for } v \ge 8 \text{ m/s}. \tag{C.3}$$

where

v is the mean wind speed (m/s) at 10 m above ground level for the snow fall season

The calculation of C_{e0} is then completed as shown in C.4.

NOTE The exposure coefficients in C.4 and Table C.3 range from 0,8 to 1,2. The above Russian approach has exposure coefficients that range from 0,4 to 1,0. Hence, the Russian coefficients would need to be modified for use with this International Standard.

C.6 Climates not having snow every year

For climates not having snow every year, a more consistent approach to the analysis of the winter wind and temperature climate uses only those situations where a considerable snow load on the ground has occurred. Finally, wind and temperature conditions are required for the probability level of the design snow scenario.

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Annex D
(informative)

Determination of thermal coefficient

This Annex gives values for the thermal coefficient for reduction of snow load on glass[2] roofs caused by heat flow through the roof.

The thermal coefficient, C_t, reduces the snow load caused by melting and is given by Formula (D.1), which was developed assuming characteristic snow load on ground $s_0 \geq 1{,}5$ kN/m^2.

$$C_t = 1 - 0{,}054 \left(\frac{s_0}{3{,}5} \right)^{0{,}25} f\left(U_0, \theta\right) \tag{D.1}$$

where

$$f\left(U_0, \theta\right) = \begin{cases} 0 & U_0 < 1{,}0 \\ (\theta - 5)\left[\sin\left(0{,}4U_0 - 0{,}1\right)\right]^{0{,}75} & 1{,}0 \leq U_0 \leq 4{,}5 \text{ and } 5 \leq \theta \leq 18 \\ \theta - 5 & U_0 > 4{,}5 \text{ and } 5 \leq \theta \leq 18 \end{cases} \tag{D.2}$$

U_0 is the thermal transmittance assuming the external thermal surface resistance is equal to zero [W/(m^{2}K)];

s_0 is the characteristic snow load on the ground ($s_0 \geq 1{,}5$ kN/m^2);

θ is the lowest expected internal temperature during the winter (°C).

If $\theta < 5$ °C, $\theta = 5$ °C applies. If $\theta > 18$ °C, $\theta = 18$ °C applies in Formula (D.2).

For significantly lower values of s_0, especially in combination with low roof angles, $C_t = 1{,}0$ should apply. The unit for the argument of the sine function is radians (if degrees are preferred, the argument should be multiplied by a constant 57,3). The parameter U_0 represents the glass-covered[2] area only. If the thermal transmittance of the roof, U, is based on a different value of the external thermal surface resistance, $R_e > 0$, U is transformed to U_0 by Formula (D.3):

$$U_0 = \frac{U}{1 - UR_e} \tag{D.3}$$

where

U is the thermal transmittance of the roof [W/(m^{2}K)];

R_e is the external surface resistance for U (m^{2}K/W).

Values of C_t are given in Figures D.1, D.2, and D.3.

If a calculated C_t value is less than unity, a thorough check and possible adjustments shall be undertaken according to the following specifications:

- if the monthly mean temperature for the coldest month of the year is below –8 °C, C_t shall be increased by the factor 1,2; however, $C_t \leq 1{,}0$;

---

[2] This may also apply to other materials.

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- if the calculated additional local maximum load due to drifting exceeds 30 % of the mean snow load on the roof surface excluding drifting, the exceeding part of the load shall not be reduced by the thermal coefficient C_t;
- if sliding onto the roof surface is possible, C_t = 1,0 applies.

A check that melting water can be drained from the roof surface without risk of icing shall always be carried out.

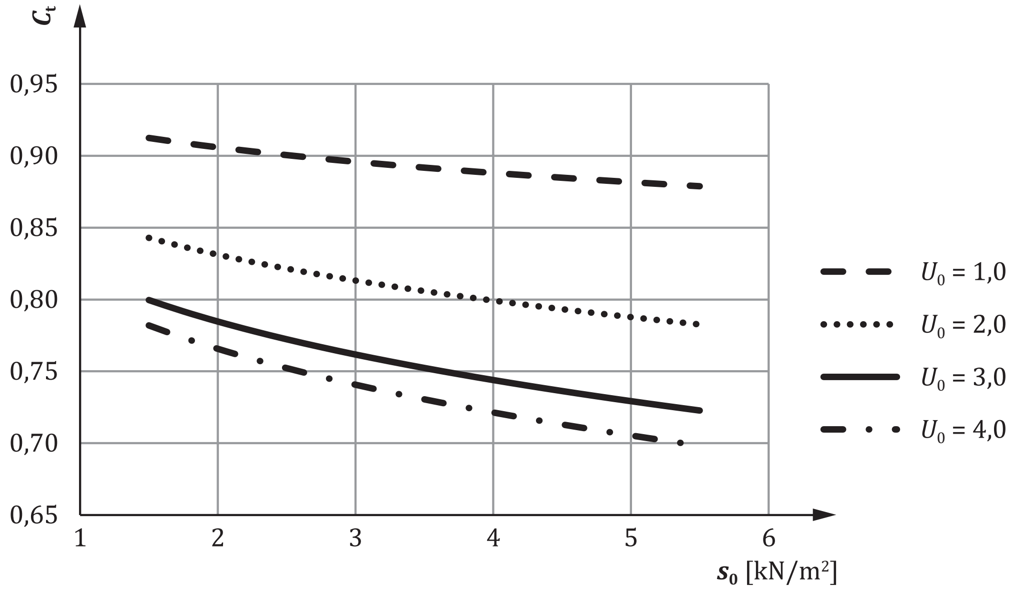

Figure D.1 — Thermal coefficient C_t for θ = 10 °C

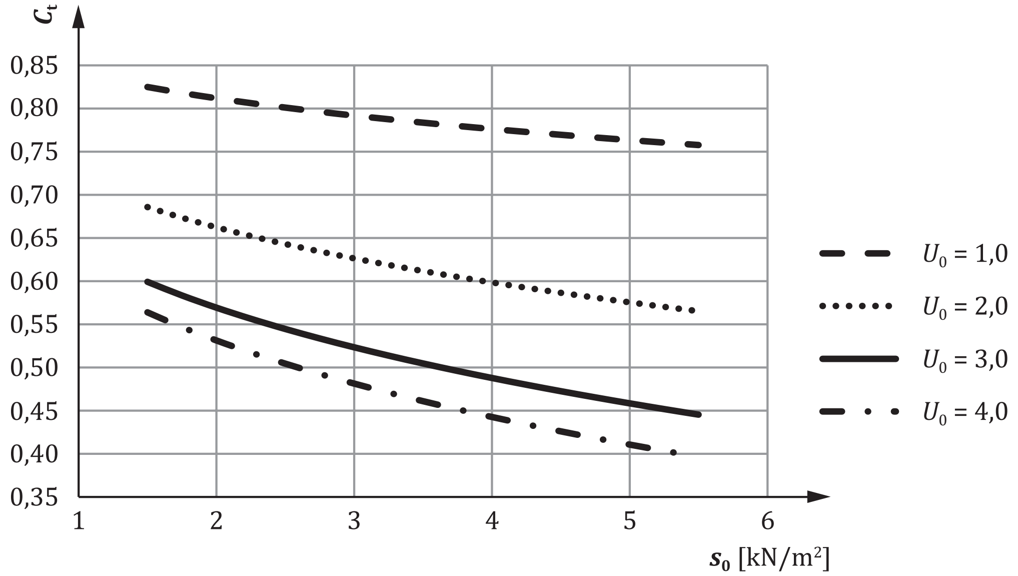

Figure D.2 — Thermal coefficient C_t for θ = 15 °C

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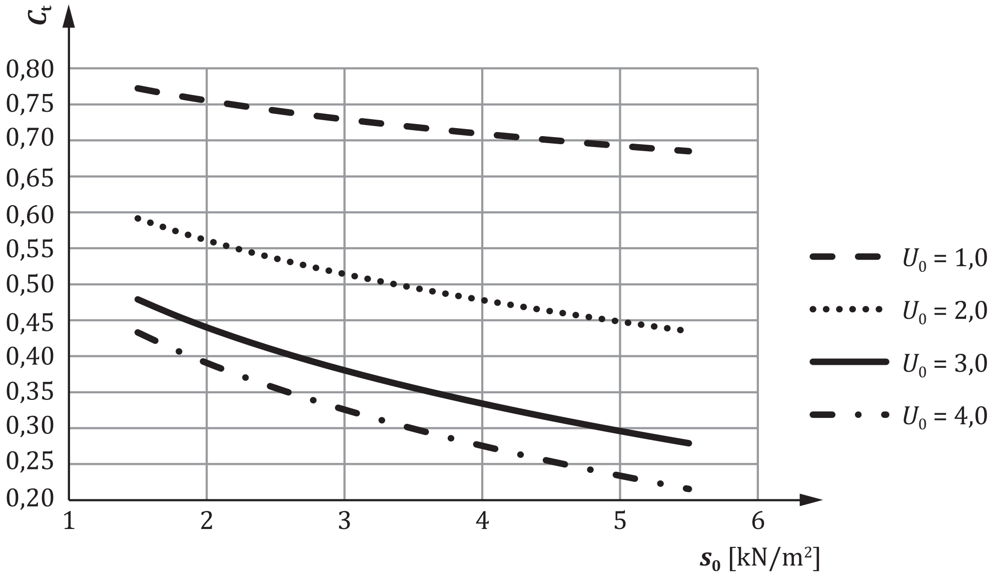

Figure D.3 — Thermal coefficient C_t for θ = 18 °C

Annex E
(informative)

Roof snow retention devices

E.1 General

Forces on snow fences associated with the snow load on a sloped roof are mainly the component of the mass of the snow along the roof surface, the frictional forces, and the compression force at the eave. Adhesive or tensile forces are important when the snow is frozen to the roof surface material, or when the snow is anchored to the ridge or any obstructions on the roof surface.

Friction and adhesion are the primary resisting forces. These forces will be decreased by a thin layer of water on the roof surface from melting snow or rain.

E.2 Static load

Snow fences can in most cases be designed for static loads assuming zero adhesion and tension forces. Under these assumptions, the snow fence can be designed for the static load, F_0, parallel to the slope of the roof, defined by Formula (E.1):

$$F_0 = s_{b0} l_1 \left(\sin\beta - k_1 \cos\beta \right) \tag{E.1}$$

where

s_{b0} is the basic snow load according to B.1 with roof slope $\beta = 0$;

l_1 is the horizontal projection of the distance along the roof from the snow fence to the top of the roof;

k_1 is the coefficient of friction;

β is the slope of the roof above the snow fence.

The static load, F_0, can in most cases be assumed to act on the fence at a vertical height, h_1, as given by Formula (E.2), above the roof surface:

$$h_1 = 0{,}5 s_0 / \left(\rho g \right) \tag{E.2}$$

where

ρ is the density of the snow on the ground;

g is the acceleration due to gravity.

It is recommended to set $\rho = 300\ \text{kg/m}^3$.

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E.3 Height of snow fence

Sufficient height of the snow fence to prevent sliding is mainly dependent on the snow depth on the roof, the roof angle, and the friction between separate layers of snow. If the friction is relatively low, sliding from a top layer is possible for roof angles above approximately 25°.

In this Annex, the design value of snow fence height, h_2, is given by Formula (E.3). This height is considered to be conservative due to an assumption of low friction between separated snow layers.

$$h_2 = \begin{cases} (\mu s_0 / \rho g)\cos\beta\left(1{,}1 - (30-\beta)/30\right) & 0^\circ < \beta < 30^\circ \\ 1{,}1 s_0 / \rho g \cos\beta & \beta > 30^\circ \end{cases} \qquad \text{(E.3)}$$

It is recommended that $\rho = 300\ \mathrm{kg/m^3}$.

E.4 Dynamic load

The dynamic force on a snow fence from sliding snow can be theoretically estimated by the use of a model based on a chain or a rope sliding along the roof surface with zero friction.

If this model is applied and l_2 is set equal to l_1 (see Figure E.1), the dynamic force, F_{dyn}, can be calculated from Formula (E.4):

$$F_{\mathrm{dyn}} = k_2 F_0 \qquad \text{(E.4)}$$

where

k_2 is a coefficient equal to 3,0;

F_0 is given by Formula (E.1).

When l_2 is of the order $0{,}5l_1$ to $0{,}8l_1$, and the snow layer cannot accelerate to a stop due to internal forces, it is recommended to set $k_2 = 1{,}75$ in Formula (E.4).

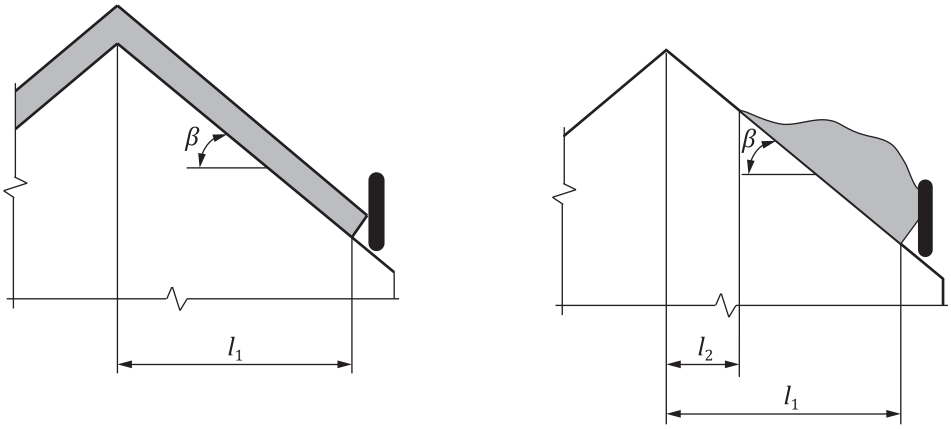

Figure E.1 — Parameters to be considered when determining dynamic forces on a snow fence

Annex F
(informative)

Snow loads on roof with snow control

F.1 General

When sufficiently reliable control device or method is used, snow load on the roof can be reduced using the following concept.

F.2 Snow load on roof with snow control

Snow load on the roof with snow control is given by Formula (F.1):

$$s = \mu_b s_n - s_c \tag{F.1}$$

where

μ_b is the basic load coefficient defined in 3.4;

s_n is the snow load on the ground with accumulation for n days (kN/m^2) defined in F.3.1;

s_c is the controlled snow load (kN/m^2) defined in F.4.

F.3 Ground snow load with accumulation for *n* days

F.3.1 Formula for ground snow load with accumulation for *n* days

When the roof snow is reliably controlled, snow load on the ground, s_n, is determined from Formula (F.2):

$$s_n = C_e d_n \rho_n g \tag{F.2}$$

where

C_e is the exposure coefficient that takes into account local topography;

d_n is the representative snow depth on the ground (m) when the snow load on the roof is controlled, as defined in F.3.2;

ρ_n is the equivalent density for ground snow with roof snow control; see A.2.2 if the equivalent density is not available;

g is the acceleration due to gravity.

F.3.2 Representative snow depth with accumulation for *n* days

Representative snow depth on the ground, d_n, is defined as the annual maximum value of snow accumulation for n days with a return period of certain years (100 years, for example), and is estimated from meteorological data of the ground snow depth observed for a certain period. n is typically corresponding with the duration of single event of snow duration of each building site.

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F.4 Controlled snow load

Controlled snow load, s_c, is generally determined after field research and experiments investigating the capacity of sliding or melting devices[26]. In other words, s_c is the differential between initial snow load expected when heavy snow fall starts and removed snow load by the device whose performance is guaranteed even during heavy snow fall. In the case of using melting devices, the length of evaluation period n (day) for snow accumulation is decided with the performance and reliability of the roof snow control system.

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Annex G
(informative)

Alternative methods to determine snow loads on roofs not covered by the prescriptive methods in this International Standard

The analytical snow load provisions in this International Standard and its annexes are based primarily on full-scale observations of snow accumulations on simple common shapes of roof, including allowances for the non-uniform loads that can arise due to drifting and sliding. For unusual roof shapes and surrounding conditions, for shapes not covered by this International Standard, and for large span roofs where snow loads significantly impact the balance between cost and safety, scale model studies in wind tunnels or water flumes and/or special computational studies are recommended.

The physical process of snow accumulation occurs due to precipitation with or without wind, redistribution of existing snow cover, and the combination of both. Snow removal occurs due to scouring by wind, melting, and sliding. The snow loads at any given instant depend on the preceding history of these processes in the hours, days, and weeks beforehand. The length of this history that is relevant will depend on the winter climate at the site. Where prolonged cold periods are experienced, the length of history that needs to be considered will be longer. Theoretical and physical models of these processes can be used to make predictions of snow loads. There are a range of types of snow with varying terminal velocities, angles of repose, and ability to be picked up by wind. The modelling methods selected should take into consideration these variations.

The methods that have been used to model snow loading fall into three categories:

1) those in which the consequences of particular storms are simulated by using scaled models and introducing particles into the wind tunnel or water flume to simulate snow particles and their accumulations;

2) those in which the wind velocity patterns are measured on scaled models and the snow drifting and accumulation is numerically inferred with reliance on field data on snow transport rates and other information. Snow particles are not physically simulated in this approach;

3) those that use the methods of computational fluid dynamics, including the interaction effects of snow particles and the air flow.

All these methods are useful for identifying the potential formation of unusual snowdrifts, due to winds blowing from selected directions. However, in climatic regions where below freezing temperatures persist for lengthy periods, maximum snow loads can be the result of cumulative snowfalls and drifting events from a variety of directions over a prolonged part of the winter season. In such situations, it is desirable to track snow accumulations on a 1 h to 3 h basis by recognizing the consequences of each snowfall and wind event. Numerical methods are needed to keep track of the snow fall, snow drifting, snow melting, refreezing, rainfall, and the percolation and runoff of melt and rainwater. Method 2 is best suited for this purpose as it is able to rapidly re-evaluate the snow load every hour, using the historical hourly meteorological data as well as the heat transfer representatives of the roof, thus enabling statistical predictions to be made of extreme loads. However, methods 1 and 3 are capable of providing better detail of certain drift shapes due to individual events. Therefore, a mixture of methods is often desirable. Examples of the use of alternative prediction methods can be found in References [21], [22], [23], [24], [25], [27], and [30].

Since all prediction methods involve a number of simplifications and assumptions about snow accumulation processes, it is important that where possible they be calibrated against field data (e.g. References [28] and [29]).

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