FRILO
Software
A NEMETSCHEK COMPANY

Timber Design HO11+

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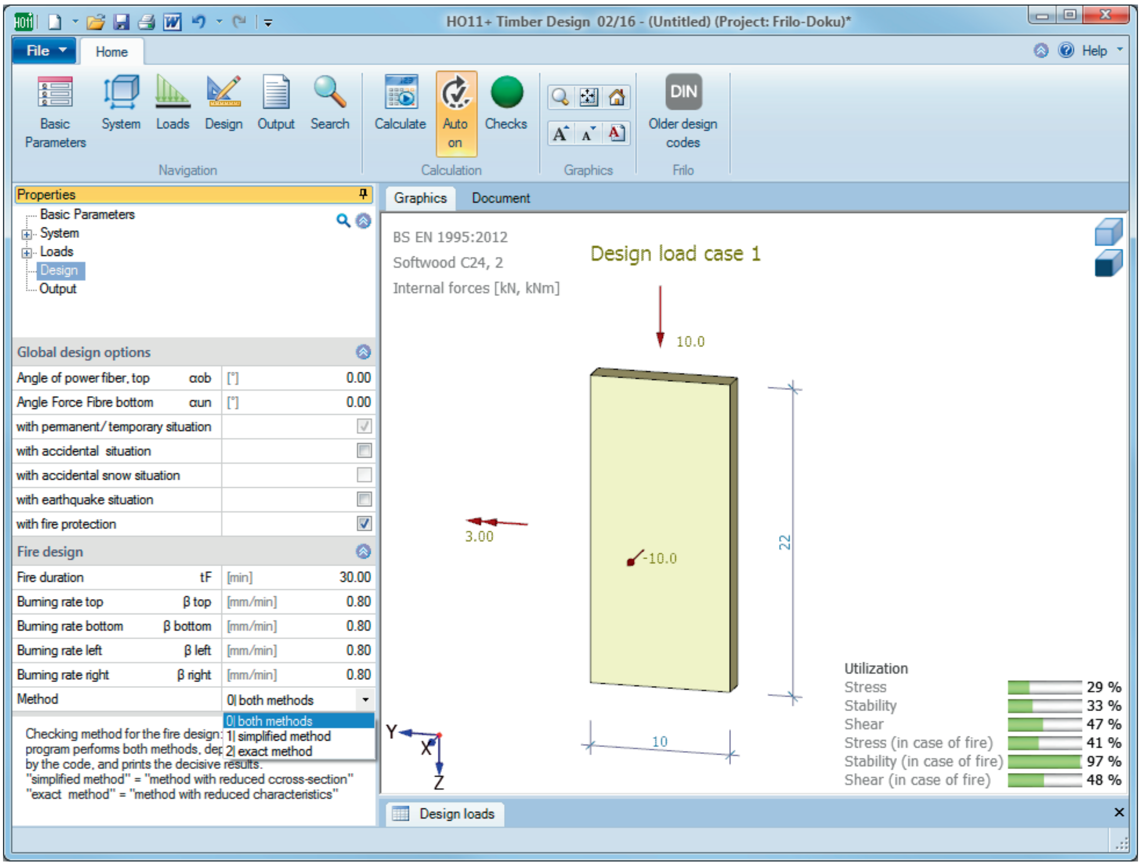
Version: 2/2016

As of 23/06/2016



Timber Design HO11+

Inhaltsverzeichnis

Further information and descriptions are available in the relevant documentations:

Basic operating instructions-PLUS	General operating instructions for the user interface of Frilo applications
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
Menu items.pdf	
Output and printing	
Import and export.pdf	

Application options

The software application is suitable for the verification of timber cross sections in accordance with the design rules specified in:

- EN 1995
- DIN EN 1995
- ÖNORM EN 1995
- UNI EN 1995
- NTC EN 1995
- BS EN 1995

The HO11 application performs typical stress-resistance verifications of tension-, compression- or bending-loaded timber members as well as buckling safety and stability verifications. If shear and torsion effects apply, shear-stress analyses are performed in addition. The buckling resistance and lateral stability are verified on an equivalent member system.

For classified timber components in the sense of DIN 4102-4/-22 or EN 1995, 1-2, the fire-resistance period can be determined by means of a hot design process with consideration of the specified burning rates.

In combination with EN 1995:2008, you can optionally specify resulting load cases or independent single actions with the associated load-action period (LAP) and combine them for the bearing strength verification.

Basis of calculation

For the verifications in accordance with EN 1995, you can optionally determine the internal design forces from the combinations for the bearing strength verifications as per EN 1990. The verifications are performed for solid timber. The fire-safety verifications are based on EN 1995-1-2.

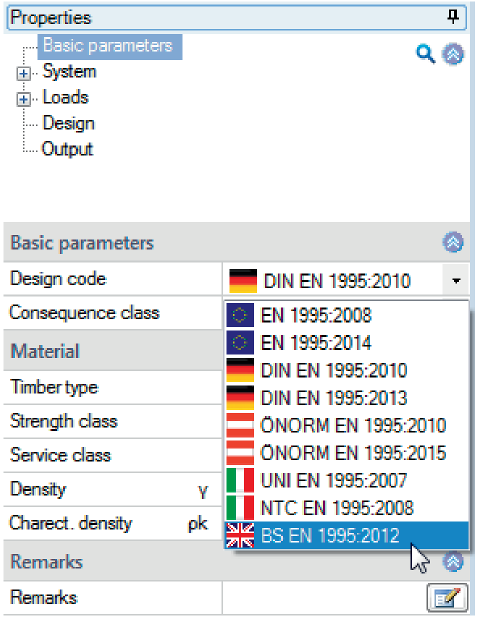
The local member and cross section coordinates comply with the specifications of DIN 1080. The x-axis runs in direction of the positive member axis. The y- and z-axes lie inside the cross section and the positive z-axis points downwards. The x-y-z system consists of three orthogonal legs.

Internal forces and geometric vectors are positive if they are oriented in the direction of the positive axes. The moments *My* and *Mt* are positive if they describe a right-hand helix around the y- and x-axes. Whereas the bending moment *Mz* is positive, according to structural conventions, when it describes a right-hand helix in direction of the negative z-axis in such a way that tension is produced on the positive cross-section sides (dashed lines) when a positive moment load applies.

Data entry

Basic parameters

Select the desired standard for the consequence class.



Material

Select the timber category, either timber or composite timber,

and the timber type (available options depend on the selected standard):

Softwood, hardwood, glulam.

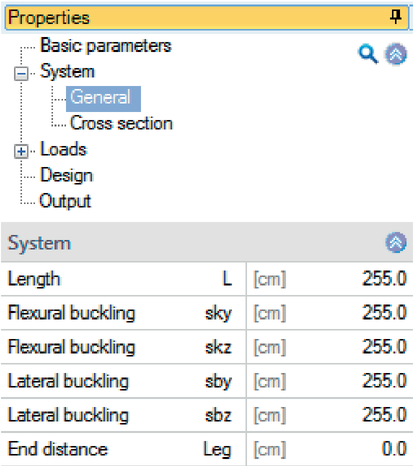
Subsequently, select the strength class.

The influence of humidity on the timber materials is controlled by assigning the building/component to a use/service class.

You can enter the density γ in addition.

System

General



L the member length *L*, is a default for the effective lengths for flexural and lateral buckling.

sky/skz effective length for flexural buckling in the z- or y-direction (associated to *Iy* or *Iz*).

sby/sbz effective length for lateral buckling of the compression flange in the y- or z- direction (associated to M_y and M_z).

Note: $sb_{y/z}$ *are similar to the lengths* $sk_{y/z}$ *in terms of mechanical effects.*

Leg distance to end-grain face; distance of the design cross section to the end-grain face, required e.g. for the shear force increase.

The local coordinate axes (x, y, z) for the member system are defined in accordance with DIN 1080.

In the two-dimensional member system, y is the bending axis and z the lateral buckling axis. In the three-dimensional member system, y corresponds to the main axis I and z to the main axis II.

The effective lengths are equivalent lengths that allow the assessment of buckling problems inside the global structural system. The buckling stability of a system is a function of the geometry, the stiffnesses and the current loading. Therefore, the effective length can be seen as the distance in length between the deflection points of an ideal buckling and deformation figure in the examined member section.

The effective length for lateral buckling can be interpreted in a similar manner. It is characterised by flexural buckling of the compression zone or the compression flange. As supports should be defined as fork supports, in general both values are of the same order of magnitude. If lateral supports have been defined in the compression zone, you can use the reduced length. You should note that the effective length sb_y corresponds to sk_z in terms of the mechanical effect. The same applies to sb_z and sk_y.

The flexural buckling coefficients *Lambda* and *Omega* as well as the lateral buckling coefficients *LambdaB* and *KB* are identified by the coordinate indices of their reference lengths *sk* and *sB*.

Cross section

You can define the cross section as a multi-piece rectangular cross section via its dimensions (b/d = by/dz). You can consider weakening of the cross section for the stress analyses by defining a recess on the individual cross section. The stiffness values are determined by the software under the condition that the individual cross sections are arranged symmetrically and connected to each other without shear. In connection with multi-piece cross sections, the transfer of actions to the individual cross sections must be ensured as with a member bundle – the loading is distributed proportionally to the individual cross sections.

by cross section width in the y-direction

dz cross-sectional height in the z-direction

Number in y number of cross sections defined in the y-direction

ay spacing between the cross sections in the y-direction

Number in z number of cross sections defined in the z-direction

az spacing between the cross sections in the z-direction

with hole this options displays the parameters to define a "weakening of the cross section".

Cross-section Dimensions			
Width	by	[cm]	10.0
Height	dz	[cm]	22.0
Number in y			1
Distance in y	ay	[cm]	0.0
Number in z			1
Distance in z	az	[cm]	0.0
with hole			☑
Hole			
CoG Distance	yS	[cm]	0.0
CoG Distance	zS	[cm]	0.0
Width	dy	[cm]	0.0
Height	dz	[cm]	0.0

The area *A*, the shear areas *AQ*, the section moduli *Wyy* and *Wzz* as well as the torsional section modulus *WT* are added up from the individual cross sections, if a multi-piece cross-section was defined. The composite action is not considered. The processing of the cross sectional properties is based on the units: cm, cm^2, cm^3, cm^4.

Stiffness values for symmetrical multi-piece cross sections:

htot = dz · kz + az · (kz - 1) (total height in the z-direction)

btot= by · ky + ay · (ky - 1) (total width in the y-direction)

A = by · dz · ky · kz

AQy = by · dz · ky · kz / 1.5 (shear area for max_TauY = Q/AQy)

AQz = by · dz · ky · kz / 1.5 (shear area for max_TauZ = Q/AQz)

WT = WT (individual cross section) · ky · kz

(torsional stiffness, interpolation of WT based on the table for rectangular cross sections)

$I_{yy} = b_y \cdot d_z^3 / 12 \cdot k_y \cdot k_z$ (second moment of area)

$i_{yy} = \sqrt{I_{yy} / A}$ (radius of inertia)

$W_{yy} = I_{yy} / (d_z/2)$ (resistance moment for My)

$I_{zz} = b_z \cdot b_y^3 / 12 \cdot k_y \cdot k_z$ (second moment of area)

$i_{zz} = \sqrt{I_{zz} / A}$ (radius of inertia)

$W_{zz} = I_{zz} / (b_y/2)$ (section modulus for Mz)

Hole

You can define an individual recess in this section.

The weakening is assumed to act in each partial cross section.

Note: *The required verifications for openings as per DIN EN 1995-1-1:2010, NCI NA 6.7, such as the verification of the transverse tension resistance, are not handled in this software application! Only the typical stress-resistance verifications are performed.*

yS distance of the centre of gravity (CoG) of the recess in the y-direction

zS coordinate of the centre of gravity (CoG) of the recess in the z-direction

dy width of the recess in the y-direction

dz height of the recess in the z-direction

The magnitudes of the deductions are calculated:

dA = dby · dbz = area deducted from the full cross-sectional area

dIyy = dby · ddz^3 / 12+dA · zs^2

dWyy = dIyy / (dz/2) = deducted section modulus

dIzz = ddz · dby^3 / 12+ dA · zs^2 = deducted section modulus

dWzz = dIzz / (by/2)

dAQy = deducted area for the shear stress analysis (not determined by calculation)

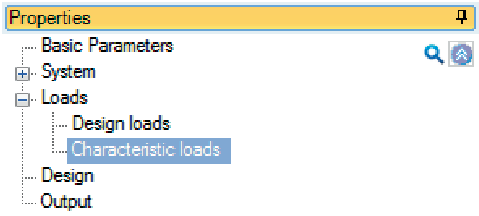
dAQz = deducted area for the shear stress analysis (not determined by calculation)

dWT = deducted **torsional section modulus** (not determined by calculation)

Where multi-piece cross sections are concerned, the deductions are multiplied with the number of cross sections and displayed for the composite cross section. Weakening is not considered in the fire safety verification.

Loads

Loads



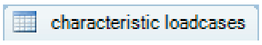
Select the load type: Design values, characteristic values or both.

Define the first load case directly in the data-entry mask.

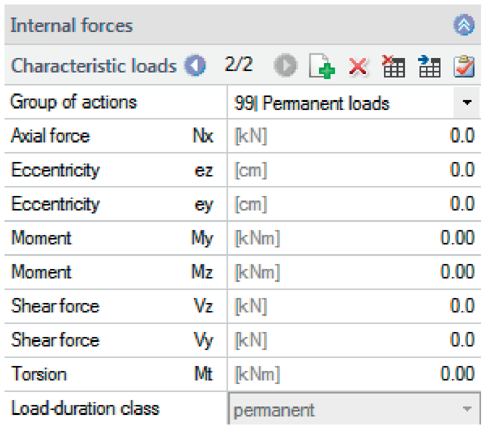
Add additional load cases with the help of the load case toolbar:

- see Data entry via tables (Basic Operating Instructions)

To add load cases, always set up a new load case first by activating the  button (a new load case definition mask is displayed each time).

Alternatively, add additional load cases via the load case table, which is accessible on the 

tab (below the graphic screen).



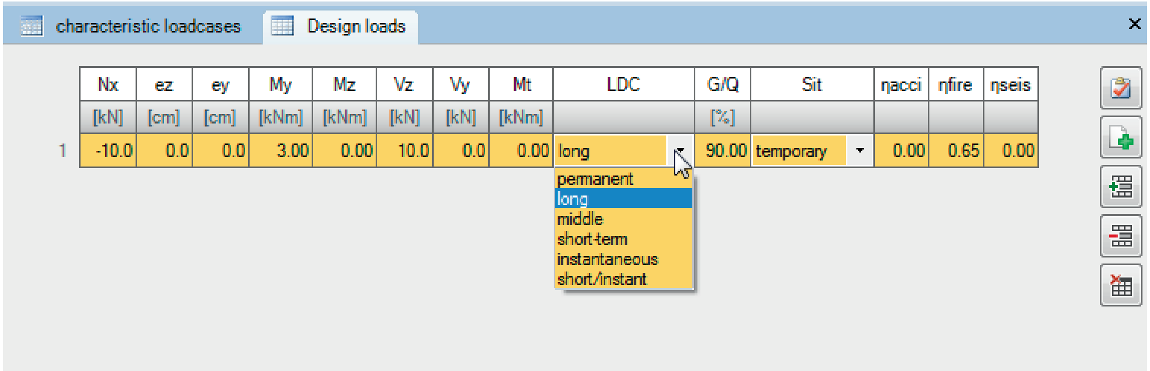
Group of actions selection of the action group.

Nx	axial force (in the x-direction); compression is negative, tension is positive
ez	eccentric transfer of axial force (positive in the z-direction)
ey	eccentric transfer of axial force (positive in the y-direction)
My	internal moment around the y-axis; positive if the vector orientation is in direction of the positive y-axis
Mz	internal moment around the z-axis; positive if the vector orientation is in direction of the positive z-axis
Vz	shear force, positive in the z-direction, generates the moment *My*
Vy	shear force, positive in the y-direction, generates the moment *Mz*
Mt	torsion moment, positive around the x-axis

Internal forces and geometric vectors are positive if they are oriented in direction of the positive axes. The moments *My* and *Mt* are positive when they describe a right-hand helix around the y- or x-axis. Whereas the bending moment *Mz* is positive, according to structural conventions, when describing a right-hand helix in direction of the negative z-axis in such a way that tension is produced on the positive cross-section sides (dashed lines) when a positive moment load applies.

Optionally, you can define design loads, assign the load duration class (LDC) and the design situation to them and use these loads in the bearing strength verification.

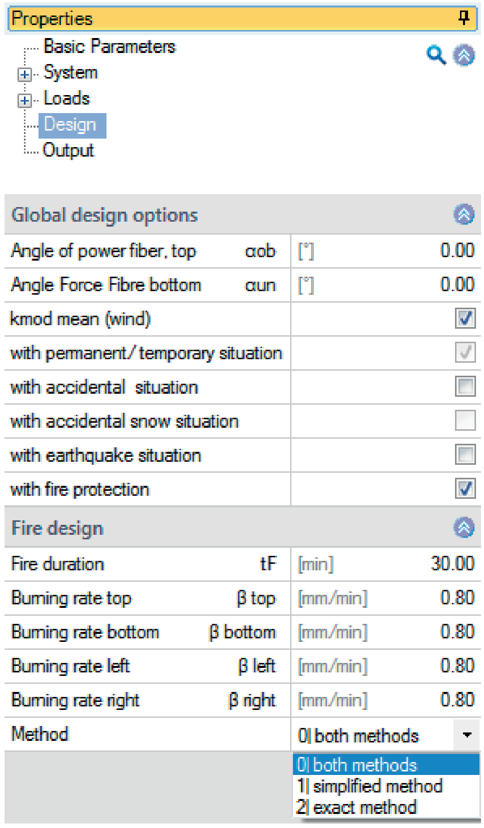
Because the verifications in the different design situations can be performed on different design levels the design loads of the permanent and transient design situations can optionally be converted with the help of the factors η_{acci}, η_{fire} and η_{seis}.



η_{acci}	factor to convert design loads of the permanent and transient design situations for the accidental situation.
η_{fire}	factor to convert design loads of the permanent and transient design situations for the fire situation.
η_{seis}	factor to convert design loads of the permanent and transient design situations for the earthquake situation.

Design

General design options



$\alpha_{top/bot}$ — with an angle between the force vector and the cut grain on the truss top or bottom chord, additional loading is generated due to deflection. A stress combination coefficient is calculated from this additional loading that is referenced to the bending strength in accordance with the standard.

kmod mean — for wind action, $k_{mod,short}$ is used as per EN 1995. Some National Annexes allow using the mean value of the short and very short kmod factors in the calculation:
kmod = kmod ($k_{mod,short}$ + $k_{mod,very\ short}$)/2
Tick this option to use the mean value as specified in the NA.

Structural fire design

Tick the option "With fire protection" to display the data-entry fields for the fire design.

tF — burn-off period [min], 30 for the verification as F30 B

β — burn-off velocity [mm/min] in the cross section top/bottom/left/right, e.g. 0.8 [mm/min] for softwood

Method — verification method for the fire design:
when you select the "Both methods" option, the software performs the calculation with both methods depending on the selected standard and puts out the decisive result.
"Simplified method" = "method with reduced cross sections"
"Exact method" = "method with reduced stiffnesses"

For multi-piece cross sections, currently only the burning behaviour of the single member is considered.

Weakening of the cross section is not handled in this fire safety verification. In special cases, you should define an equivalent cross section that was matched to the weakening state.

You can optionally disable this verification.

See also: Fire protection analysis timber.pdf

For the fire safety verification as per EN 1995-1-2 you can optionally use either the method of reduced cross sections described in paragraph 4.2.2 or the method of reduced properties described in paragraph 4.2.3. The shear-force resistance is verified with the help of the approximation formula of DIN 4102, because there is no other solution approach available. Discontinuous burn-off loss is not treated.

Stress-resistance verifications in accordance with EN 1995

The software performs the typical stress-resistance verifications for tension, compression or bending load, the stability verifications, which take flexural buckling or lateral buckling failure of a beam into account with the characteristic equivalent system lengths l_{ef} as well as shear stress analyses for shear force and torsion. The verifications of the resistance to compressive stress are only performed if a negative axial force applies and are marked with a negative sign. Stability verifications will only be performed when an area of the cross section is overcompressed. The verifications are based on the corresponding definitions of EN 1995. Any limitations for materials subject to approval must be evaluated separately if the software documentation does not contain any information on that matter.

Stability coefficients for flexural buckling

Effective slendernesses: $\lambda_z = s_{kz} / i_z$ or $\lambda_y = s_{ky} / i_y$

If the load relation of g/q > 0.70, $E_{0.05} = E_{0.05}/(1 + k_{def})$, if the component is mainly under pressure.

The factor $\beta_c = 0.2$ applies to solid timber; $\beta_c = 0.1$ to laminated timber.

Relative slenderness ratio: $\lambda_{rel} = \lambda / \pi \cdot \sqrt{f_{c,0,k} / E_{0,05}}$

Auxiliary value: $k = 0.5 \cdot (1 + \chi \cdot (\rho\varepsilon\lambda - 0.3) + {}^2{}_{rel})$

Flexural buckling coefficients: $k_c = 1 / (k + \sqrt{k^2 - \lambda^2_{rel}}) \leq 1{,}0$

The flexural buckling coefficients are determined for both loading directions y, z and are considered according to their direction in the stability equations. The consideration of the direction was disregarded in the previous standard.

Stability coefficients for lateral buckling

Radii of inertia of lateral buckling $i_{my} = \sqrt{I_{zz} \cdot I_{xx}} / W_{yy}$ or $i_{mz} = \sqrt{I_{yy} \cdot I_{xx}} / W_{zz}$

The program calculates always simplified:

$$i_{my} = \frac{b^2}{h} \text{ or } i_{mz} = \frac{h^2}{b}$$

Effective slenderness: $\lambda_B = l_{ef} / (\pi \cdot i_m) \cdot \sqrt{f_{m,k} / \sqrt{E_{0,05} \cdot G_{05}}}$

The program calculates always simplified:

$$\lambda_{rel,m} = l_{ef} / (0{,}78 \cdot i_m) \cdot \sqrt{f_{m,k} / E_{0,05}}$$

if $\lambda_{rel,m} \leq 0.75$ then $k_{crit} = 1{,}00$;

if $\lambda_{rel,m} \leq 0.75$ and $\lambda_{rel,m} < 1.40$ then $k_{crit} = 1.56 - 0.75 \cdot \lambda$;

if $_{rel,m} \geq 1.40$ then $k_{crit} = 1.00$;

Preliminary values

Increase or reduction of the permissible strength limits because of particularities of the structural system or the component (e.g. $k_l = 1{,}10$) will no longer be considered.

Material safety coefficient:

γ_m = 1.30 for permanent/transient design situations

γ_m = 1.00 for accidental design situations

With k_{red} = 0.7 for rectangular cross sections h/w $\leq$ 4; VH, BSH, BFSH;

With k_{red} = 1.0 for all other cross sections

Cross-sectional properties

Ax_{gross}	= Ax
Wyy_{gross}	= Wyy
Wzz_{gross}	= Wzz
Wxx_{net}	= Wxx - dWT
AVy_{net}	= AVy - dAQy
AVz_{net}	= AVz - dAQz
Ax_{net}	= Ax - dA
$Wyyy_{net}$	= Wyy - dWyy
Wz_{net}	= Wzz - dWzz

Design moments

My,d =: My,d + Nx,d · ez / 100 [kNm]

Mz,d =: My,d + Nx,d · ez / 100 [kNm]

Dimensions/units:

Cross sectional properties:	b/d [cm/cm], A [cm^2], W [cm^3], I [cm^4], i [cm]
System lengths:	Lx=Ls [m], sk [m], sB[m]
Stresses:	Sigma [MN/m^2] = [N/mm^2], Tau [MN/m^2] = [N/mm^2]
Conversion of the axial force portion:	10 [kN/cm^2] = 1.0 [MN/m^2]
Conversion of the moment portion:	1,000 [kN · m/cm^3] = 1.0 [MN/m^2]

Stress verifications

The stress-resistance and stability verifications are based on EN 1995-1-1, 6.1 – 6.3

Verifications of edge stresses

$$f_{my,d} = \frac{f_{my,k}}{\gamma_M} \cdot k_{mod}, f_{mz,d} = \frac{f_{mz,k}}{\gamma_M} \cdot k_{mod}, f_{c,0,d} = \frac{f_{c,0,k}}{\gamma_M} \cdot k_{mod}, f_{t,0,d} = \frac{f_{t,0,k}}{\gamma_M} \cdot k_{mod},$$

$$\text{DIN04}: \text{factor}(f_v)_{press,NH,BSH,LH} = 1{,}50; \text{factor}(f_v)_{tens,NH,BSH,LH} = 0{,}75$$

$$\text{DIN08,EN5}: \text{factor}(f_v)_{press,LH} = 1{,}50; \text{factor}(f_v)_{press,NH,BSH} = 2{,}0; \text{factor}(f_v)_{tens,LH} = 0{,}75$$

The inclination angles between the force orientation and the grain direction can be specified for the top (z=-d/2) and bottom (z=+d/2) edges. Compression as longitudinal stress generates transverse compression, whereas tension generates transverse tension. The shear strength is lower under tension and higher under compression.
The stress verifications are based on EN 1995-1-1, 6.4.

Output

The "Document" tab displays the data to be put out.

See also:

Output and printing

As a standard the output scope includes the detailed output of loads with all kinds of intermediate values to ensure traceability.

Optionally you can disable the detailed output and reduce the scope to the defined parameters and the essential results.

Results:

The maximum utilization is displayed on bottom right of the graphic window.

Reference literature

/1/ DIN EN 1995-1-1:2010, DIN EN 1995-1-2:2010

/2/ DIN EN 1990:2010

/3/ Scheer, C., Knauf Th., Meyer-Ottens, C.: Rechnerische Brandschutzbemessung unbekleideter Holzbauteile. Ernst&Sohn Verlag - Bautechnik 69 (1992) Booklet 4, p. 179 - 189

/4/ DIN 4102 Part 4: Brandverhalten von Baustoffen und Bauteilen, 5.1 Grundlagen zur Bemessung von Holzbauteilen, Anmerkung 8); Beuth-Verlag Berlin March 1994.

/5/ Holzbau-Taschenbuch: Bemessungsbeispiele nach Eurocode 5, 11th Edition. Ernst & Sohn, Berlin 2014.

/6/ DIN 4102-4/-A1 (Draft of November 2003): Brandschutzbemessung von Bauteilen und Verbindungen im Holzbau (DIN 1052:1988, DIN 1052-1/A1:1996)

/7/ DIN 4102-4/-22 (Draft of November 2003): Brandschutzbemessung von Bauteilen und Verbindungen im Holzbau (DIN 1052:2004)