INTERNATIONAL STANDARD

ISO

4355

Second edition
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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

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 4355 was prepared by Technical Committee ISO/TC 98, *Bases for design of structures*, Subcommittee SC 3, *Loads, forces and other actions.*

This second edition cancels and replaces the first edition (ISO 4355:1981), which has been technically revised.

The first edition was based on knowledge available up to 1977.

Snow loads specified in the first edition were mainly based on a wide range of experience and national standards. Consequently, the specified snow loads in some cases were rather high in order to be on the safe side. In this second edition, later investigations (e.g. field measurements, physical, theoretical and statistical analyses) have also been taken into account in order to improve the level of accuracy and to extend the domain of standardized specifications of snow loads.

Although this second edition has more detailed specifications, there is still a need for judgement by experts in practical snow load design as the data-base is still very limited for many types of roof.

In national design standards for loads, load coefficients are normally used to take into account the uncertainty in calculated design load values.

Annexes A to F of this International Standard are for information only.

Introduction

The intensity and distribution of snow load on roofs may 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 the product of the characteristic snow load on the ground, s_0, specified for the region considered, and a shape coefficient μ 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 may be redistributed as a result of wind action; melted water may flow into local areas and refreeze; snow may slide or may be removed.

The format for the snow load on roofs presented in this International Standard contains a number of additional parameters as compared with the first edition (in which such additional parameters were discussed in the text) for the designer to decide upon. In essence, however, the general format has not been changed. The effect of exposure may, with the new format, be treated in a more elaborate way than earlier. A variation with the slope of the roof is introduced in order to improve the physical representation and to make the format easily applicable to computer interpretation.

In order to apply this International Standard, each country will have to establish maps and/or other information concerning the geographical distribution of ground snow load 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 will 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 ground snow load in the form of zone maps, tables or formulae.

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

For examining the effect of the wind on the distribution of snow loads on roofs of unusual shapes or shapes not dealt with in this International Standard or in national standards, suitable models (e.g. tests carried out in a wind tunnel especially equipped for reproducing accumulation phenomena) may give significant results.

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 may 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 Definitions

For the purposes of this International Standard, the following definitions apply.

2.1
characteristic snow load on the ground
s_0
load with accepted probability of not being exceeded during some reference period, T_r years

NOTE 1 It is expressed in kilonewtons per square metre (kN/m^2).

NOTE 2 In meteorology the term "weight of the ground snow cover" is also used.

2.2
value of snow load on roofs
s
product of the characteristic snow load on the ground and an appropriate nominal shape coefficient

NOTE 1   The value of *s* is also dependent on the exposure of the roof and the thermal characteristics of the building.

NOTE 2   It refers to a horizontal projection of the area of the roof.

NOTE 3   It is expressed in kilonewtons per square metre (kN/m^2).

2.3
nominal shape coefficient
μ_i
shape coefficient with primary dependence on the geometry of the roof, in particular the roof slope

NOTE   It is dimensionless.

2.4
slope reduction 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

2.5
drift load coefficient
μ_d
coefficient which, multiplied by μ_b, defines the amount and distribution of additional load on a leeward side or part of a roof, depending on the exposure of the roof and the geometrical configurations of the roof

2.6
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

2.7
exposure reduction coefficient
C_e
coefficient defining the balanced load on a flat horizontal roof of a cold building, as a fraction of the characteristic snow load on the ground

NOTE 1   The exposure coefficient includes the effect of snow being removed from flat roofs by wind. This effect depends on the temperature and the corresponding wind of the region.

NOTE 2   It is dimensionless.

2.8
thermal reduction coefficient
C_t
coefficient defining the reduction of the snow load on the roof as a function of the heat flux through the roof, causing snow melting

NOTE   It is dimensionless.

2.9
surface material coefficient
C_m
coefficient defining a reduction of the snow load on roofs made of surface materials with low surface roughness

2

3 Snow load on roofs

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

Formally, the snow load on roofs may be defined as a function, F, of several parameters. Thus

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

where the symbols are as defined in clause 2.

Since the functional form and relative dependence of the various parameters of the function F of equation (1) are not documented yet, the determination of snow load on roofs must be obtained through approximations of the function F of equation (1).

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 will generally vary throughout the roof.

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

The assumption that the snow load on the roof will be proportional to the characteristic snow load on the ground has led to the widely used format:

$$s = s_0\, \mu\left(C_e, C_t, C_m, \mu_b, \mu_d, \mu_s\right) = s_0\, \mu \tag{... (2)}$$

NOTE   For values of C_t different from unity, C_t is defined as a function also of s_0. This is due to the lack of data for short-term snowfall intensity. Moreover, in cases when the μ_d and μ_s coefficients are dependent on the amount of snow on a higher level roof, these coefficients are defined as functions of s_0. This is also the case when geometrical edge values are defined.

The functions μ of equation (2) depend on a number of parameters, and require extensive specifications and illustrations for various kinds of roof configurations, roof exposure, roof temperature, roof material, etc.

This International Standard defines the snow load on the roof as the sum of a balanced load, 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):

$$s = s_b + s_d + s_s \tag{... (3)}$$

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

$$s_b = s_0 C_e\, C_t\, \mu_b \tag{... (4)}$$

$$s_d = s_0 C_e\, C_t\, \mu_b\, \mu_d \tag{... (5)}$$

$$s_s = s_0\, C_e\, C_t\, \mu_s \tag{... (6)}$$

The balanced load, s_b, is uniformly distributed in all cases, except for curved roofs, where the distribution varies with the slope β (see 5.4.5.5).

The balanced load defines the load on a horizontal roof, and the load on the windward side of a pitched roof. Since any direction may be the wind direction, the balanced 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 may 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.

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

A load case 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 important for structures which are sensitive to the form of the load distribution (e.g. curved roofs, arches, domes or other structures).

4   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 a well-sheltered area.

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.

5   Snow load coefficients

5.1   Exposure coefficient

The exposure coefficient, C_e (see 2.7), depends on the topography, the intensity of winter wind, and the temperature.

Methods for the determination of C_e are given in annex B.

For regions where there are not sufficient winter climatological data available, it is recommended to set $C_e = 0,8$. However, the designer should always assess whether calm weather conditions (i.e. $C_e = 1,0$) during the snowfall season might yield more severe conditions for the structure.

5.2   Thermal coefficient

The thermal coefficient, C_t (see 2.8), is introduced to account for the reduction of snow load on roofs with high thermal transmittance, in particular glass-covered roofs, from melting caused by heat loss through the roof. For such cases C_t may take values less than unity. 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.

NOTE   The intensity of snowfall for short periods, approximately 1 to 5 days, 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.

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

5.3   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 5.4.2.

The surface material coefficient, C_m (see 2.9), is defined to vary between unity and 1,333, and takes the fixed values:

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

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

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

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

5.4 Shape coefficients

5.4.1 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 are illustrated for one specific wind direction. Since prevailing wind directions may not correspond to the wind directions during heavy snow falls, all roofs should be designed for the condition that the wind during snow fall may have any direction with reference to the roof location.

For monopitch roofs and multispan roofs consisting of parallel monopitch roofs, a drift load part has been assumed to correspond to half the additional load on a pitched roof.

NOTE The subdivision of the shape coefficients into balanced load, drift load and slide load coefficients may not seem physically logical in all cases (e.g. multiple pitched roofs). However, the system has been applied for all roof shapes in view of the fact that the most unfavourable load conditions are taken care of by this subdivision.

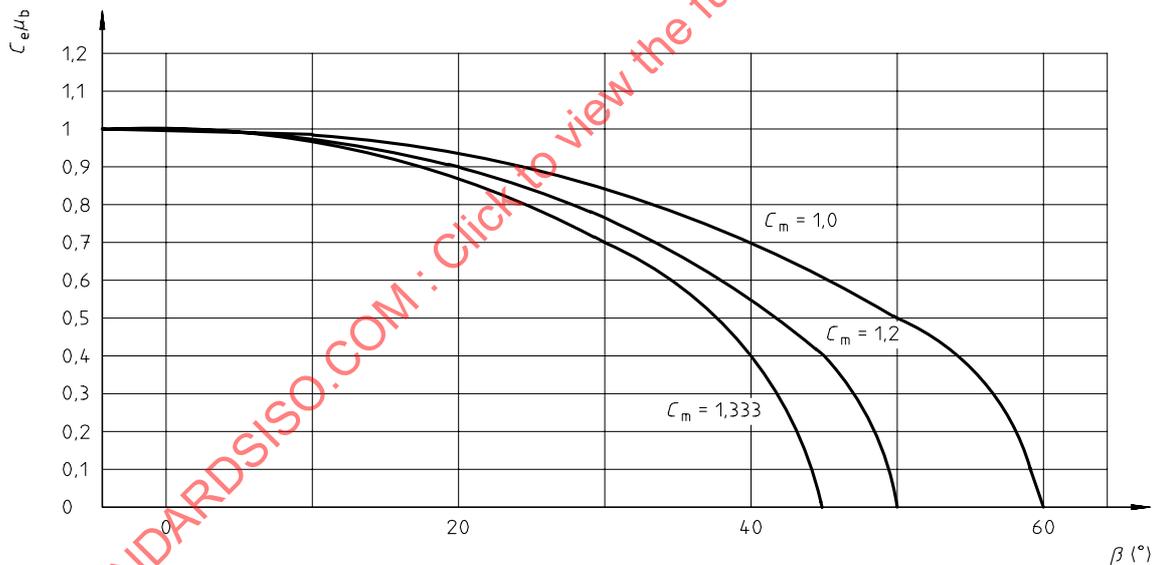Figures 1 to 4 are included to illustrate the function variations.

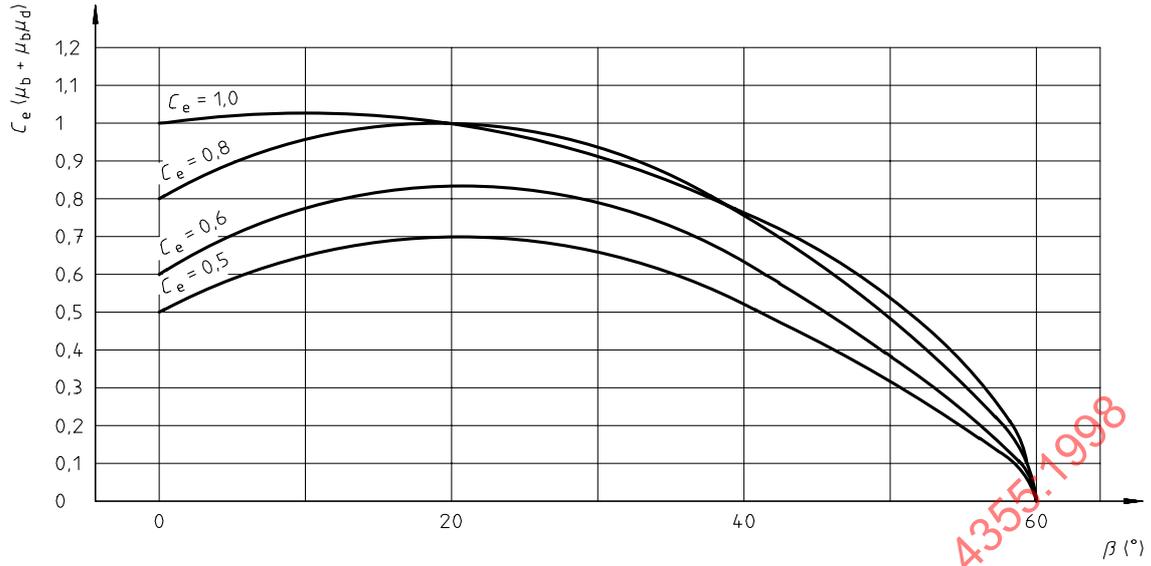**Figure 1 — $C_e\mu_b$ values for defined values of C_m with $C_e = 1,0$**

Figure 2 — $C_e(\mu_b + \mu_b\,\mu_d)$ **values for defined** C_e **values with** $C_m = 1{,}0$
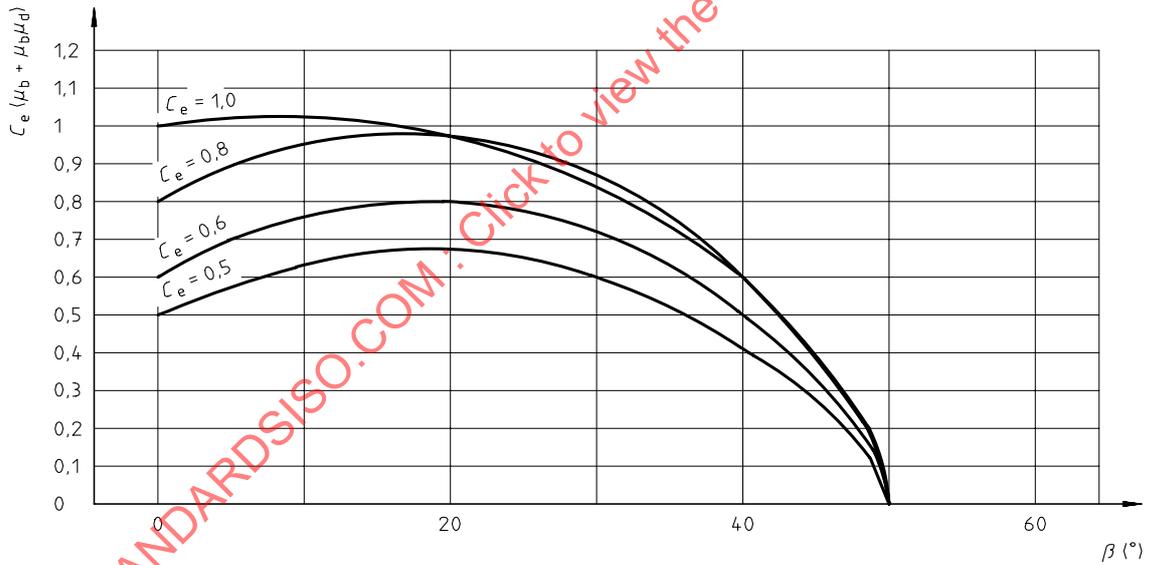

Figure 3 — $C_e(\mu_b + \mu_b\,\mu_d)$ **values for defined** C_e **values with** $C_m = 1{,}2$
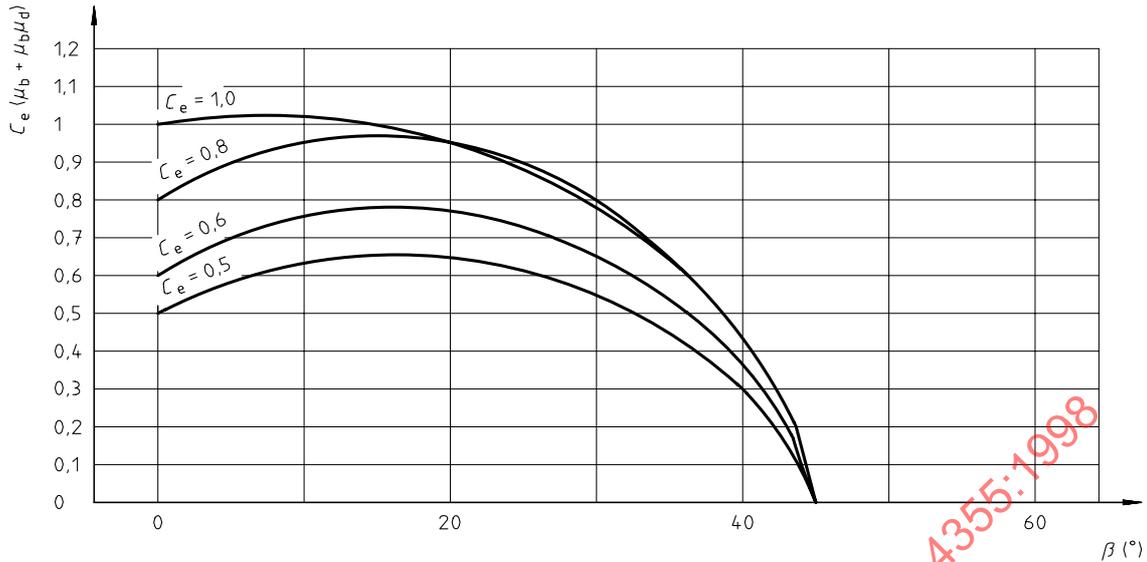
Figure 4 — $C_e(\mu_b + \mu_b\,\mu_d)$ values for defined C_e values with C_m = 1,333

5.4.2 Slope reduction coefficient

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 2.4), which is given by the function:

$$\mu_b = \sqrt{\cos(C_m\,1,5\,\beta)} \quad \text{(for } C_m\,1,5\,\beta < 90°) \qquad \qquad \text{... (7)}$$

$$\mu_b = 0 \quad \text{(for } C_m\,1,5\,\beta \geqslant 90°)$$

For roofs with snow rails or obstructions preventing the snow from sliding off, $\mu_b = 1,0$. For multiple pitched roofs and inner bays of multispan roofs, sliding may lead to redistribution of the snow load.

5.4.3 Drift load coefficient

The geometrical influence of the shape on the drift load accumulating on the leeward side of a pitched roof is defined by the shape coefficient $\mu_b\,\mu_d$, which for a roof with roof angle β is defined by the function:

$$\mu_b\,\mu_d = \mu_b(2,2C_e - 2,1C_e^2)\sin(3\beta) \quad \text{(for } 0° \leqslant \beta \leqslant 60°) \qquad \qquad \text{... (8)}$$

$$\mu_b\,\mu_d = 0 \quad \text{(for } \beta > 60°)$$

Equation (8) includes the effects of loss of snow being blown away from the roof by wind, and is scaled to yield total loads corresponding to measured loads on ordinary pitched roofs.

NOTE   The form of the drift load coefficient ensures that a certain drift load part must always be checked even for regions with very calm weather; i.e. $C_e = 1,0$.

5.4.4 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 may 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 shape coefficient μ_s.

An approximate slide load model is presented in 5.4.5.6, in which the slide load distribution is assumed to be linear, where it is assumed that 50 % of the maximum load on the upper roof will slide down (and that the coefficient of friction of the upper roof is zero) and that snow will slide from the top of the upper roof.

The impact loading on multilevel roofs due to slide load should be considered.

5.4.5 Snow load distribution on selected types of roof

NOTE   A discussion of s_0 is given in clause 4, and C_e, C_t and C_m are discussed in 5.1, 5.2 and 5.3 respectively.

5.4.5.1 Simple pitched roofs (positive roof slope)

See figure 5. For asymmetrical simple pitched roofs, each side of the roof shall be treated as one-half of a corresponding symmetrical roof.
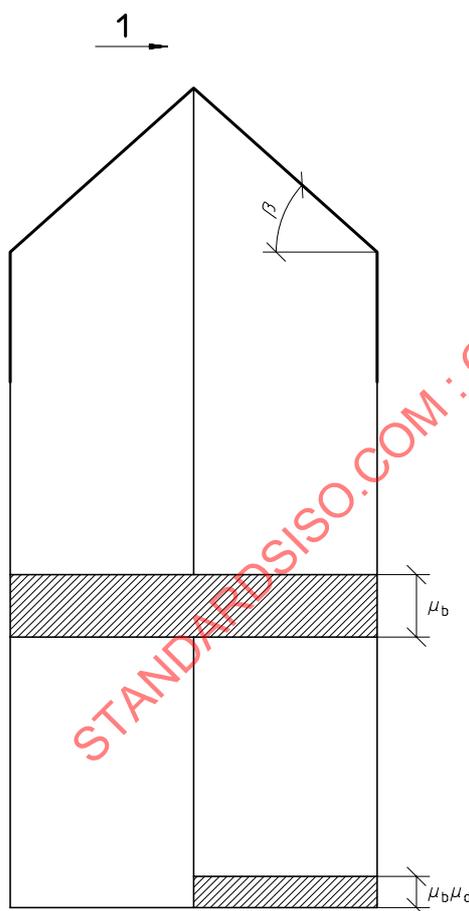
Windward side: $s = s_b$
Leeward side: $s = s_b + s_d$

Balanced load part

$s_b = s_0 C_e C_t \, \mu_b$

$\mu_b = \sqrt{\cos(C_m \, 1{,}5 \, \beta)}$ (for $C_m \, 1{,}5 \, \beta \leq 90°$)

$\mu_b = 0$ (for $C_m \, 1{,}5 \, \beta > 90°$)

Drifted load part

$s_d = s_0 C_e C_t (\mu_b \, \mu_d)$

$\mu_d = (2{,}2 C_e - 2{,}1 C_e^2) \sin(3\beta)$ (for $\beta \leq 60°$)
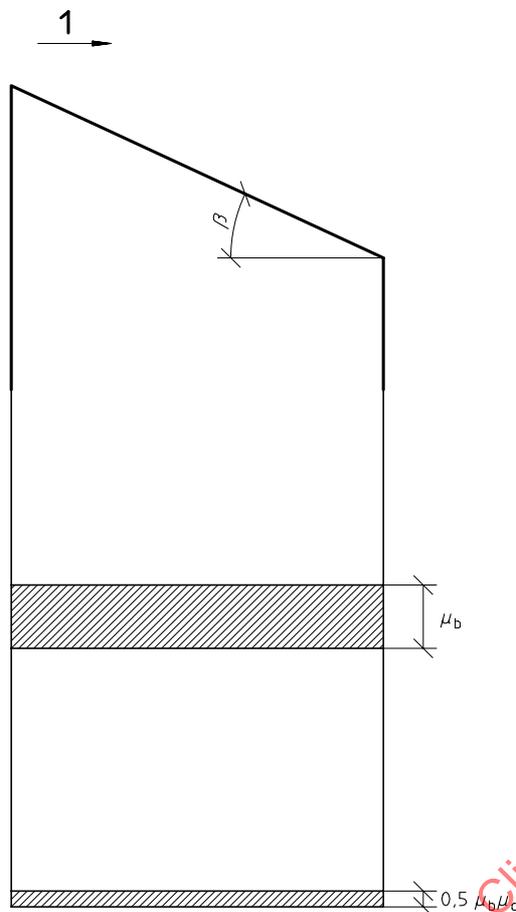
$\mu_d = 0$ (for $\beta > 60°$)

Key

1 Wind direction

Figure 5 — Snow load distribution on a simple pitched roof

5.4.5.2 Simple flat and monopitched roofs

See figure 6.

Leeward slope situation: $s = s_b + s_d$

Balanced load part

$s_b = s_0 C_e C_t \mu_b$

$\mu_b = \sqrt{\cos(C_m \, 1,5 \, \beta)}$ (for $C_m \, 1,5 \, \beta \leq 90°$)

$\mu_b = 0$ (for $C_m \, 1,5 \, \beta > 90°$)

Drifted load part [a)]

$s_d = s_0 C_e C_t \, 0,5(\mu_b \, \mu_d)$

$\mu_d = (2,2 \, C_e - 2,1 C_e{}^2) \sin(3\beta)$ (for $\beta \leq 60°$)
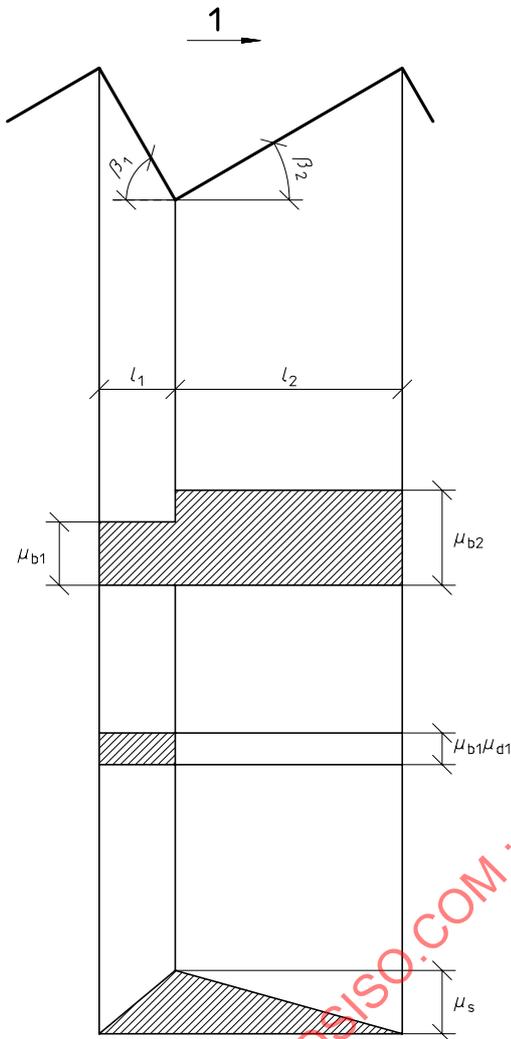
$\mu_d = 0$ (for $\beta > 60°$)

Key

1 Wind direction

a) 50 % of the drift load for corresponding simple pitched roof.

Figure 6 — Snow load distribution on a monopitched roof

5.4.5.3 Simple or multipitched roofs, and hanging roofs (inner bay negative roof slope)

See figure 7. For hanging roofs of circular or oval plan form, the μ values for the basic and sliding load may be considered as load values along a chord, whereas the drift load may be assumed to refer to the wind direction chord.

Windward side: $s = s_b$
Leeward side: $s = s_b + s_d$
Slide distributed: $s = s_b + s_d + s_s$

Balanced load part

$s_b = s_0 C_e C_t \mu_b$

$\mu_b = \sqrt{\cos(C_m 1{,}5\beta)}$ (for $C_m 1{,}5\beta \le 90°$)

$\mu_b = 0$ (for $C_m 1{,}5\beta > 90°$)

Drifted load part

$s_d = s_0 C_e C_t (\mu_b \mu_d)$
$\mu_d = (2{,}2 C_e - 2{,}1 C_e{}^2) \sin(3\beta)$ (for $\beta \le 60°$)
$\mu_d = 0$ (for $\beta \geqslant 60°$)

Sliding load part (redistributed) [a]

$s_s = s_0 C_e C_t \mu_s$
$\mu_s = 2{,}0 [1 - \mu_{b1}) (1 + \mu_{d1}) l_1 + (1 - \mu_{b2}) l_2]/(l_1 + l_2)$ [b]
$\mu_s = 2$ (for $C_m 1{,}5\beta \geqslant 90°$) [c]

Key
1 Wind direction

NOTE 1 For shape coefficient, see figure 8.
NOTE 2 $\beta = \beta_1$ or β_2

a) The slide load part may partly be redistributed snow and partly drifted snow.
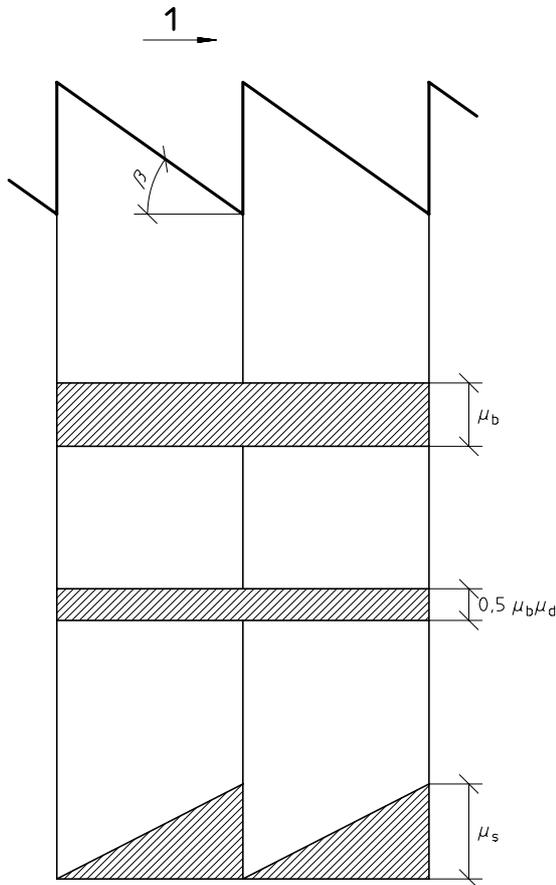
b) For $l_1 = l_2$ and $\beta_1 = \beta_2$: $\mu_s = (1 - \mu_b) (2 + \mu_d)$

c) Since snow cannot slide away from the roof.

Figure 7 — Snow load distribution for a multipitched roof

5.4.5.4 Two-span or multispan roofs

See figure 8.

Windward side: $s = s_b$
Leeward side: $s = s_b + s_d$
Slide distributed: $s = s_b + s_d + s_s$

Balanced load part

$s_b = s_0 C_e C_t \, \mu_b$

$\mu_b = \sqrt{\cos(C_m \, 1{,}5\beta)}$ (for $C_m \, 1{,}5\beta \leq 90°$)
$\mu_b = 0$ (for $C_m \, 1{,}5\beta > 90°$)

Drifted load part [a]

$s_d = s_0 C_e C_t \, (0{,}5\mu_b \, \mu_d)$

$\mu_d = (2{,}2C_e - 2{,}1C_e^2) \sin(3\beta)$ (for $\beta \leq 60°$)
$\mu_d = 0$ (for $\beta > 60°$)

Sliding load part (redistributed) [b]

$s_s = s_0 C_e C_t \, \mu_s$

$\mu_s = \left[1 - \sqrt{\cos(C_m 1{,}5\beta)}\right]\left[2 + (2{,}2C_e - 2{,}1C_e^2)\sin(3\beta)\right]$

$\mu_s = 2$ (for $C_m \, 1{,}5\beta \geq 90°$) [c]

Key

1 Wind direction

a) 50 % of the drift load for corresponding simple pitched roof.

b) The slide load part may partly be redistributed snow and partly drifted snow.
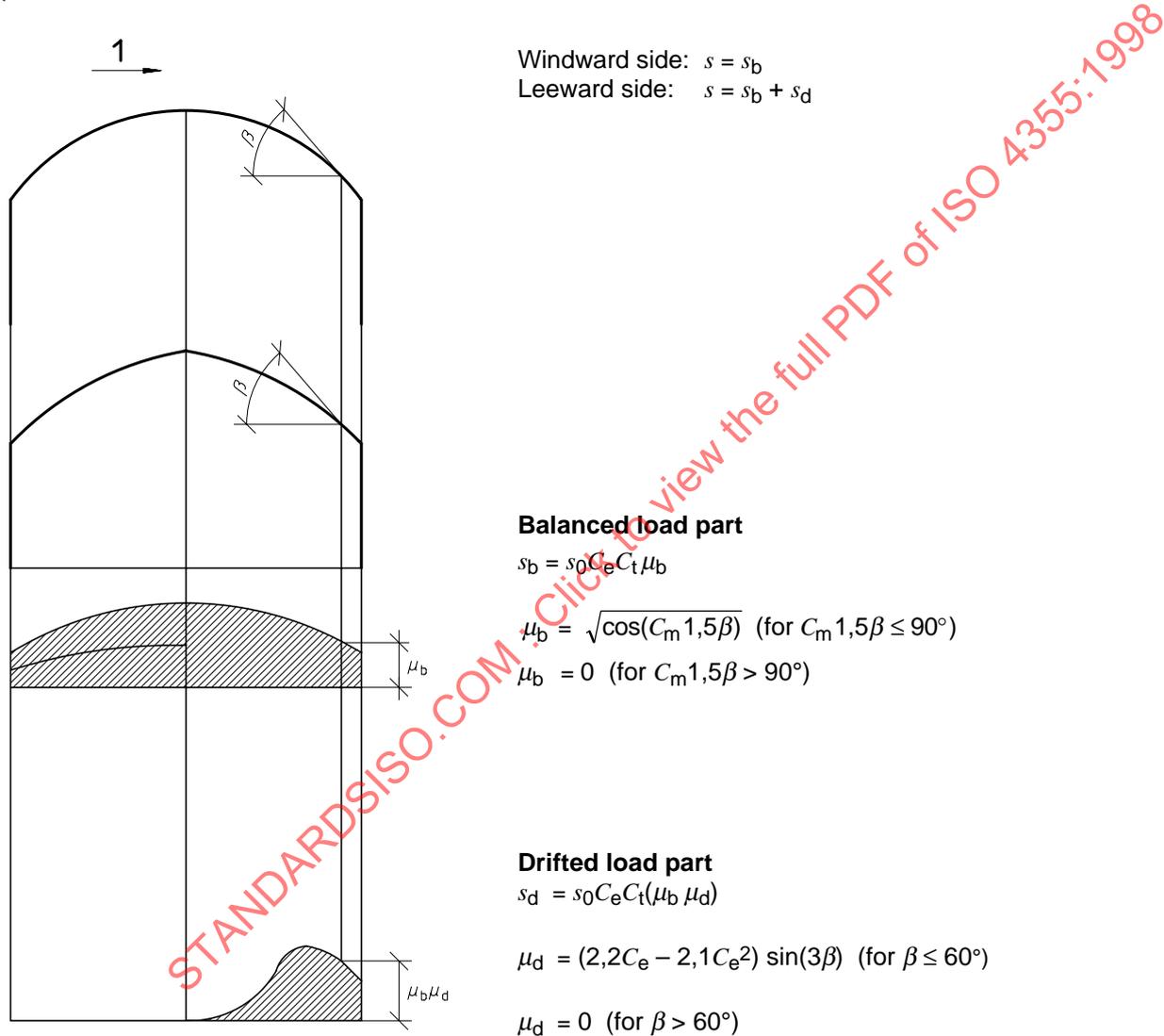
c) Since snow cannot slide away from roof.

Figure 8 — Snow distribution load for a multispan roof

5.4.5.5 Simple curved roofs, pointed arches and domes

See figure 9.

For domes of circular plan form, an axially symmetrical balanced load may be given as the corresponding balanced arch load. The drift load may likewise be given by the corresponding arch drift load, along the plan diameter being parallel to the wind direction multiplied by a reduction factor $(1 - a/r)$ where r is the plan radius and a is the horizontal distance from the wind direction diameter to any parallel plan chord. However, for large domes it is recommended to perform wind tunnel tests.

According to 3.3, partial loading should always be considered. For arches it is recommended, unless more unfavourable conditions are foreseen, to consider half of the balanced load on the windward side as a moveable part of the total load.

Windward side: $s = s_b$
Leeward side: $s = s_b + s_d$

Balanced load part

$s_b = s_0 C_e C_t \mu_b$

$\mu_b = \sqrt{\cos(C_m 1{,}5\beta)}$ (for $C_m 1{,}5\beta \leq 90°$)

$\mu_b = 0$ (for $C_m 1{,}5\beta > 90°$)

Drifted load part

$s_d = s_0 C_e C_t(\mu_b \mu_d)$

$\mu_d = (2{,}2 C_e - 2{,}1 C_e^2)\sin(3\beta)$ (for $\beta \leq 60°$)

$\mu_d = 0$ (for $\beta > 60°$)

Key

1 Wind direction

Figure 9 — Snow load distribution on a curved roof

5.4.5.6 **Multilevel roofs** (Lower roof with slope β_l)

For lower roofs with slopes normal to the cross-section of figure 10, the basic load is determined from figures 5 to 9. The total drift load is equal to the load reduction on the upper roof due to exposure, i.e. $s_0\ (1-0,95C_e)l_1$. Alternative formulae for μ_d are described in annex C.

If $l_d > l_2$, the trapezoidal form of figure 10 applies. If $l_s > l_2$, the trapezoidal form of figure 10 applies.
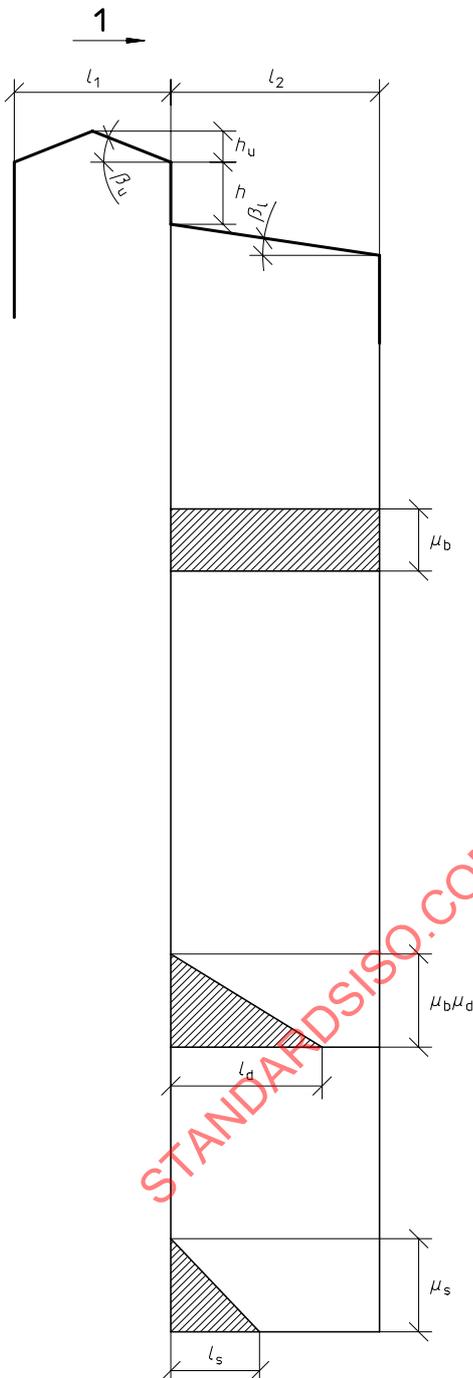
Windward side: $s = s_b$
Leeward side: $s = s_b + s_d$
Slide: $s = s_s$

Balanced load part

$s_b = s_0 C_e C_t\, \mu_b$

$\mu_b = \sqrt{\cos(C_m\, 1{,}5\beta_l)}$ (for $0° \leq C_m\, 1{,}5\beta_l \leq 90°$)

$\mu_b = 1{,}0$ (for $\beta_l < 0$) [a]

$\mu_b = 0$ (for $C_m\, 1{,}5\beta_l > 90°$)

Drifting load part

$s_d = s_0 C_e C_t(\mu_b\, \mu_d)$

$\mu_d = \sqrt{0{,}5(1-0{,}95C_e)\,(l_1\rho g / s_0)}$

If $l_1 < 10$ m, $l_1 = 10$ m applies.
If $l_1 < 0{,}5\, l_2$, l_1 shall be replaced by $0{,}5\, l_2$.

$\mu_b\, \mu_d \leq (\rho g / C_e C_t\, s_0)\, h - \mu_b$

where l_1, h are in metres, s_0 is in kN/m², ρg (ρ is the density of the snow and g is acceleration due to gravity) is in kN/m³, and may be set to 3,0 kN/m³

$l_d = 4\ (\mu_b\mu_d)(s_0/\rho g)$
$l_d < 15$ m

Sliding load part

$s_s = s_0 C_e C_t\, \mu_b\mu_s$

$\mu_s = (h_u/l_s \tan\beta_u)$ [b]

$\mu_s \leq (\rho g / C_e C_t\, s_0)h - \mu_b\, \mu_d$

$l_s = 2h_u \cos\beta_u\left(\sqrt{(h/h_u) + p^2} - p\right)$

$p = \sin\beta_u - \tan\beta_l \cos\beta_u$

For $h < 3\ (s_0/\rho g)$: $\mu_s = 1{,}0$

Key

1 Wind direction

a) Sloping towards taller part of building.

b) Impact effects shall be considered.

Figure 10 — Snow load distribution on a multilevel roof

For multilevel flat roofs, the drifting load part, s_d, is shown in figures 11 to 13.
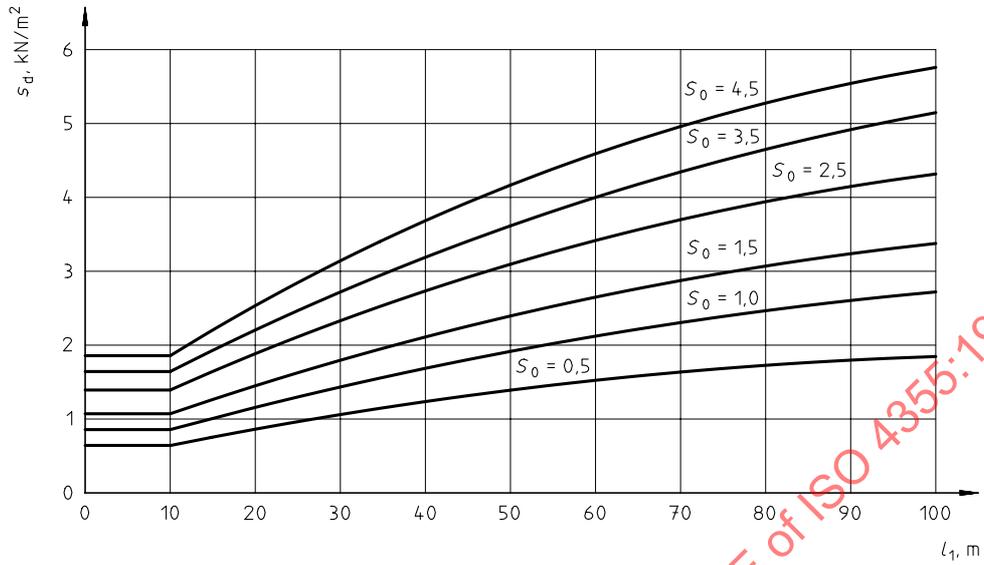
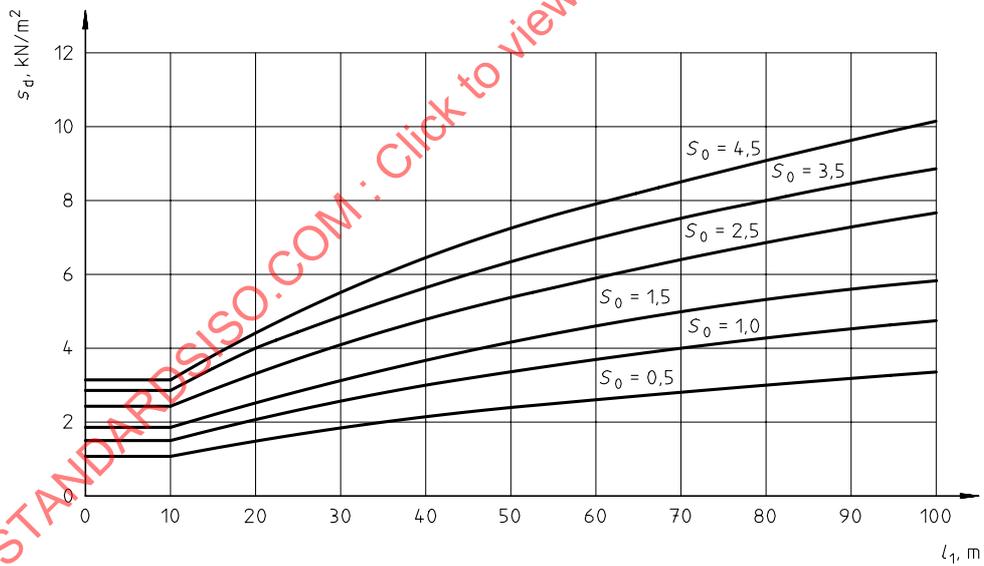**Figure 11 — Drifting load part, s_d, for multilevel flat roofs with $C_t = 1,0$ and $C_e = 1,0$**

Figure 12 — Drifting load part, s_d, for multilevel flat roofs with $C_t = 1,0$ and $C_e = 0,8$
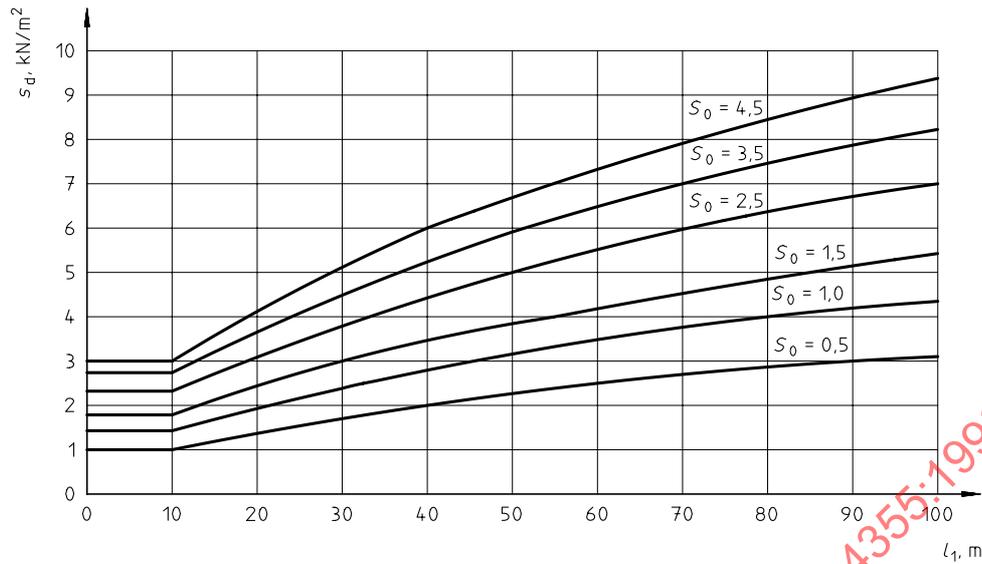
Figure 13 — Drifting load part, s_d, for multilevel flat roofs with $C_t = 1,0$ and $C_e = 0,5$

5.4.5.7 Additional drift load and sliding load accumulated on ground or on lower level roof, acting against the upper arch or pitched roof

See figure 14.

A lower level roof should be checked for the sliding load as an alternative load case as compared with the load cases of 5.4.5.6. Impact effects shall be considered.
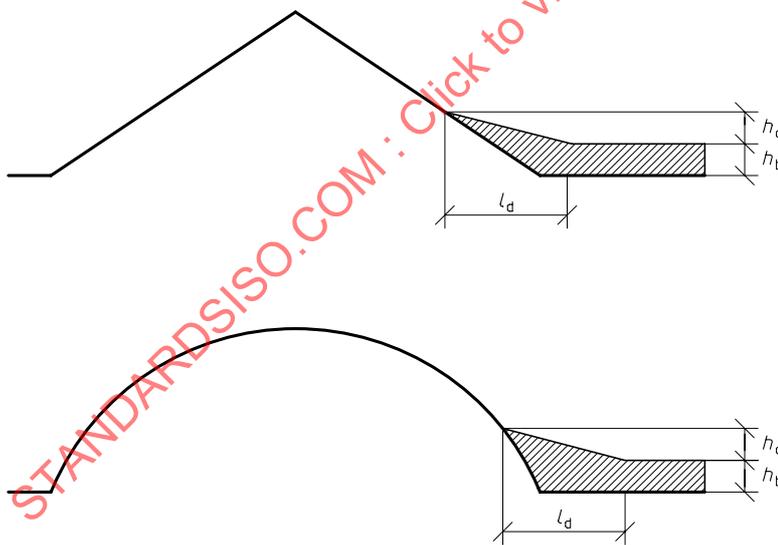
$s = s_0 (\mu_d + \mu_b)$

On ground: $\mu_b = 1,0$

$h_d = \mu_d s_0/(\rho g)$ $(\mu_d = 3,0)$

$h_b = \mu_b s_0/(\rho g)$

$l_d = 6 s_0/(\rho g)$

where

s_0 is in kN/m^2,
ρg is in kN/m^3.

$s = s_0 (\mu_d + \mu_b)$

On ground: $\mu_b = 1,0$

$h_d = \mu_d s_0/(\rho g)$ $(\mu_d = 3,0)$

$h_b = \mu_b s_0/(\rho g)$

$l_d = 6 s_0/(\rho g)$

where

s_0 is in kN/m^2,
ρg is in kN/m^3.

Figure 14 — Additional drift load and sliding load acting on upper arch or pitched roof

5.4.5.8 Pointed arches

See figure 15.

Depending on the size of the roof slope at the peak, β_t, pointed arches are treated as pitched roofs or as arches as follows:

$\beta_t \geqslant 15°$: use figure 5 for pitched roofs;
$\beta < 15°$: use figure 9 for arches.
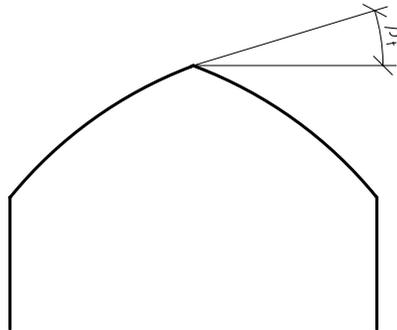
Figure 15 — Pointed arch

5.4.5.9 Roofs with local projections and obstructions

See figure 16.

For obstructions on roofs, drift loads will often occur on both sides of the obstruction irrespective of the wind direction. Therefore an unbalanced drift situation is not shown.
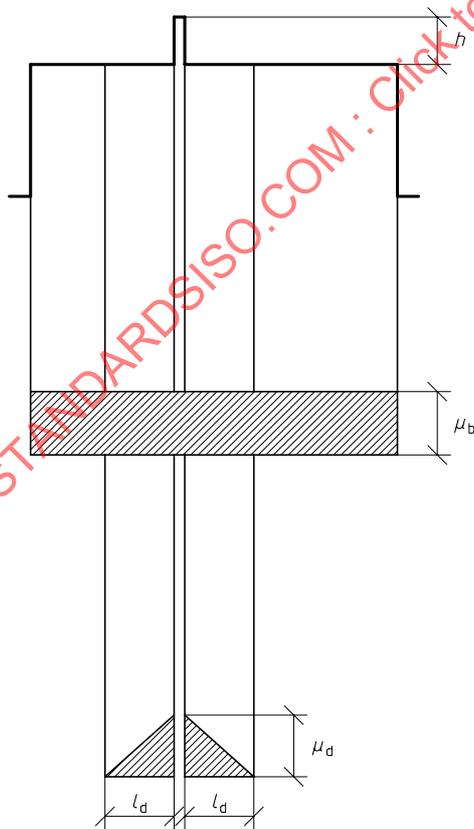
Balanced load part

$s_b = s_0 C_e C_t \mu_b$

$\mu_b = 1,0$

Drifted load part

$s_d = s_0 C_e C_t \mu_d$

$\mu_d = \rho g h / s_0 C_t C_e - \mu_b \leqslant 1,5$

$l_d = 4\mu_d s_0 C_e C_t / (\rho g)$

$5\text{ m} \leqslant l_d \leqslant 15\text{ m}$

where

h is in metres,
s_0 is in kN/m^2,
ρg is in kN/m^3.

Figure 16 — Snow load distribution for a roof with local projections and obstructions

Annex A
(informative)

Methods for determination of the characteristic snow load on the ground

A.1 Snow zones and maps

The characteristic snow load on the ground, s_0, preferably with a return period of 50 years[2], should be available in national standards.

NOTE 1   A return period is the average interval, in years, between events which equal or exceed a given magnitude.

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 may influence the snow load.

NOTE 2   In the USA and Canada, important studies on defining the characteristic snow load on the ground have recently been carried out and are discussed in references [1] and [2].

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 kilopascals, 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 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. Snow sampling equipment and the observation procedure should be in accordance with WMO recommendations [3].

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 related to snow depth

In the USA [4] the following relationship between snow load and snow depth is used:

$$s_{50} = 1{,}91(d_{50})^{1{,}33} \hspace{4cm} \text{... (A.1)}$$

where

s_{50} is the snow load (kPa) on the ground with a return period of 50 years;

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

Equation (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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2) When more appropriate, a return period greater than 50 years can apply.

A.2.2 Density of snow

The average density of snow layer is still an important parameter for determining snow load, since the snow depth at many stations 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 the USSR [5] the following expression has been proposed:

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

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 derived from empirical investigations in Japan is:

$$\rho = A \sqrt{d} + B \qquad \text{... (A.3)}$$

where

ρ is the snow density (kg/m^3);

d is the snow depth (m);

A and B are constants influenced by the mean temperature of the snow zone during the accumulation season.

A.2.4 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 must 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 [6].

A.3 Statistical treatment of basic data

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

A.3.1 Statistical distributions

Unless analyses of the data indicate otherwise, it is recommended that either the Lognormal or the Gumbel distribution Type 1 be used as distribution curve for annual maximum snow load.

NOTE   Statistical literature on extreme values, for example references [7], [8] and [9], is recommended.

In regions with few measurements, mean and variance (parameters of the distributions) can often be calculated from regression models. It will be advantageous, under these circumstances, to consider only one distribution throughout the whole climatic region.

In regions not having snow every year, a mixed probability function formed by climatological series of zero and non-zero snow load values can be constructed. Such methods have been developed for the Lognormal distribution [10].

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 [2].

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 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.

Annex B

(informative)

Determination of the exposure coefficient

B.1 General

The exposure coefficient, C_e, is a general coefficient reflecting the effect of snow removal at a roof location independent of the roof shape. The definition of C_e is given in 2.7.

In this annex, C_e is determined as described in B.5, after the characteristics of the regional winter wind and temperature climates have been considered. These characteristics are outlined under B.2 and B.4, respectively. The effect from local topography is determined from B.3.

Wind during a snow fall may 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, may 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 [11], and analyses of observation projects concerning snow loads on buildings have been carried out by several researchers (see references [12] to [14]). Water flume studies of drifting are described in reference [15], and wind tunnel studies in references [16] and [17].

Quantitative values of the main variables involved in drifting are not yet available to such an extent that they can provide a general basis for calculating the exposure coefficient by statistical methods. Therefore the values of C_e in this annex should be regarded as nominal. Although the range of C_e is 0,5 to 1,0, only C_e = 1,0, 0,8, 0,6 and 0,5 are used as a consequence of the limited accuracy in the practical determination of C_e.

B.2 Winter wind climate

The mean frequency of wind speed above a threshold value (10 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 winter wind climates given in table B.1 should be considered, normally by using the average values of the three coldest months of the year.

Table B.1 — Winter wind categories

Average monthly number of days, N, with occurrence of 10 min average wind speed exceeding 10 m/s	Winter wind category
$N < 1$	I
$1 \leq N \leq 10$	II
$N > 10$	III

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

B.3 Local topography

If the local topography at a site indicates a significantly lower wind speed than that recorded by the most representative nearby meteorological station, a change in category under B.2 shall be considered as follows.

When the recorded wind frequency is within the lowest half of the interval defined by the range of Category II given from table B.1, Category I applies. For frequencies between 10 and 15 for Category III, Category II applies.

B.4 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 B.6.

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

Table B.2 — Winter temperature categories

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

B.5 Exposure coefficient

When the winter wind and temperature categories have been determined from tables B.1 and B.2 respectively, and adjusted due to local topography according to B.3, the exposure coefficient can be determined from table B.3.

Table B.3 — Exposure coefficient, C_e

		Winter wind category		
		I	II	III
Winter	A	1,0	1,0	0,8
temperature	B	1,0	0,8	0,6
category	C	0,8	0,8	0,5

The value $C_e = 0,5$ (i.e. Category C III) applies only to buildings in open terrain extremely exposed in all directions.

B.6 Alternative determination of the exposure coefficient

In the Soviet Union [12] the following formulae for the exposure coefficient have been derived for regions having mean winter temperature (average temperature for the three coldest month of the year) less than –5 °C:

$C_e = 1,0$ for $v \leqslant 2$ m/s

$C_e = 1,2 - 0,1v$ for $2 < v < 8$ m/s

$C_e = 0,4$ for $v \geqslant 8$ m/s

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

For winter temperatures higher than –5 °C, no drifting is considered.

Annex C
(informative)

Shape coefficients for multilevel roofs

C.1 General

The shape coefficients for multilevel roofs, as given in 5.4.5.6, are derived from a study comparing similar formulae commonly used in Canada, USA and USSR (see [18] and [19]).

C.2 Basic formulae

In the USSR the procedure determining the drift load coefficient for multilevel roofs, μ_w, is (see figure C.1):

$$\mu_w = 1 + [m_1 l_1 + m_2 (l_2 - 2h)]/h \qquad\qquad \text{... (C.1)}$$

where

l_1 is the length of the upper roof (m);

l_2 is the length of the lower roof (m);

h_1 is the roof height difference (m);

m_1 and m_2 are coefficients;

$m_1 = m_2 = 0,5$ for plane roofs with slopes $\beta \leqslant 20°$ and vaulted roofs with $f/l_1 \leqslant 1/8$; otherwise, $m_1 = m_2 = 0,3$;
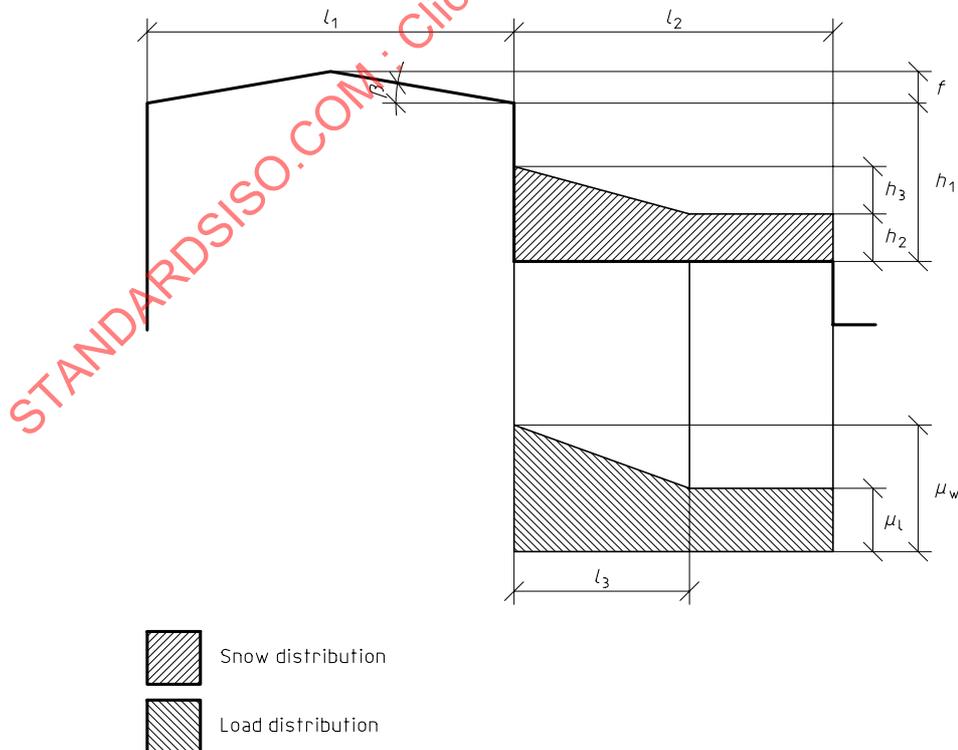
f is the rise of the vault.

Figure C.1 — Parameters related to typical multilevel roof

The coefficients m_1 and m_2 may be adjusted to take into account conditions for transfer of snow on the roof surface (i.e. wind, temperature, etc.).

The value $\mu_1 = 0,8$ shall be used.

l_3 is determined by:

$l_3 = 2h_1$

Restrictions:

$l_3 \leqslant 15$ m and $\mu_w \leqslant kh_1/s_0$

where

$k = 2$ kN/m^3;

s_0 is the snow load (kPa).

In the USA the depth, in metres, of the additional drift accumulation, h_3, is determined by (see figure C.1):

$$h_3 = 0,415 \sqrt[3]{l_1}\ \sqrt[4]{(s_0 + 0,479)} - 0,457 \qquad\qquad \text{... (C.2)}$$

where

l_1 is the upper roof length (m);

s_0 is the snow load on the ground (kPa).

Restriction:

$h_3 < h_1 - h_2$

where

h_1 is the roof height difference;

h_2 is the depth of the uniformly distributed snowlayer on the roof.