Roof: Loads - Design

The present documentation provides additional information on our Dach+ (roof) application.

Contents

Basic Documentation – Overview

In addition to the individual program manuals, you will find basic explanations on the operation of the programs on our homepage www.frilo.com in the Campus-download-section.

Tip: Go back - e.g. after a link to another chapter / document - in the PDF with the key combination "ALT" + "left arrow key".

Load assumptions as per EN 1991

The program generates standard load cases for given basic load and coefficient values.

Special conditions can be taken into account by entering additional load cases.

The load case combinations are then automatically determined by the program from the standard load cases and optional additional load cases.

Snow load – EN 1991-1-3

The snow load "s_i" is determined in accordance with the relevant National Annex to EN 1991-1-3. The load values are referenced to the ground projection.

In connection with projections, additional concentrated loads S_e applying at the eaves are taken into account in accordance with EN 1991-1-3, 6.3. The snow load on the eaves is considered as a separate individual load case.

Standard	Snow load [kN/m² Gfl]	Snow load on eaves [kN/m eaves lengths]
Proposed by DIN EN 1991-1-3	$s_i = \mu_i \cdot C_e \cdot C_t \cdot s_k$ with C_e=1 and C_t=1	$S_e = \frac{s_i^2}{\gamma}$ with $\gamma = 3\frac{kN}{m^2}$
ÖNORM B 1991-1-3	$s_i = \mu_i \cdot C_e \cdot C_t \cdot s_k$ with C_e=1 and C_t=1	$S_e = 0{,}5 \cdot s_i$
NA to BS EN 1991-1-3	$s_i = \mu_i \cdot C_e \cdot C_t \cdot s_k$ with C_e=1 and C_t=1	$S_e = \frac{s_i^2}{\gamma}$ with $\gamma = 3\frac{kN}{m^2}$

The shape coefficients μ are stipulated in the individual National Annexes.

Depending on the geographical situation, coordination with meteorological data is required. Therefore, the snow load value s_i is editable and can be changed for subsequent calculations ("User-defined values" button).

This applies also to the snow load on the eaves.

Optionally, the alternative drifted snow load case (case ii) can be taken into account in accordance with the standard ("Snow accumulation left/right" option). As the inclination angles of abutting roof areas are not known in the software application, the existing roof pitch is used for the average inclination angle $\bar{\alpha}$ at the eaves. $\bar{\alpha}$ can be taken into account for rafters at the ridge. The drifted snow loads are calculated in accordance with EN 1991-1-3, 5.3.4 with the respective average inclination angle of the roof:

$s_{i,Eaves} = \mu_2(\alpha) \cdot s_k$

$s_{i,Ridge} = \mu_3(\bar{\alpha}) \cdot s_k$, if α_{le} and α_{ri} are known. Otherwise with $\bar{\alpha} = \alpha_{Roofarea}$

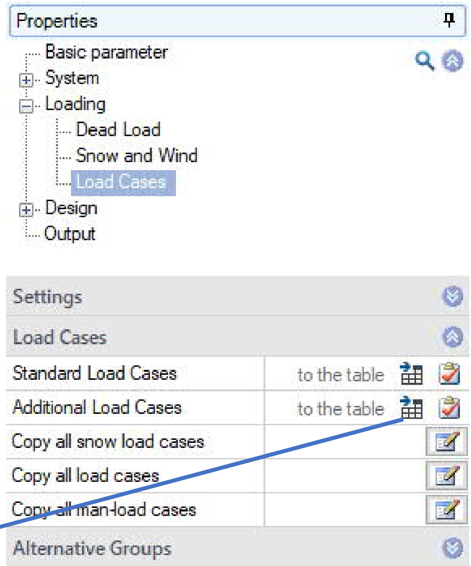
In order to consider snow drifts in particular sections (e. g. on jack rafters of valley rafters), you can specify another reference length. By default, the reference length is set to the projection length of the rafter.

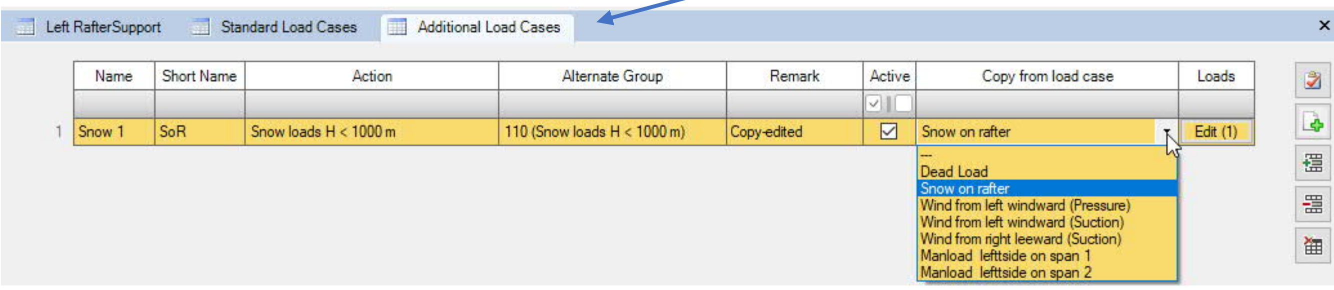
Snow accumulations on roof areas abutting to each other with known roof pitches, snow drifts at roof structures or additional snow loads resulting from offsets in height or snow guards cannot be taken into consideration in the above-mentioned approaches to standard snow load.

These particularities can be entered in the Additional loads section.

The National Annexes to EN 1991-1-3 allow the consideration of accidental snow loads for particular geographical areas. Since the factors for accidental snow loads vary in the different National Annexes and are intended as a recommendation, the C_{esl} value is editable in the software.

If another value is specified, the software application generates additional superpositions in accordance with the stipulations for accidental design situations and verifies these superpositions in addition. Only the decisive results are put out.





Regular snow load — the snow load can be assigned to different action groups depending on the selected National Annex. When specifying an altitude in the wind and snow loads dialog, the action group is adjusted automatically in particular cases.

Wind load – EN1991-1-4

Wind pressure

The external wind pressure is determined in accordance with EN 1991-1-4, 5.2:

Wind pressure $w_e = c_{pe} \cdot q$ [kN/m² perpendicular to the roof surface]

The software application assumes that the load introduction area is larger than 10 m². Therefore, always the $c_{pe,10}$ values are used as aerodynamic coefficients.

The $c_{pe,10}$ values are determined for the flow direction $\theta = 0°$ and the inner rafters in accordance with EN 1991-1-4, 7.2.3 to 7.2.5. This produces different wind loads for the G, H, J and I areas.

The G and J areas are assessed up to a distance of $e/10$ from the floor plan or the ridge. e is the smaller value of b (wind action width) or 2h (building height).

If alternative values are used, always the pressure coefficient is taken into account instead of the load-easing suction coefficient.

The aerodynamic coefficients as per 7.2.3 to 7.2.6 cannot be varied by selecting a different National Annex, whereas the other aerodynamic coefficients (e.g. for wind acting on walls) can. The values can be taken from the tables in the respective National Annex.

Wind uplift

For projections, the aerodynamic coefficient of the abutting wall is taken into account for wind uplift. For the windward side, the D-area coefficient and for the leeward side, the E-area coefficient is used.

On the top side, the wind pressure on the adjacent roof area is considered, i. e. the windward cantilever is entirely categorized as G area and the leeward cantilever as I area.

Man load P = 1 [kN] - EN 1991-1-1

Man loads applying in unfavourable points can be taken into account in the calculation of the internal forces in accordance with EN 1991-1-1, 6.3.4.

Depending on the National Annex, you can choose between consideration as a single or distributed load.

In the combination process, man load is treated as a separate action group (category H) and combined in accordance with the rules of EN 1990-1. A simultaneous inclusion of man load together with snow and wind load is not required according to EN 1991-1-1, 3.3.2(1).

Superpositions as per EN 1990-1

The combination rules for the semi-probalistic partial safety concept are laid down in EN 1990-1.

For the structural safety verification, the combinations for the permanent and transient design situations are generated. In addition, the accidental design situation (e. g. accidental snow load cases) can optionally be taken into account.

For the serviceability verification as per EN 1995-1-1, 7.2, only the infrequent and quasi-permanent design situations are relevant.

The software application generates internally all combinations in accordance with the specified rules and performs all corresponding verifications. Only the combinations that are decisive in the individual verifications are put out, however.

Calculation

To calculate, click on the "Calculate" button in the upper menu bar.

Option Auto-Calculation

This option can be switched on under File - Settings if the runtime behavior of your computer is satisfactory, so that a new calculation can be carried out immediately with each input change.

Sign definition

The signs of the internal forces and the support reactions are defined in accordance with the conventions of the FRILO Framework application RSX.

The following conditions apply to internal forces:

- Axial forces N are positive as tension forces and negative as compression forces.
- The signs of shear forces Q are determined in accordance with the acknowledged rules of civil engineering.
- Bending moments M are positive if they generate tension in the tension zone of the member (dashed line parallel to the axis).

The supporting forces are put out as reaction forces.

- Horizontal support reactions are positive when they act in the negative direction of the x-axis.
- Vertical support reactions are positive when they act from the bottom to the top.
- Torques at the support are positive when the act anti-clockwise.

The support reactions are referenced to the global x-z system of coordinates.

Load-bearing capacity verification as per EN 1995-1-1

The stresses are calculated for each load case in all eightpart points on each member from the locally applying internal forces. Only the decisive stresses are put out.

The stress resistance verifications are performed as specified by para. 6.2. For the shear stress resistance verification, the full shear force applying to the support is taken into account.

The stability verification is based on the equivalent bar method specified by para. 6.3.

The buckling length sK for the stability verification of the rafters is determined by default from the eigenvalue analysis for each load case. Since at low normal forces stressed beams can produce huge buckling lengths, sK is limited to 0.9 times the length of the rafters. The user also has the optional capability to change the border conditions, or to define the buckling lenght for every bar - see “Buckling- and tilting length”.

Serviceability verifications as per EN 1995-1-1

The serviceability verifications are based on the stipulations of the National Annexes to EN 1995-1-1, 7.2. and 2.2.3:

Standard	Verifications	Design situation
Proposed by EN 1995-1-1	w_{Inst}, w_{fin}, w_{net}	Characteristic situation
ÖNORM B 1995-1-1	$w_{Q,inst}$, w_{fin}*	Characteristic situation
	w_{net}	Quasi-permanent situation
DIN EN 1995-1-1/NA:2010	As specified by EN 1995-1-1	

The deformations $w_{Q,inst}$, w_{fin}* in the characteristic design situation and w_{fin} in the quasi-permanent design situation are calculated in accordance with ÖNORM B 1995-1-1:2009, 5.7.2.
The limitation of vibrations in accordance with EN 1995-1-1, 7.3 is currently not taken into account.

Hot design as per EN 1995-1-2

Part 2 of EN 1995 deals with the hot design.
The following burning rates are specified as recommended values in table 3.1:

Timber	βn [mm/min]
Softwood ($\rho_K \geq 290 \frac{kg}{m^3}$)	0.8
Laminated timber	0.7
Hardwood ($\rho_K < 450 \frac{kg}{m^3}$)	0.7
Hardwood ($\rho_K \geq 450 \frac{kg}{m^3}$)	0.55

These values can be changed in the NAs.
The selected NA determines the calculation method to be used (accurate/simplified) and whether a method is allowed, mandatory or forbidden.

EN 1995-1-2. 4.2.2 determines the simplified method (reduced cross section).
EN 1995-1-2, 4.2.3 describes the more accurate method (reduced cross section and reduced properties).

Simplified method

The burn-off loss results from the expression $d_{ef} = d_0 + d(t_f)$

The cross section is reduced by the burn-off loss and the cross sectional properties are determined for the reduced cross section: $b_{fi} = b - n \cdot d_{ef}$ $d_{fi} = d - n \cdot d_{ef}$ Afi, Wfi, Ifi with bfi and dfi.

$k_{mod,fi} = 1,0$

More accurate method

First, the cross section is reduced by the burn-off loss and the cross sectional properties are determined for the reduced cross section: $b_{fi} = b - n \cdot \beta \cdot t_f = b - n \cdot d(t_f)$ $d_{fi} = d - n \cdot \beta \cdot t_f = d - n \cdot d(t_f)$
Afi, Wfi, Ifi with bfi and dfi.

The strengths values are calculated as follows: $X_{d,fi} = k_{mod,fi} \cdot \frac{X_{0,2}}{\gamma_{M,fi}} = k_{mod,fi} \cdot \frac{k_{fi} \cdot X_{0,05}}{\gamma_{M,fi}}$

Bending	$k_{mod,fi} = 1 - \frac{1}{225} \cdot \frac{u}{A}$
Compression in direction of the grain	$k_{mod,fi} = 1 - \frac{1}{125} \cdot \frac{u}{A}$
Tension in direction of the grain, modulus of elasticity and shear modulus	$k_{mod,fi} = 1 - \frac{1}{333} \cdot \frac{u}{A}$

Timber	k_{fi}
Solid wood	1.25
Laminated timber	1.15

With laminated timber, the dispersion is lower and the bell curve narrower. The distance between 5 % and 20 % is therefore smaller and kfi too.

Special case: shear design under fire exposure

For mainly shear-loaded components, scientific findings are not available yet.

Experiments by M. Peter revealed that a beam mainly under shear load, which should have a sufficient load-bearing capacity according to the results of the simplified method failed in the supports under shear load!

Therefore, shear resistance is not verified in the hot design.

Instead of the verification, the shear stress in the cold situation with the full cross section is merely compared to the shear stress in the hot situation with the ideal remaining cross section in accordance with the simplified method.

ÖNORM B 1995-1-2:2008-12

The standards prohibits the more accurate method. Only the simplified method with a reduced cross section as per 4.2.2 is allowed.

DIN EN 1995-1-2/NA:2010-12

The standard allows both methods (4.2.2 and 4.2.3), but explicitly recommends using the simplified method in accordance with 4.2.2.

NA to BS 1995-1-2:2004

The use of the method specified in 4.2.2 is recommended.

Collar-Beam Roof: virtual supports on a non-sway collar-beam roof

If a non-sway collar-beam roof was defined, horizontally fixed supports are automatically inserted at the collar beam connections. The calculation of the internal forces, support reactions and deformations refers exclusively to this structural strut-and-tie system. The support reactions generated at the virtual supports are treated as axial force in the collar beam in the subsequent design. The verification of the valley plate's stiffening effect is not performed!

Anti-tilting protection

Anti-tilting protection of the rafters by roof battens is permissible according to EN 1995-1-1:/NA:2010, NCI to 6.3.1, if the roof span is ≤ 15 m, the rafter spacing is ≤ 1.25 m and the ratio of the cross section's height and width h/b is ≤ 4.

Anti-tilting protection with board formwork is permissible if g/q is < 0.5, the roof span is ≤ 12.5 m and the rafter spacing is ≤ 1.25 m

The following conditions must be satisfied in addition

- Length of the roof	≥ 0.8, but roof span ≤ 25 m
- Board width	≥ 12 cm
- Board offset	≥ 2 · rafter spacing
- Joint width	≤ 1 m
- Nail fixing of board	≥ 2 nails per chord and board joint

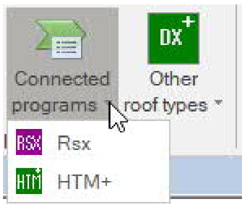
Verification of the wind suction resistance

→ See the chapter Verification of the wind suction resistance.

Load transfer

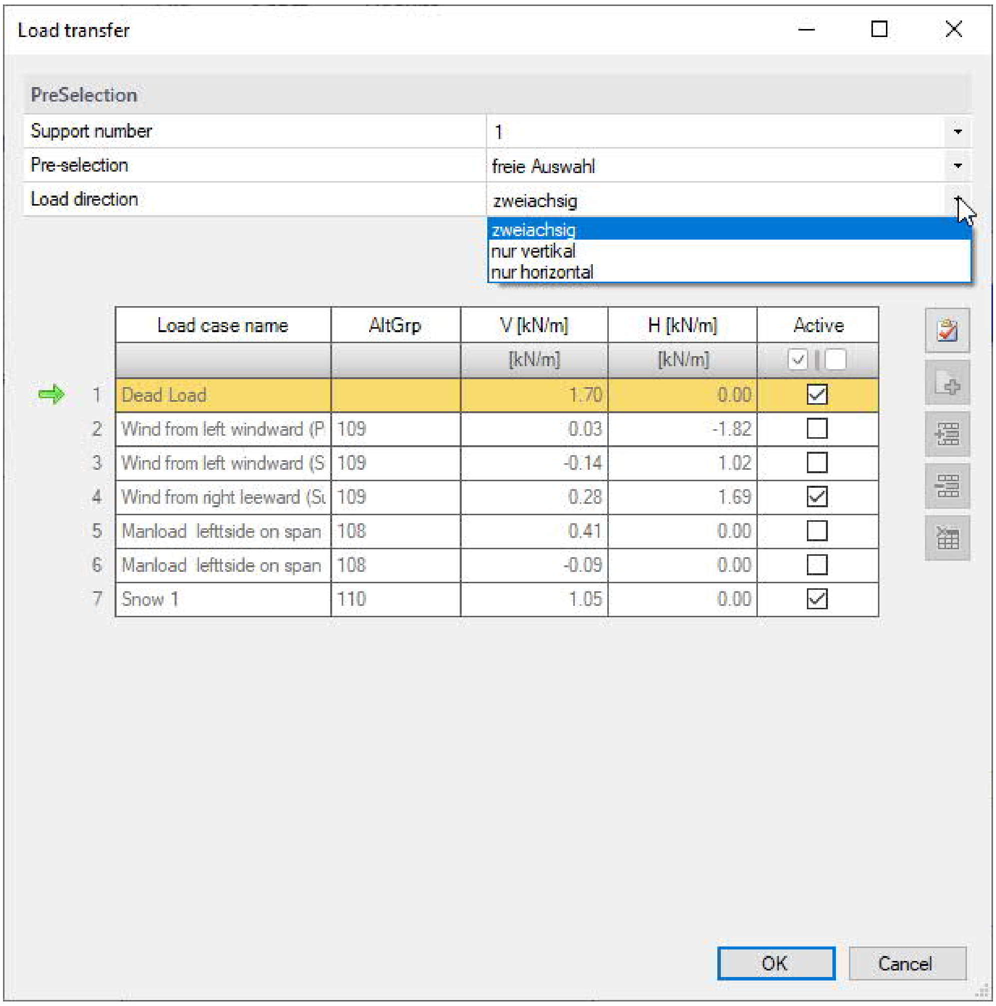
After the calculation of the roof, it is possible to start the program Continuous Beam Timber HTM+ (or in the future also Continuous Beam Steel STM+) for the dimensioning of the purlins (if these programs are licensed/installed).

The activated support reactions of the selected support (support number) are transferred to the connected program via the Load transfer dialog.



There, the single-span girder is generated with the defined material and cross section. You must select the actual purlin length and the number of spans manually in the connected program. The loads are automatically generated as multispan loads acting over the entire girder length.

Note: The data are NOT returned by the connected program!



Verification of the wind suction resistance

EN 1991-1-4:2010

The verification is always performed for the most unfavourable rafter in the edge area because the upwind loads in the F area are always greater than in the G or E area (in the middle).

In addition to the wind directions "from the left" and "from the right", also the flow direction towards the gable is taken into account.

In the uplift resistance verification always the c_{pe1} wind coefficients are used, because the uplift protections are always considered to act in particular points.

The combination process is performed as specified by EN 1990, A.1.3, table A.1.2.(A) in accordance with the stipulations on the position stability verification.

The output table specifies the design resistances in the x- and z- direction (horizontal and vertical) in addition to the required design resistance of the protections perpendicular to the rafter axis.