LWS - Wind and Snow Loads

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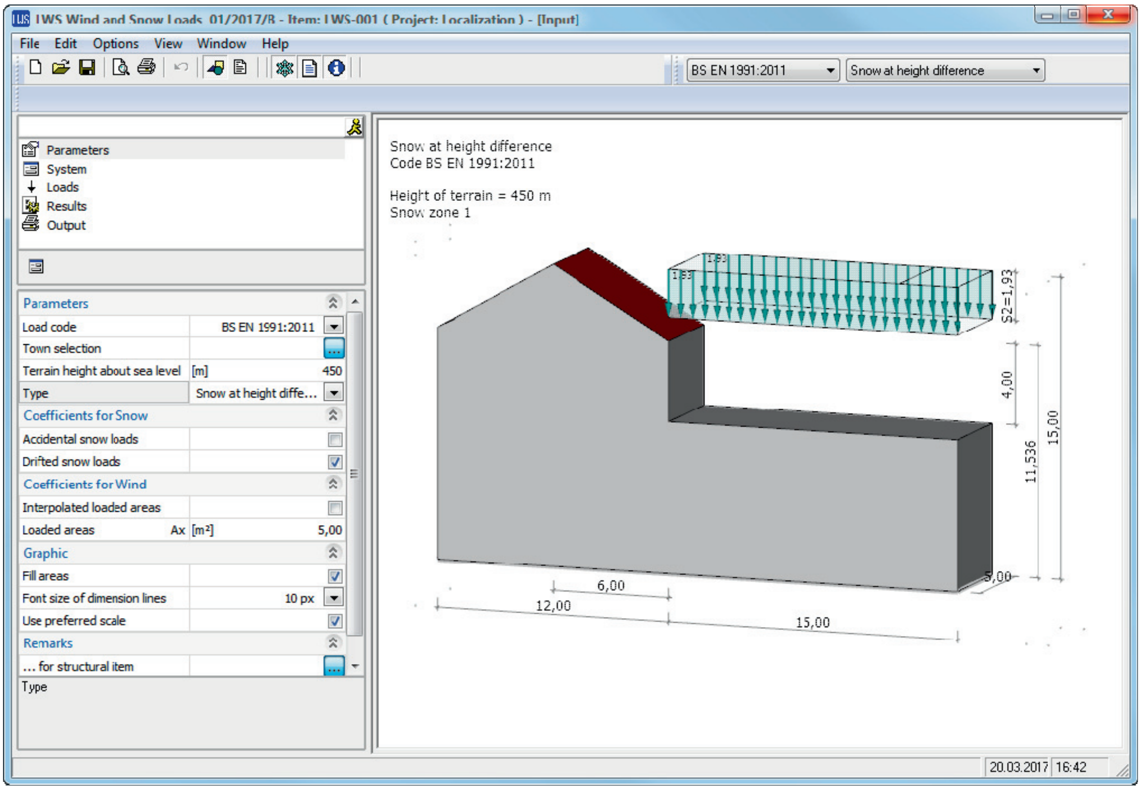

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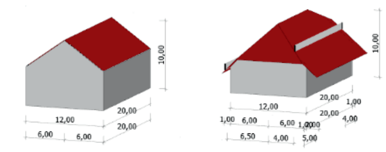
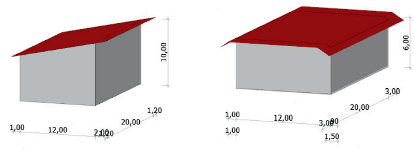
Contents

Further information and descriptions are available in the relevant documentations:

FDC – Basic Operating Instructions	General instructions for the manipulation of the user interface
FCC	Frilo.Control.Center - the easy-to-use administration module for projects and items
FDD	Frilo.Document.Designer - document management based on PDF
Frilo.System.Next	Installation, configuration, network, database
FDC – Menu items	General description of the typical menu items of Frilo software applications
FDC – Output and printing	Output and printing

Application options





The application program is suitable for the calculation of wind and snow actions on the following types of structures:

- Double-pitch roof
- Hip roof
- Single-pitch roof
- Flat roof with sharp-edged, bevelled, or rounded eaves or parapet

In addition:

- Snow drifts on superstructures
- Loads by down-sliding snow from abutting taller structures
- Canopies (Porch)
- Wind-induced internal pressure in closed buildings
- Wind action on free-standing walls

You can calculate the loads in line with the following standards:

- DIN 1055-4:03/2005 with Amendment1:03/2006, DIN 1055-5:07/2005
- EN 1991-1-3:2010-12, EN 1991-1-4:2010-12
- DIN EN 1991-1-3/NA:2010-12, DIN EN 1991-1-4/NA:2010-12
- ÖNORM B 1991-1-3:2013-09, ÖNORM B 1991-1-4:2013-05
- BS EN 1991:2005/2011
- UNI EN 1991 / NTC EN 1991

The software calculates the site-specific basic wind velocity pressure q_b and the gust velocity pressure q(z) on walls and roof surfaces with consideration of the given geographic border conditions.

The aerodynamic coefficients and the resulting wind loads, are calculated for areas = 10 m², areas < 1 m² (uplift) and, optionally, for areas between 1 and 10 m² for upwind angles of 0°, 90°, 180° and 270°. For areas with alternating pressure and suction loads, always both values are put out.

The aerodynamic coefficients and the wind loads can be put out graphically and, optionally, in the form of tables.

The wind loads are calculated exclusively in accordance with the wind pressure coefficient method.

For structures with special geometric border conditions, such as chimneys, panels, free-standing roofs, the code stipulates that wind loads be determined in accordance with the wind force coefficient method! Therefore, the present application program CANNOT be used in these cases.

In addition to the wind loads, the software allows you to determine the ground snow loads and the resulting roof snow loads as well as the snow loads on eaves at roof overhangs.

You can put out roof snow loads in a graphical representation and, optionally, also in the form of tables.

Standards and acronyms

EN 1991 1-3 / EN 1991-1-4

If the National Annexes are not mentioned explicitly, the descriptions in this document are relevant for all National Annexes.

NDP

Nationally defined parameter; parameter defined in the National Annex (NA).

Implemented National Annexes and Acronyms used

EN 1991-1-3: EN 1991-1-3:2010-12

EN 1991-1-4 EN 1991-1-4:2010-12

Implemented National Annexes (NA):

DIN EN 1991:	Germany DIN EN 1991-1-3/NA:2010-12, DIN EN 1991-1-4/NA:2010-12
ÖNORM EN 1991:	Austria ÖNORM B 1991-1-3:2006-04, ÖNORM B 1991-1-4:2011-10

See also an overview of the implemented National Annexes at www.frilo.eu

Basis of calculation

General

The software first calculates the basic wind velocity pressures for the different direction of approach as well as the ground snow load on the basis of the specified geographic border conditions.

After the definition of the system parameters, the aerodynamic coefficients with the associated wind loads and/or roof snow loads are calculated.

For the special types "wind-induced internal pressure" and "wind on free-standing walls", only the wind loads and for "snow drifts" and "roofs abutting taller structures", only the snow loads are calculated.

Wind loads

The software first determines the basic wind velocity pressure q_b. Depending on the selected standard, the value must either be specified manually by the user or is proposed automatically on the basis of the geographic border conditions.

By taking various coefficients and factors into account, the height-specific gust velocity pressure $q_p(z)$ can be calculated.

As shown in illustration 7.5, the gust velocity pressure $q_p(z)$ on all roof surfaces and walls is always calculated for the reference height z = ridge height.

The software allows a height-specific distribution of the gust velocity pressure over vertical walls in accordance with illustration 7.4 .

The external and internal pressures are calculated with the help of the aerodynamic coefficients for the different building types.

Wind action of free-standing walls is calculated with the help of aerodynamic coefficients in accordance with paragraph 7.4.

For flat roofs with parapet, the wind load on the parapet is calculated as for free-standing walls in accordance with paragraph 7.4.

EN 1991-1-4

The Eurocode proposes the following expressions for the calculation of the basic wind velocity pressure q_b:

$$q_b = \frac{1}{2} \cdot \rho \cdot v_b^2 \quad (4.10)$$

with $v_b = c_{dir} \cdot c_{season} \cdot v_{b,0}$ (4.1)

The directional and seasonal factors may be set to 1 each for reasons of simplification whereas the basic value of the basic wind velocity $v_{b,0}$ is imposed by the competent authority or the relevant National Annex.

The gust velocity pressure for the height z can be determined on the basis of q_b with the help of the terrain factor as per (4.8) and (4.9):

$$q_p(z) = c_e(z) \cdot q_b$$

As shown in illustration 7.5, the gust velocity pressure $q_p(z)$ on all roof surfaces and walls is always calculated for the reference height z = ridge height.

The terrain factor ce is determined with the help of various coefficients in the expression:

$$c_e(z) = \left[1 + 7 \cdot I_v(z)\right] \cdot c_r^2(z) \cdot c_o^2(z) \,.$$

with turbulence intensity $I_v(z) = \frac{k_I}{c_o(z) \cdot \ln \frac{z}{z_0}}$ (4.7)

The turbulence factor k_I and the topographic factor c_o may be assumed 1.0 for simplification. Methods for the accurate calculation are proposed in the annex to EN.

The friction coefficient can be determined as follows:

$c_r(z) = k_r \cdot \ln \frac{z}{z_0}$ (4.4) with $k_r = 0{,}19 \cdot \left(\frac{z_0}{z_{0,II}} \right)^{0{,}07}$

The aerodynamic coefficients are specified for the different building shapes in paragraph 7.2. The wind loads are calculated using these factors:

Exterior: $w_e = q_p(z) \cdot c_{pe}$

Interior: $w_i = q_p(z) \cdot c_{pi}$

There are no stipulations on wind action on canopies in the Eurocode (without NA).

The National Annexes may specify other methods and values!

In the following, only specifications that differ in the various National Annexes are described:

DIN EN 1991

Equation 4.8 cannot be used for Germany due to the applicable wind profile for this region. The gust velocity pressure is calculated as specified in annex NA.B instead.

In Germany, wind zones are distinguished in addition to terrain categories.

The tables NA.B.2 and NA.B.4 propose formulae for the determination of q_p and v_p for the different terrain categories and wind zones.

In Germany, the aerodynamic coefficients stipulated by the Eurocode (without NA) are used in most cases. There are some tables for vertical walls and a supplement for flat roofs, however.

Wind action on canopies is calculated using the aerodynamic coefficients specified in annex NA.V.

ÖNORM EN 1991

Equation 4.8 cannot be used for Austria due to the applicable wind profile for this region. The gust velocity pressure is calculated in accordance with NA.6.3.2.1.

In paragraph 6.3.2.1, table 1 gives different expressions for the determination of q_p depending on the terrain category. In Austria, the categories 0 and I need not be taken into consideration.

Paragraph 9.2 contains standard-specific tables for wind pressure coefficients for wind action on the different types of buildings.

Wind action on canopies is calculated using the aerodynamic coefficients specified in paragraph 9.2.9.

Snow loads

The software first determines the ground snow load s_k on the basis of the specified border conditions.

Subsequently, the roof snow load s_i can be calculated by taking various factors and the shape coefficients μ into account for the different building types.

Depending on the selected type, additional eaves and drift snow loads are determined with the help of the shape coefficients.

You can optionally put out accidental snow loads for a given factor C_{esl}.

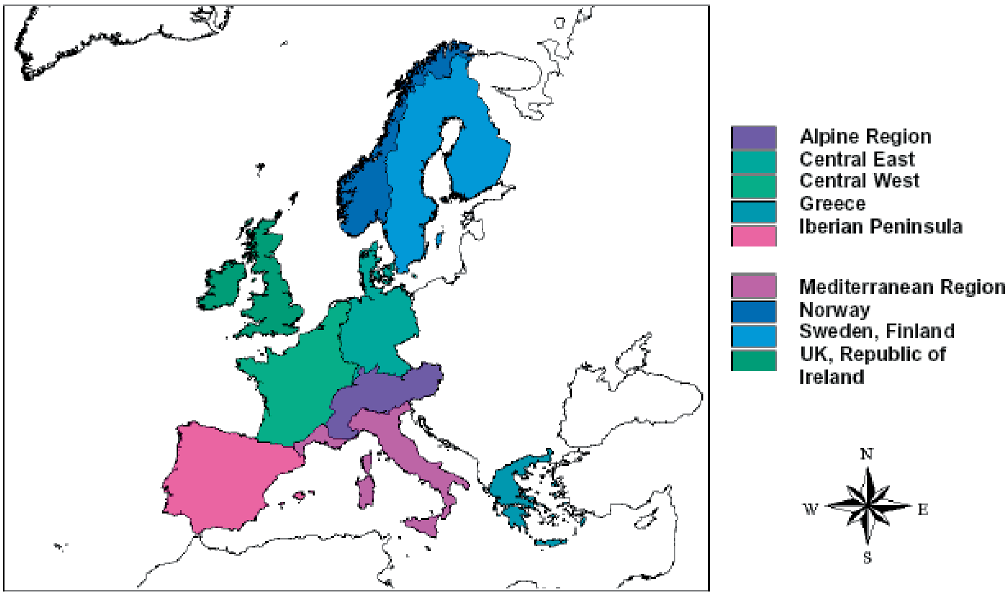
Another option allows you to put out the snow drift load cases for saddle-type roofs (case II and III).

If projections have been defined, the loads from overhanging snow at the eaves are determined. Because high roof snow loads in exposed locations may produce unrealistically high eaves snow loads, the State Building Codes often provide factors to reduce the loads from overhanging snow.

Optionally, the snow loads on user-defined snow guards can be calculated.

EN 1991-1-3

The Eurocode without NAs distinguishes in Annex C different climatic zones:



For each of these zones, table C.1 specifies a different expression for the determination of the ground snow load s_k:

Alpine Region	$s_k = (0,642 \cdot Z + 0,009) \cdot \left[1 + \left(\frac{A}{728}\right)^2\right]$
Central East	$s_k = (0,264 \cdot Z + 0,002) \cdot \left[1 + \left(\frac{A}{256}\right)^2\right]$
Central West	$s_k = 0,164 \cdot Z - 0,082 + \frac{A}{966}$
Greece	$s_k = (0,420 \cdot Z + 0,030) \cdot \left[1 + \left(\frac{A}{917}\right)^2\right]$
Iberian Peninsula	$s_k = (0,190 \cdot Z + 0,095) \cdot \left[1 + \left(\frac{A}{524}\right)^2\right]$

Mediterranean Region	$s_k = (0{,}498 \cdot Z + 0{,}209) \cdot \left[1 + \left(\frac{A}{452}\right)^2\right]$
Norway	
Sweden, Finland	$s_k = 0{,}790 \cdot Z + 0{,}375 + \frac{A}{336}$
UK, Republic of Ireland	$s_k = 0{,}140 \cdot Z - 0{,}100 + \frac{A}{501}$

The snow load on roofs is calculated from these expressions:

$s = \mu \cdot C_e \cdot C_t \cdot s_k$ (5.1),

or $s = \mu \cdot C_e \cdot C_t \cdot s_k \cdot C_{esl}$ (5.2, 4.1) for accidental situations with a recommended $C_{esl} = 2{,}0$.

The environmental coefficient C_e and the thermal coefficient C_t can be defined by the user whereas the shape coefficients μ are determined in accordance with paragraph 5.3.

In the event of projections at the eaves, you can optionally determine the loads from overhanging snow:

$s_e = k \cdot \frac{s^2}{\gamma}$ (6.4) whereby Eurocode recommends γ = 3 kN/m³ as a specific weight and for $k = \frac{3}{d}$ with $k \le d \cdot \gamma$.

If snow guards have been defined, the snow loads on the guards can be calculated as follows:

$F_s = s \cdot b \cdot \sin\alpha$ (6.5)

Loads from snow drifts at walls and superstructures can be determined in accordance with paragraph 6.2:

Regular snow load $s_1 = \mu_1 \cdot s_k$ with μ_1= 0.8 (6.1)

and $s_2 = \mu_2 \cdot s_k$ with $\mu_2 = \gamma \cdot \frac{h}{s_k}$ and γ = 2.0 (6.1), whereby $0{,}8 \le \mu_2 \le 2{,}0$ (6.2)

and $l_s = 2 \cdot h$ with $5m \le l_s \le 15m$ (6.3)

The snow sliding off from taller structures is calculated in accordance with paragraph 5.3.6 as follows:

$s_1 = \mu_1 \cdot s_k$ with $\mu_1 = 0{,}8$ (5.6) under the assumption that the lower roof surface is flat.

$s_2 = \mu_2 \cdot s_k$ with $\mu_2 = \mu_s + \mu_w$ (5.7)

The shape coefficient for snow drift is $\mu_w = \frac{b_1 + b_2}{2 \cdot h} \le \gamma \cdot \frac{h}{s_k}$ (5.8) with $0{,}8 \le \mu_w \le 4$.

It is permissible to set the shape coefficient for sliding off snow μs to 0 if a ≤ 15°. Otherwise, the value is determined by 50 % of the roof snow load of the abutting roof surface.

$$\mu_s = \begin{cases} 0(\alpha \le 15°) \\ 0{,}5 \cdot \mu_{Dachfläche}(\alpha > 15°) \end{cases}$$

The length of the snow drift is $l_s = 2 \cdot h$ with $5m \le l_s \le 15m$ (6.3)

The National Annexes may specify other methods and values!

In the text below, only the differences among the National Annexes are described:

DIN EN 1991

The snow and climatic zones specified in Annex C are not relevant for Germany. The German NA specifies its own snow zones as shown on the map NA.1 and associated formulae for the calculation of the ground snow load s_k such as the expressions NA.1 to NA.3. It also specifies its own basic amounts.

The shape coefficients μ are taken over for the most part, with the exception of the coefficients for adjacent roofs and roofs abutting taller structures, which are stipulated in the NCI to 5.3.4(4) and 5.3.6.

It is permissible to determine μ_w with the help of expression (NA.4). The expressions (NA.5) to (NA.8) stipulate deviating limits for $\mu_w + \mu_s$.

For snow loads on eaves, the German NA recommends setting the k coefficient to 0.4.

For the accidental situation, a factor C_{esl} = 2.3 should be assumed.

ÖNORM EN 1991

The snow and climatic zones specified in Annex C are not relevant for Austria. The Austrian NA specifies its own snow zones in NA.Annex A and associated formulae for the calculation of the ground snow load s_k in NA Annex B.

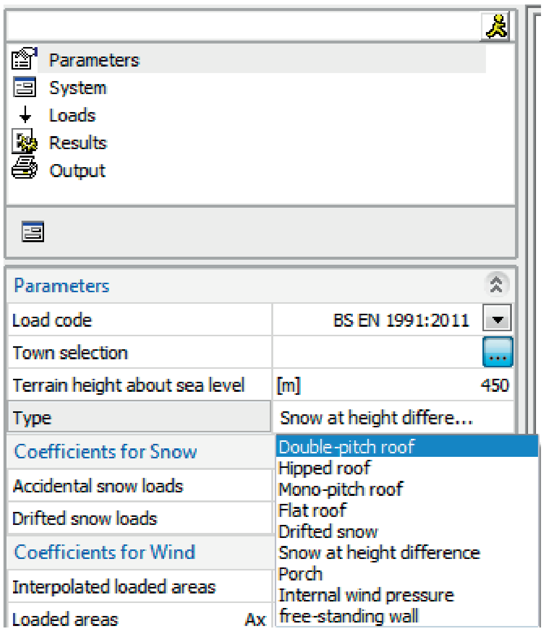
The shape coefficients μ are taken over for the most part. Specific values are defined in 4.5.2 for μ_2 and barrel roofs.

4.5.2.3 specifies deviating limits for μ_w.

For snow loads on eaves, the NA gives a separate formula in 4.6.2.

Definition

Basic parameters



To define the basic parameters, first select the load standard. The standards can be selected independently of the acquired licences.

Type select the type of building.

Depending on the selected standard, a list may be available for the selection of a municipality. The selection of the municipality provides for the pre-setting of particular parameters such as the wind or snow zone for example. If you change these values manually, the selection of the municipality is undone.

Moreover, the ground level above MSL is adjusted automatically.

Various settings

Snow coefficients

Snow load on eaves — only with DIN 1055: factor for the snow load on the eaves

With accidental snow load — switch for the consideration of accidental snow loads

Cesl — factor for accidental snow loads

Snow drift — switch to take the alternative snow load cases automatically into account

Wind coefficients

CDir — factor for the wind direction

CSeason — seasonal factor

Orography — auxiliary dialog for the optional consideration of the topography

Φ — ground surface inclination (H/Lu)

s — orography factor

Interpol. loaded area — switch to take a user-defined loaded area with a surface of $1\ m^2 < A < 10\ m^2$ into account or not.

Ax — size of the user-defined loaded area

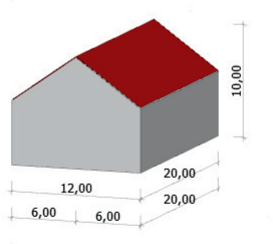
Graphical representation

Fill areas — enables colour filling of wind areas. In order to ensure readability, this option should be disabled if the results are put out on a black-and-white printer.

Structural system

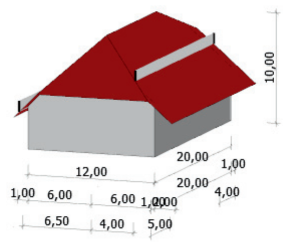
Symmetrical — if this option is enabled, the symmetrical values are set automatically and the corresponding fields are greyed out in the user interface.

Double-pitch roof



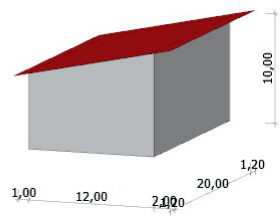
h	building height up to the ridge
ly	building length (in ridge direction, from gable to gable)
lx,le	building width on the left side of the ridge (projection length)
lx,ri	building width on the right side of the ridge (projection length)
αle	roof pitch on the left
αri	roof pitch on the right
ole	roof overhang on the left
ori	roof overhang on the right
o1	roof overhang at the front gable
o2	roof overhang at the rear gable
ble	distance of the left snow guard to the ridge (if applicable)
bri	distance of the right snow guard to the ridge (if applicable)

Hip roof



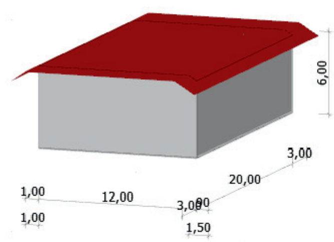
h	building height up to the ridge
ly	building length (in ridge direction, from gable to gable)
lx,le	building width on the left side of the ridge (projection length)
lx,ri	building width on the right side of the ridge (projection length)
αle	roof pitch on the left
αri	roof pitch on the right
ole	roof overhang on the left
ori	roof overhang on the right
o1	roof overhang at the front gable
o2	roof overhang at the rear gable
ble	distance of the left snow guard to the ridge (if applicable)
bri	distance of the right snow guard to the ridge (if applicable)
αun	hip pitch at the front gable
αob	hip pitch at the rear gable
lb	length of the hip at the front gable (in the projection)
lt	length of the hip at the rear gable (in the projection)

Single-pitch roof



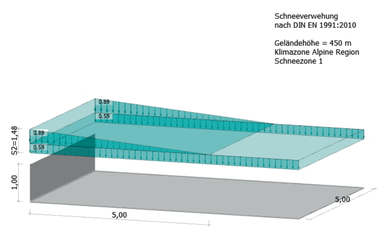
h	building height up to the ridge
ly	building length (in ridge direction, from gable to gable)
lx	building width (projection length)
α	roof pitch
ole	roof overhang on the left
ori	roof overhang on the right
o1	roof overhang at the front gable
o2	roof overhang at the rear gable
bri	distance of the right snow guard to the ridge (if applicable)

Flat roof



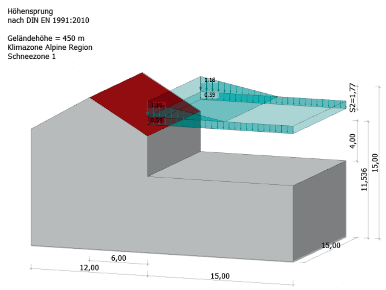
h	building height
ly	building length (in ridge direction, from gable to gable)
lx	building width (projection length)
Eaves	design of the eaves: - sharp-edged - with parapet - bevelled - rounded
ole	roof overhang on the left
ori	roof overhang on the right
o1	roof overhang at the front gable
o2	roof overhang at the rear gable
hple	parapet height on the left side
hple	parapet height on the right side
αli	bevel pitch on the left side
αre	bevel pitch on the right side
ls,li	bevel length on the left side
ls,li	bevel length on the right side
rli	radius of left rounding
rre	radius of right rounding

Snow drift



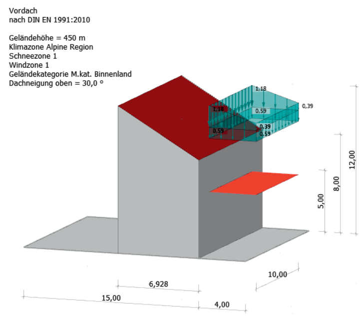
h	height of the superstructure
l	length of the superstructure

Roof abutting taller structures



b1	width of the taller building
b3	effective building width (ridge to eaves) on the abutting side
b2	width of the smaller building
ht	eaves height (of the taller building)
αob	pitch of the roof surface abutting the taller building
h	difference in height between the smaller building and the taller building (eaves).
ly	length of the building (only required for the graphical representation)

Canopy



hf	ridge height of the building
bG	width of the building
αob	roof pitch of the building
b3	effective building width (ridge to eaves) on the abutting side
h1	height of the canopy above ground level
b1	width of the canopy
d1	length (depth) of the canopy

Wind-induced internal pressure

Opening	*only with DIN 1055*
ly	length of the building
lx	width of the building
h	wall height
ΔAle	total of openings on the left side
ΔAle	total of openings on the right side
ΔA1	total of openings on the front side
ΔA2	total of openings on the rear side

Free-standing wall

l	wall length
l1	angle side length (with angular walls)
h	wall height
b	wall width
φ	solidity ratio: 1 = solid wall … 0.8 = wall which is 80 % solid

Loads

The available options depend on the selected standard

- climatic zone
- snow zone
- wind zone (DIN EN 1991)

You can make your selection via a list or a map (dialog).

In addition

- terrain category
- basic wind velocity pressure (vb0)
- basic wind pressure (qb0)

DIN 1055:2006:

qref impounding wind reference pressure. The value is determined automatically in line with the selected wind zone and cannot be edited.

Loads for advanced calculations

Depending on the selected type of building, the following parameters can be defined in this section:

sk ground snow load

q(h) velocity pressure of the reference height h

q(b) velocity pressure of the reference height b, if a stepwise reduction of the wind load is justified by the wall height.

q(h,90) velocity pressure of the reference height h for wind approaching the gable side. The value can differ from that for wind approaching laterally because the wind action width is different.

q(b) velocity pressure of the reference height b for wind approaching the gable side, if a stepwise reduction of the wind load is justified by the wall height.

Notes:

The parameters to define might differ depending on the active National Annex.

Basic values for snow - DIN EN 1991-1-3/NA:2010:

The selection of a climatic zone can be dispensed with in Germany.

Basic values for snow - ÖNORM B 1991-1-3:2009

The selection of a climatic zone can be dispensed with in Austria.