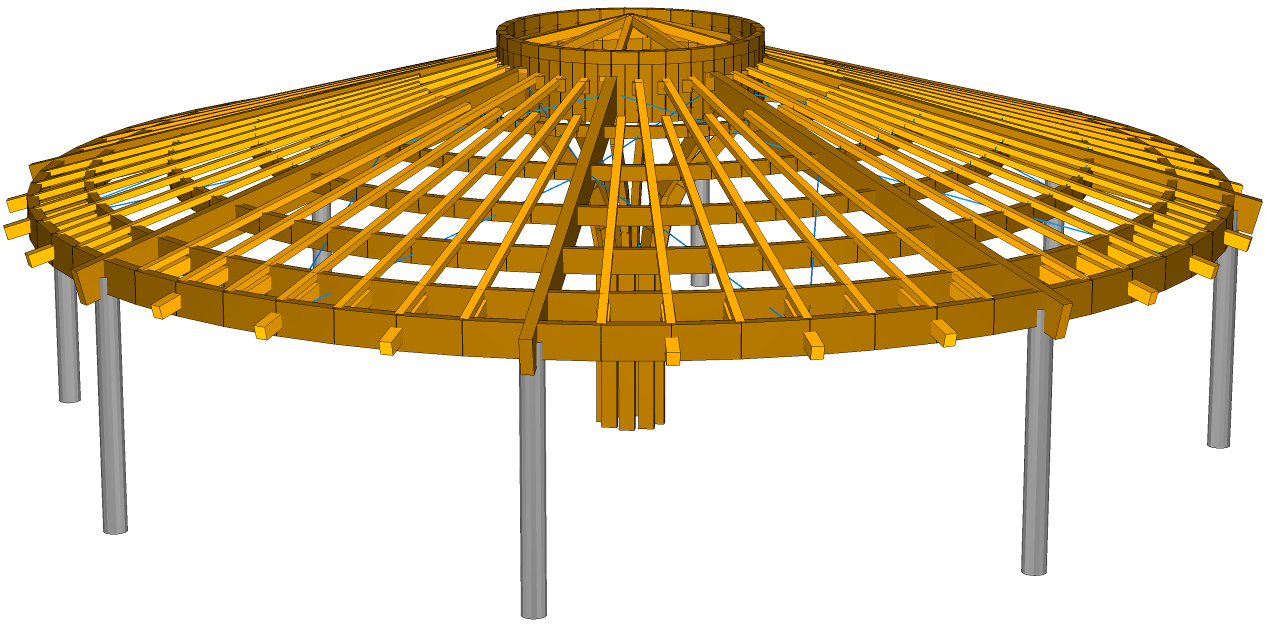
Timber Checks

according to EN 1995-1-1 with National Annexes Austria Germany Great Britain Sweden



InfoGraph

Software für die Tragwerksplanung

Contents

EN 1995-1-1 Timber Checks

Basics

The timber checks according to EN 1995-1-1 (Eurocode 5) can be used for buildings and engineering constructions for the design at normal temperature and under fire conditions with observance of the following standards:

- EN 1995-1-1:2014 and EN 1995-1-2:2009 (Basic document)
- DIN EN 1995-1-1/NA:2013-08 and DIN EN 1995-1-2/NA:2010-12 (Germany)
- OENORM B 1995-1-1:2015-06 and OENORM B 1995-1-2:2011-09 (Austria)
- SS EN 1995-1-1/BFS:2019 and SS EN 1995-1-2/BFS:2019 (EKS 11, Sweden)
- BS EN 1995-1-1/NA:2009-10 and BS EN 1995-1-2/NA:2006-10 (Great Britain)

The desired rule is selected in the *Settings* dialog in the *Analysis* menu. When selecting the material the following alternatives are available:

- *C14* to *C50* for softwood as per EN 388:2016, Table 1
- *D18* to *D80* for hardwood as per EN 388:2016, Table 3
- *GL20h* to *GL32h* for homogeneous glued laminated timber as per EN 14080:2013, Table 5
- *GL20c* to *GL32c* for combined glued laminated timber as per EN 14080:2013, Table 4
- *GL75* for glued laminated timber made of construction beech (BauBuche) as per ETA-14/0354:2018, Tables 2 and 3
- In Germany for glued laminated timber the application rules of DIN 20000-3:2015 are decisive.

The design is carried out after the static calculation. To do so, you need to assign the calculated load cases to the actions in accordance with EN 1991-1-1:2002/AC:2009 and EN 1991-1-2:2002/AC:2009 (Eurocode 1). The program will take into account the preset safety factors and combination coefficients defined in EN 1990:2021 (Eurocode 0) for the desired design situations to automatically calculate the decisive design internal forces for either the entire system or a group of selected elements. For every set of internal forces the modification factor k_{mod} is automatically determined from the service class of the section and the decisive load-duration.

Rectangle sections and polygon sections can be used as cross-sections. Beams with the *Beam* section type are not checked as the section geometry is not known for them.

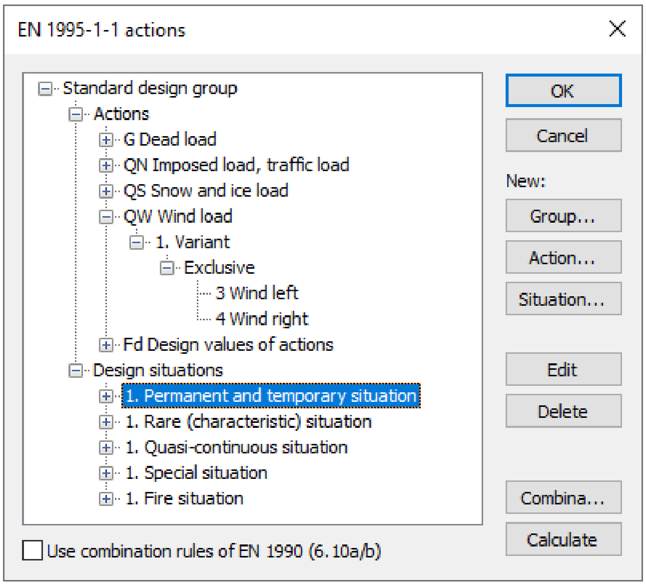
For area sections, the extremal internal forces for the defined action combinations are determined without performing a check and saved in the database for graphical representation.

The EN 1995-1-1 and EN 1995-1-2 guidelines are primarily cited for the following descriptions. Reference to the relevant national settings is only made if they contain different or complementary rules. The passages in question are marked by a vertical line left of the text.

Input

Actions and Design Situations

The load design values are calculated based on the internal forces of individual load cases and load case combinations. To do so, the existing load cases and load case combinations must be assigned to actions. These actions are then used to establish the desired design situations. The following dialog is opened from the database or the *Settings* in the *Analysis* menu.



Action...

Open the dialog for entering new actions:

- Permanent actions (G, GE, GH)
- Variable actions (QN, QS, QW, QT, QH, QD)
- Accidental actions (A)
- Actions due to earthquakes (AE)
- Design values of actions (Fd)
  The assigned load cases should contain a design-relevant set of loads with combination coefficients and partial safety factors for actions and material such as for example a load group for the stability check according to EN 1995-1-1, Clause 2.2.2 (1)P. The selected load cases are combined exclusively.

Group...

Open the dialog for entering a new design group. According to e.g. standard EN 1991-1-1, Chapter 6.2.2 (2), certain components (sections) may be designed with reduced imposed loads. Therefore, variable actions (Q) and design situations can be changed here.

Situation...

Open the dialog for entering new design situations.

Edit

Open the Edit dialog for the selected action or situation.

Delete

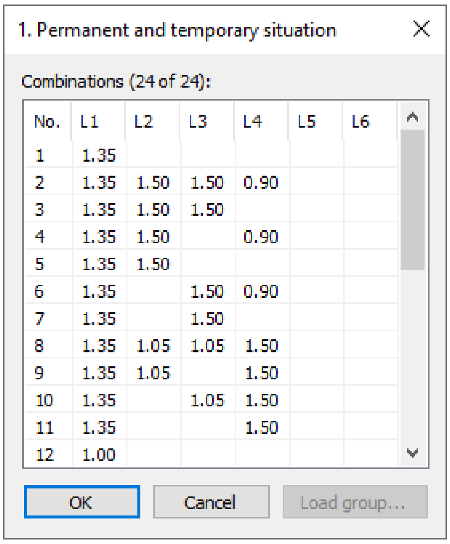
Delete the selected action or situation.

Combinations...

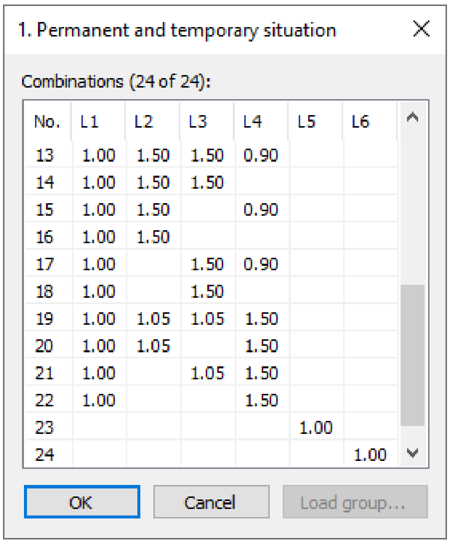
Opens a dialog that contains the first 999,999 load case variants to be combined for the selected design situation and includes an option to create load groups for selected variants. These variants can be used for second-order theory analysis.

The following example shows the total variants of the *permanent and temporary situation* according to Eq. (6.10) to be examined with the load cases (L1...L6) involved and their weighting factors.

Actions	Load cases	γ_{sup}	γ_{inf}	ψ_0
Dead load	1	1.35	1.0	-
Imposed load, traffic load	2, 3 (inclusive)	1.5	0	0.7
Wind load	4	1.5	0	0.6
F_d Design values of actions	5, 6	1.0	1.0	-



No.	L1	L2	L3	L4	L5	L6
1	1.35					
2	1.35	1.50	1.50	0.90		
3	1.35	1.50	1.50			
4	1.35	1.50		0.90		
5	1.35	1.50				
6	1.35		1.50	0.90		
7	1.35		1.50			
8	1.35	1.05	1.05	1.50		
9	1.35	1.05		1.50		
10	1.35		1.05	1.50		
11	1.35			1.50		
12	1.00					



No.	L1	L2	L3	L4	L5	L6
13	1.00	1.50	1.50	0.90		
14	1.00	1.50	1.50			
15	1.00	1.50		0.90		
16	1.00	1.50				
17	1.00		1.50	0.90		
18	1.00		1.50			
19	1.00	1.05	1.05	1.50		
20	1.00	1.05		1.50		
21	1.00		1.05	1.50		
22	1.00			1.50		
23					1.00	
24						1.00

Calculate

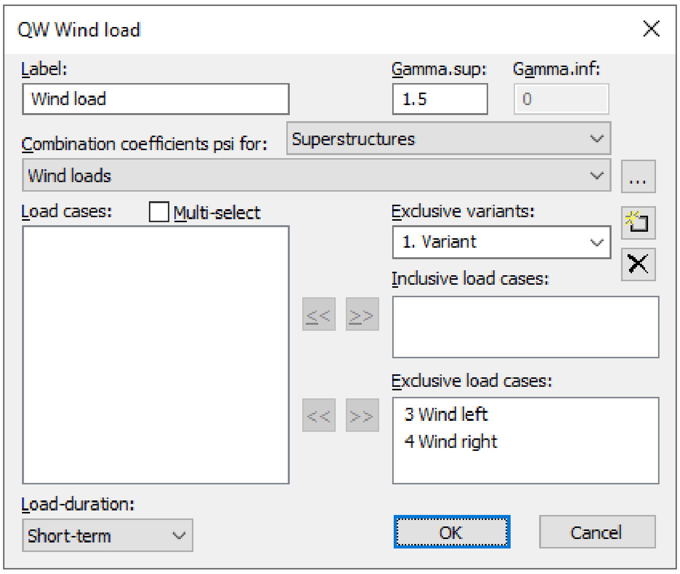
Calculate the defined design situations. Once calculated, the extremal results (internal forces, support reactions) can be accessed for all situations in the database. This allows you to evaluate the results without having to open the checking module. Each time you open the checking module, all results will be automatically recalculated using the currently valid actions and then stored in the database for the elements to be checked.

Use combination rules of EN 1990 (6.10a/b)

Optionally the Eq. (6.10a/b) are used for the combination of the permanent and temporary situation, otherwise Eq. (6.10).

Definition of an Action

The illustration below shows an example of the dialog field for entering a variable action. The dialog fields for other action types are of a similar appearance.



Label

User-defined label for the action.

Gamma.sup, Gamma.inf

Partial safety factors γ_{sup} and γ_{inf}.

SS EN 1990:

The program suggests the partial safety factors as they result in accordance with Section A, Article 11, for safety class 3 from $\gamma_d \cdot \gamma_{sup}$ with the reduction factor $\gamma_d = 1.0$ as per Article 14. If required, lower safety classes can be taken into account entering lower values.

Combination coefficients psi for:

Input fields for selecting the combination coefficients for variable actions. The ... button allows you to view and change the selected combination coefficients ψ_0, ψ_1 and ψ_2.

Load cases

List of possible load cases or load case combinations. You can choose an item from the list by selecting it and clicking the >> button or by using drag & drop.

Multi-select

Load cases and combinations can be added to the actions more than once.

Exclusive variants

Variable actions may consist of multiple exclusive variants that are mutually exclusive. The variants themselves contain both inclusive and exclusive parts. You can add or delete action variants with the  or  buttons.

Inclusive load cases

Selected load cases and combinations that can act simultaneously. Since the number of internal forces to be checked increases exponentially, especially with a large number of load cases, it may be useful to use a load case combination instead of load cases.

Exclusive load cases

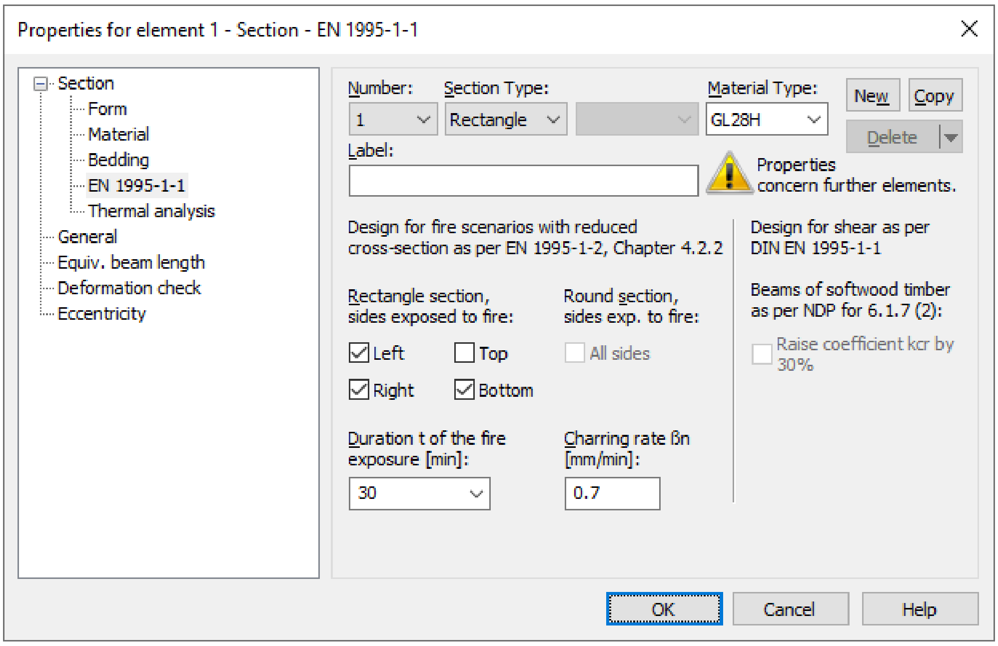
Selected load cases and combinations that exclude each other.

Load-duration

The load-duration class according to EN 1995-1-1, Chapter 2.3.1.2, is used to determine the modification factor k_{mod} for the material strengths. The classes as per Table 2.2 with the national decisive values are suggested.

Fire Exposures

The definition of fire exposures for the check method with reduced cross-section according to EN 1995-1-2, Chapter 4.2.2, is made in the section dialog. The check of the cross-section resistance can be activated in the analysis settings dialog and additionally requires the definition of a design combination for fire conditions.



Sides exposed to fire

Determination of the sides with fire exposures. The z-axis of the beam points to the bottom and the y-axis to the right. Round sections are exposed along their whole perimeter.

Duration t

Duration t of the fire exposure for the calculation of the notional charring depth $d_{\text{char,n}}$ according to Eq. (3.2). In accordance with Chapter 3.4.2 unprotected surfaces throughout the time of fire exposure are assumed.

$$d_{\text{char,n}} = \beta_n \cdot t \qquad (3.2)$$

Charring rate ßn

Design value of the notional charring rate in accordance with Chapter 3.4.2 (2) for the calculation of the charring depth according to Eq. (3.2). The value given in Table 3.1 is preset.

Note

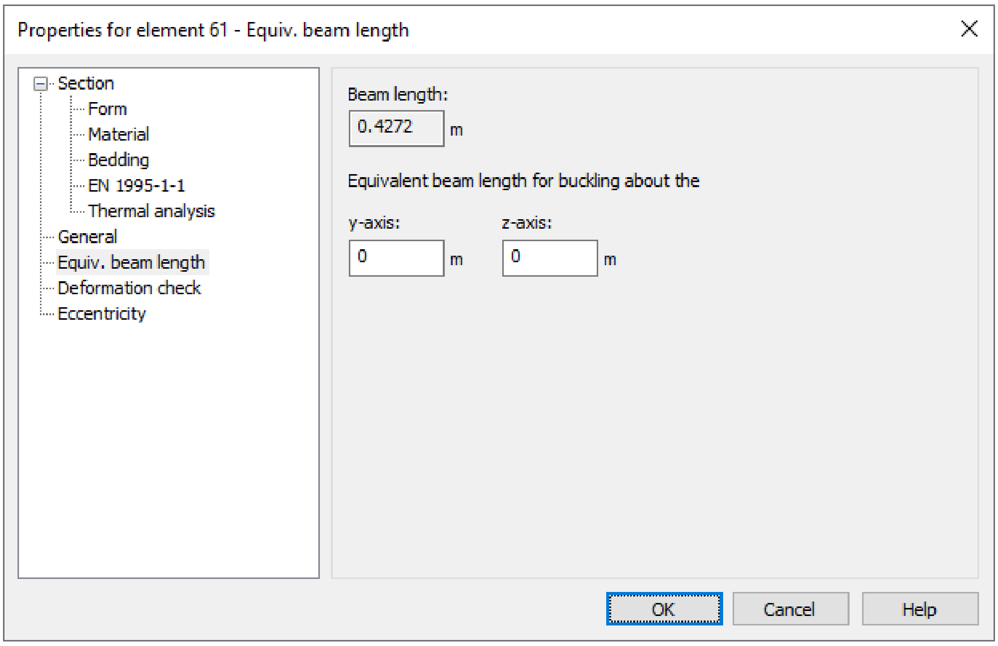
Fire exposures for the check with the advanced calculation method as per EN 1995-1-2, Chapter 4.4, are entered at the dialog page '*Termal analysis*'. A description concerning this can be found in the manual section '*Structural Analysis for Fire Scenarios*'.

Partial Safety Factors

The partial safety factors of the construction materials are preset with the nationally applicable values as specified in EN 1995-1-1, Table 2.3. In design situations resulting from earthquakes, the factors of the permanent and temporary design situation apply in accordance with EN 1998-1:2004, Chapter 5.2.4 (2). For accidental and special combinations as well as for fire scenarios the factor 1 is assumed. The partial safety factors for the actions are specified in the definition of the actions based on EN 1990, Table A.1.2(B).

Equivalent Beam Length

For the buckling check with the equivalent beam method according to EN 1995-1-1, Chapter 6.3.2, the equivalent beam lengths must be defined in the properties dialog of the concerned beams. The check is activated in the analysis settings dialog.



y-axis, z-axis

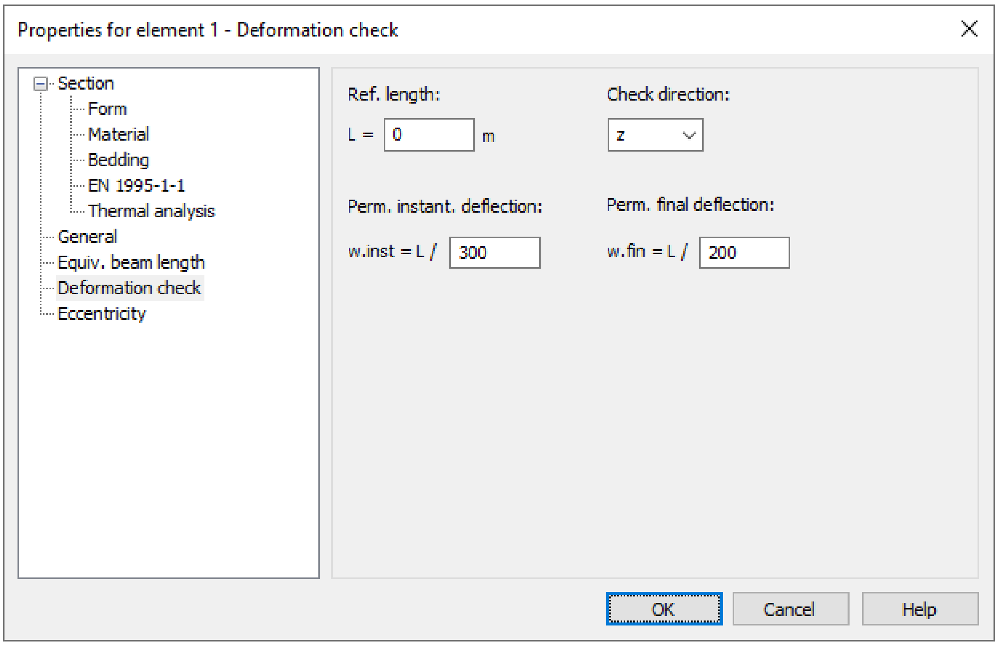
The specification of an appropriate equivalent beam length under consideration of support and load conditions is subject to the discretion and the responsibility of the user. If the value 0 is entered no check is carried out for the corresponding direction.

Note

If a structural member with constant cross-section is divided into multiple beam elements, the buckling length decisive for the whole structural member shall be applied to all elements. A computational determination of buckling lengths and buckling eigenmodes by the FEM program is possible for selected load combinations (see description of *Load group*).

Deformation Check

The specifications for the deformation check according EN 1995-1-1, Chapter 2.2.3, are made in the properties dialog of the beams. The check is activated in the analysis setting dialog.



Reference length

The reference length is the length of a field (in the case of a continuous girder, the distance between the supports) and should be the same for all beams of this field. It is needed for the calculation of the permissible deflection according to Chapter 7.2 (2). If L = 0 is specified, no deformation check is performed for this beam.

Check direction

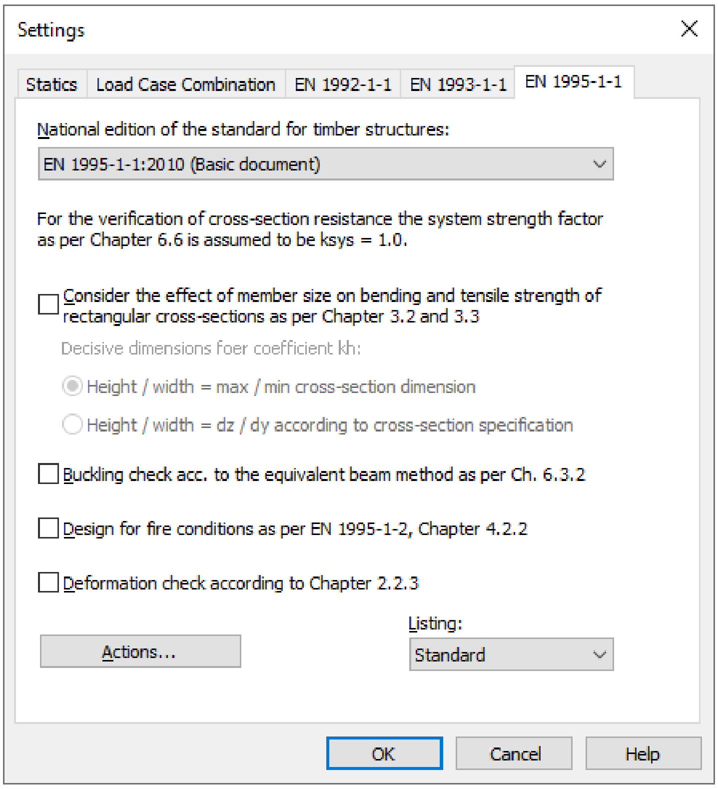
The deformation check can be performed for the local directions y and z or for the resulting direction r.

Perm. instantaneous deflection, Perm. final deflection

User-defined limits for the deflection of bending beams according to Chapter 7.2 (2), Table 7.2.

Analysis Settings

The *EN 1995-1-1* dialog field can be accessed using the *Settings* option of the *Analysis* menu.



National edition of the standard

The edition you select will be used for all subsequent entries and calculations.

Consider the effect of member size

The bending and tensile strength of solid timber and glued laminated timber can be increased by the factor k_h depending on the cross-section dimensions according to the rules of EN 1995-1-1, Chapters 3.2 and 3.3. The decisive dimension for the calculation of the factor k_h is selected by the user.

Buckling check

The check with the equivalent beam method is carried out according to EN 1995-1-1, Chapter 6.3.2. The equivalent beam length of the beams to be checked can be defined in the properties dialog.

Design for fire conditions

Rectangular and circular cross-sections are checked for the entered fire situation using the reduced cross-section according to EN 1995-1-2, Chapter 4.2.2. The fire exposure is described in the section dialog.

Deformation check

The check according to EN 1995-1-1, Chapter 2.2.3 is performed at the calculation locations of the beams. A sufficient number of calculation locations should be considered. The specifications for the check are defined in the corresponding properties dialog of the beams.

Actions...

Open the dialog for describing actions.

Listing

- *No*: No log is generated by the design program.
- *Standard*: During analysis a log with a tabular output of the calculated utilizations is created.
- *Detailed*: This log differs from the standard log by additionally offering information on the analyzed internal force combinations.
- *Standard>permissible*: Standard log of the check locations at which the permissible limits are exceeded.
- *Detailed>permissible*: Detailed log of the check locations at which the permissible limits are exceeded.

Ultimate Limit States

Design Combinations

In accordance with EN 1990 (Eurocode 0), Chapter 6.4.3, the following combinations are taken into account in the ultimate limit states:

- For the combination of the permanent and temporary design situation either Equation (6.10) or the most unfavorable equation from (6.10a) and (6.10b) is permitted.

$$\sum_{j\geq 1} \gamma_{G,j} \cdot G_{k,j} \text{"+"} \gamma_P \cdot P \text{"+"} \gamma_{Q,1} \cdot Q_{k,1} \text{"+"} \sum_{i>1} \gamma_{Q,i} \cdot \psi_{0,i} \cdot Q_{k,i} \qquad (6.10)$$

$$\sum_{j\geq 1} \gamma_{G,j} \cdot G_{k,j} \text{"+"} \gamma_P \cdot P \text{"+"} \gamma_{Q,1} \cdot \psi_{0,1} \cdot Q_{k,1} \text{"+"} \sum_{i>1} \gamma_{Q,i} \cdot \psi_{0,i} \cdot Q_{k,i} \qquad (6.10a)$$

$$\sum_{j\geq 1} \xi_j \cdot \gamma_{G,j} \cdot G_{k,j} \text{"+"} \gamma_P \cdot P \text{"+"} \gamma_{Q,1} \cdot Q_{k,1} \text{"+"} \sum_{i>1} \gamma_{Q,i} \cdot \psi_{0,i} \cdot Q_{k,i} \qquad (6.10b)$$

For the coefficient ξ the value of $\xi = 0.85$ results from Table A.1.2(B).

DIN EN 1990, OENORM B 1990:
Equation (6.10) is used for the combination.

SS EN 1990:
Equations (6.10a) and (6.10b) apply with following modifications:

$$\sum_{j\geq 1} \gamma_d \cdot \gamma_{G,j} \cdot G_{k,j} \text{"+"} \gamma_P \cdot P \qquad (6.10aSS)$$

$$\sum_{j\geq 1} \xi_j \cdot \gamma_d \cdot \gamma_{G,j} \cdot G_{k,j} \text{"+"} \gamma_P \cdot P \text{"+"} \gamma_d \cdot \gamma_{Q,1} \cdot Q_{k,1} \text{"+"} \sum_{i>1} \gamma_d \cdot \gamma_{Q,i} \cdot \psi_{0,i} \cdot Q_{k,i} \qquad (6.10bSS)$$

Assuming reliability class 3, factor γ_d is set to 1. (see Section A, Article 11 and 14). The coefficient ξ is set to the value of $\xi = 0.89$.

BS EN 1990:
The coefficient ξ in Equation (6.10b) is set to the value of $\xi = 0.925$.

- Combination for accidental design situations

$$\sum_{j\geq 1} G_{k,j} \text{"+"} P \text{"+"} A_d \text{"+"} (\psi_{1,1} \text{ or } \psi_{2,1}) \cdot Q_{k,1} \text{"+"} \sum_{i>1} \psi_{2,i} \cdot Q_{k,i} \qquad (6.11b)$$

$\psi_{1,1} \cdot Q_{k,1}$ is used by the program for this combination.

OENORM B 1990-1:
$\psi_{2,1} \cdot Q_{k,1}$ is decisive.

- Combination for design situations caused by earthquakes

$$\sum_{j\geq 1} G_{k,j} \text{"+"} P \text{"+"} A_{Ed} \text{"+"} \sum_{i\geq 1} \psi_{2,i} \cdot Q_{k,i} \qquad (6.12b)$$

- Combination for design situations under fire conditions acc. to EN 1991-1-2 (Eurocode 1), Ch. 4.2.1

$$\sum_{j\geq 1} G_{k,j} \text{"+"} P \text{"+"} (\psi_{1,1} \text{ or } \psi_{2,1}) \cdot Q_{k,1} \text{"+"} \sum_{i>1} \psi_{2,i} \cdot Q_{k,i}$$

In accordance with EN 1991-1-2, Clause 4.3.1 (2), the value $\psi_{2,1} \cdot Q_{k,1}$ is used by the program.

DIN EN 1991-1-2:
For wind actions $\psi_{1,1} \cdot Q_{k,1}$, otherwise $\psi_{2,1} \cdot Q_{k,1}$ is to be used.

SS EN 1991-1-2, BS EN 1991-1-2:
The value $\psi_{1,1} \cdot Q_{k,1}$ is decisive.

Additionally, for the results of a stability check according to the second-order theory the

- Special combination

$$F_{d,1}; ... ; F_{d,n}$$

is available. In this combination the design value of actions (F_d) are superposed exclusively.

For each combination you can define different design situations for the construction stages and final states. Each check is performed for all situations of a combination.

Design Values According to the Second-Order Theory

The calculation according to the second-order theory as per Clause 2.2.2 (1)P is carried out as part of the internal forces calculation considering the cross-section properties at normal temperature. For this you need to create – with the help of load groups – appropriate load cases from decisive loads (see also function *Combinations* in the action dialog).

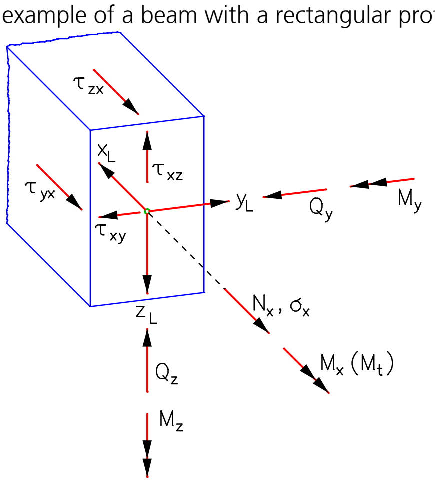
As the partial safety factors are already to be taken into account for the internal forces calculation, within the load groups the respective actions must be multiplied with their corresponding partial safety factor γ_G or γ_Q as well as with γ_M according to Table 2.3, without consideration of the load-duration.

In the check the load cases calculated according to the second-order theory are assigned to an action F_d and superposed in the *Special Combination* as an exclusive selection. The results are checked against the characteristic values of the cross-section resistances.

Stress Determination

Coordinate Systems

The following illustration shows the definition of the coordinate systems for internal forces, loads and stresses using the example of a beam with a rectangular profile. The section edge is defined as a closed polygon.



The longitudinal force N_x runs through the centroid, the lateral forces Q_y and Q_z run through the shear center of the section which, in this case, coincides with the centroid. The vectors of the moments M_x, M_y, M_z and stresses σ_x, τ_{xy}, τ_{xz} run parallel to the coordinate axes.

Longitudinal Stresses

The necessary section properties for determination of the longitudinal stresses from longitudinal force and bending are determined elementarily with the segmentation method from the coordinates of the polygon.

More specifically, these are:

y_s, z_s	Centroid coordinates.
A	Area of the section.
I_y, I_z	Moments of inertia in relation to the coordinate axes.
I_{yz}	Deviation moment of inertia.
I_1, I_2	Moments of inertia in relation to the main axes.
φ	Twisting angle of the main axes.
W_y, W_z	Moments of resistance for the calculation of the extremal longitudinal stresses from M_y, M_z.

For the analysis of a section, the stresses are determined at the automatically defined calculation points. The longitudinal stress σ for a point (y,z) of the section results from

$$\sigma(y,z) = N_x \frac{1}{A} + M_y \frac{\Delta z I_z - \Delta y I_{yz}}{I_y \cdot I_z - I_{yz}^2} + M_z \frac{\Delta y I_y - \Delta z I_{yz}}{I_y \cdot I_z - I_{yz}^2}$$

with $\Delta y = y - y_s$ and $\Delta z = z - z_s$.

Shear Stresses

Lateral force

For load as a result of lateral force, the differential equation of the so-called shear warpage ω_τ

$$\frac{\partial^2 \omega_\tau}{\partial y^2} + \frac{\partial^2 \omega_\tau}{\partial z^2} = -\frac{Q_z\, z}{G\, I_y} \quad \text{or} \quad -\frac{Q_y\, y}{G\, I_z}$$

is solved numerically with the help of the boundary element method. From this the following shear characteristics are determined:

$\tau_{Qy,1}$	Shear stress for the lateral force $Q_y = 1$.
$\tau_{Qz,1}$	Shear stress for the lateral force $Q_z = 1$.
W_{qy}, W_{qz}	Area values for calculation of the extremal shear stresses from Q_y and Q_z with $\tau_{Qy} = Q_y / W_{qy}$ and $\tau_{Qz} = Q_z / W_{qz}$.

If selected in the Section dialog, the shear stresses across the section width will be averaged.

Torsion

For load as a result of St. Venant torsion, the differential equation of the unit warpage ω

$$\frac{\partial^2 \omega}{\partial y^2} + \frac{\partial^2 \omega}{\partial z^2} = 0$$

is decisive. Its solution leads to the following characteristics:

I_t	Torsion moment of inertia.
$\tau_{Mx,1}$	Shear stress for the torsional moment $M_x = 1$.
W_t	Moment of resistance for the calculation of the extremal shear stress from M_x.

Construction Material Properties

Characteristic Values

For sections made of construction timber the characteristic material properties are taken from EN 338:2016, Tables 1 and 3, for solid timber and from EN 14080:2013, Tables 4 and 5, for glued laminated timber.

DIN EN 1995-1-1:

In accordance with Chapter 3.3 (NA.10) for all strength classes of glued laminated timber made of softwood the characteristic shear strength is set to $f_{v,k}$ = 3.5 N/mm².

OENORM B 1995-1-1:

In accordance with Clause 6.1.7 (2) a shear strength of $f_{v,k}$ = 2.3 N/mm² is assumed for solid timber made of softwood and $f_{v,k}$ = 2.5 N/mm² for glued laminated timber made of softwood.

ETA-14/0354:

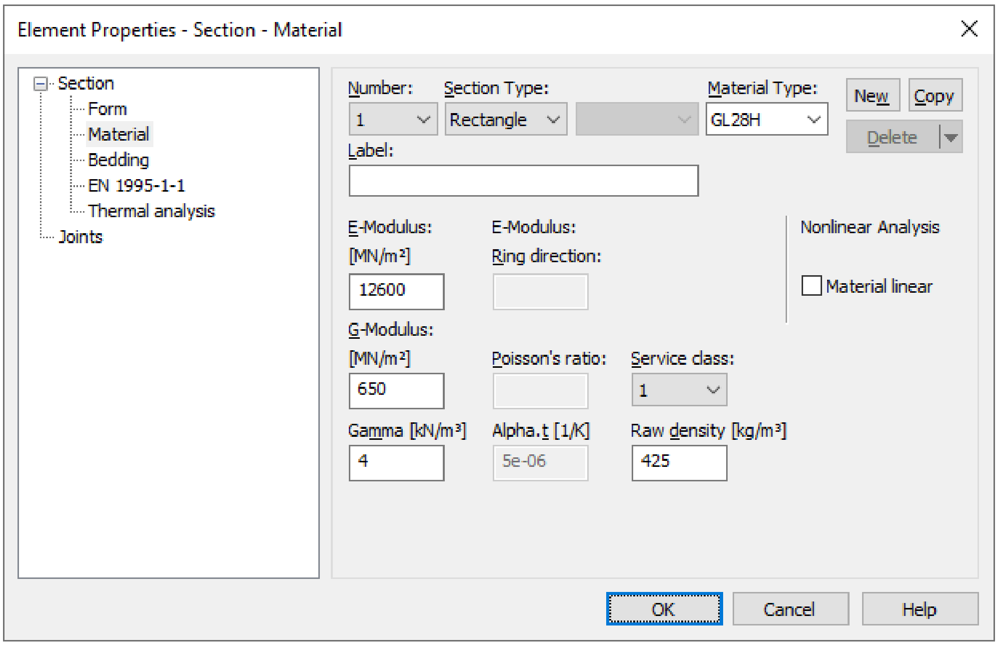
Glued laminated timber made of construction beech (BauBuche) GL75 is approved for service classes 1 and 2. The characteristic values according to Tables 2 and 3 of the ETA apply.

Moisture Content and Load-Duration

The moisture content and the load-duration affect the strength and stiffness properties of timber according to Clause 2.3.1.1 (2) P. During design they are therefore to be taken into account for the mechanical resistance using a modification factor. The program considers this automatically depending on the user-defined properties. When performing the check for fire conditions with reduced cross-section, the modification factor is assumed to be 1.0 according to EN 1995-1-2, Clause 4.2.2 (5).

Service class

For the determination of the moisture content, structures shall be assigned to one of three service classes as described in Chapter 2.3.1.3. The assignment is made on the material property page of the section dialog. Therewith different service classes can be defined for specific parts of the structure.



Load-duration

In accordance with Chapter 2.3.1.2 the actions are to be assigned to classes as per Table 2.1 to determinate the strength properties. The assignment is made within the action dialog where the classification according to Table 2.2 is suggested.

Modification factor k_{mod}

The modification factor takes into account the effect of the moisture content and the load-duration on the material strengths. Numerical values for the factor k_{mod} are given in Table 3.1 of the standard. In the check of the cross-section resistance it is used for determination of the resistance according to Eq. (2.17):

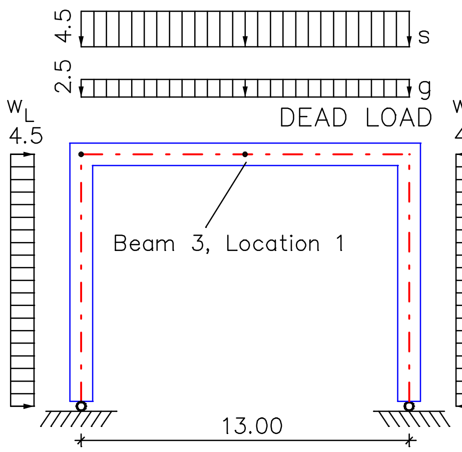
$$R_d = k_{mod} \cdot R_k / \gamma_M \tag{2.17}$$

where

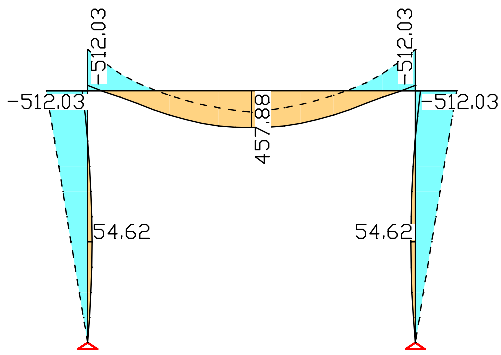
R_d	is the design value of the resistance (load-bearing capacity).
R_k	is the characteristic value of the resistance.
γ_M	is the partial safety factor of the material property.

If a load combination contains actions which belong to different load-duration classes, the value of k_{mod} corresponding to the action with the shortest duration should be used according to Clause 3.1.3 (2). The effect of the modification factor on the design value of the resistance can lead to the result that an action combination becomes decisive which does not provide the maximum design value of the appropriate load. Because of that all possible combinations of load cases are analyzed in the checks.

Each set of internal forces which is analyzed provides the decisive load-duration from the involved actions. Together with the service class it determines the factor k_{mod} of the material. The following example illustrates the issue. Relevant facts in the listing are underlined.



Structure with loads



Internal forces min/max My; 1. Permanent and temporary Situation

Action	Load cases	Label	Load-duration
G	1	Dead load, permanent load	Permanent
QS	2	Snow	Medium-term
QW	3	Wind from left	Short-term
	4	Wind from right	Short-term

Location 1

```
Beam 3: x = 0.00 m (Beam Length 6.50 m)
Section 1: Rectangle, GL32H, Class 1, h/w=900/300 mm, A=270000 mm²
km=0.70, khy/kht=1.00/1.07, kcr=0.67
```

1. Permanent and temporary comb. (PC.1): G+QS+QW

```
Relevant values from 16 sets of internal forces
Set      Nx[kN]     Qz[kN]    My[kNm]  Load-dur. kmod
1     :  -29.77      -0.00     378.10  Permanent 0.60
5     :  -51.20     -25.96     403.77  Sho.-term 0.90

Load case combinations for the relevant sets of internal forces
Set    Combination
1     : 1.35*L1
5     : 1.35*L1+0.75*L2+1.50*L3
```

In the check both sets of internal forces presented in the log provide the maximum utilization for bending (set 1) and for lateral force (set 5). The set of internal forces with the maximum bending moment at the check location (M_y = 457.88 kNm) is not decisive because of the effect of k_{mod} on the resistance.

Effect of Member Size

The effect of member size on strength can be taken into account for solid timber and glued laminated timber according to Chapter 3.2 and 3.3. The program considers this automatically if the user selects this option in the analysis settings.

If the decisive dimension of the cross-section h [mm] falls below the material-specific reference value the characteristic bending strength $f_{m,k}$ resp. the tensile strength $f_{t,k}$ can be increased by a factor k_h. According to the selection in the analysis settings, the decisive dimension for the bending strength is assumed either with the largest cross-sectional dimension (standard) or with the dimension in the z direction (d_z) specified by the cross-section. For the tensile strength, either the smallest cross-sectional dimension (standard) or the dimension in y direction (d_y) is used.

Solid timber

For solid timber with rectangular cross-section and a characteristic density $\rho_k \leq 700$ kg/m³ the reference value is 150 mm according to Chapter 3.2 and the factor is

$$k_h = \min(\ (150/h)^{0.2};\ 1.3) \quad (3.1)$$

DIN EN 1995-1-1:
For the tensile strength the largest section dimension according to NCI of Chapter 3.2 (3) is always decisive.

Glued laminated timber

For glued laminated timber with rectangular cross-section the reference value is 600 mm according to Chapter 3.3 and the factor is

$$k_h = \min(\ (600/h)^{0.1};\ 1.1) \quad (3.2)$$

DIN EN 1995-1-1:
For the tensile strength the largest section dimension according to NCI of Chapter 3.3 (3) is always decisive. An increase of the bending strength as per Eq. (3.2) is only applied for bending stress perpendicular to the smaller dimension (M_y) according to Section (NA.9). The option to increase the strength value in case of stress from bending perpendicular to the larger dimension (M_z) according to Chapter (NA.6) is not used by the program.

ETA-14/0354:
For glued laminated timber made of construction beech (BauBuche) GL75, the strengths are bindingly specified in Table 3 of the approval, taking into account the component size. Chapter 3.3 of the standard is therefore not applied in the program.

Design Method for Fire Conditions

Structural fire design is carried out according to the reduced cross-section method as described in EN 1995-1-2, Chapter 4.2.2. The corresponding property page of the section dialog allows to define fire exposures for the affected rectangular and round cross-sections. The check of the cross-section resistance can be activated in the analysis settings dialog and additionally requires entering a design situation for fire conditions.

The residual cross-section is determined by reducing the initial cross-section about the charring depth d_{ef} according to Eq. (4.1) and is verified to fulfill the condition for bracing members in Clause 4.3.5 (2).

$$d_{ef} = d_{char,n} + k_0 \cdot d_0 \quad (4.1)$$

$$d_{char,n} = \beta_n \cdot t \quad (3.2)$$

where

d_0	= 7 mm;
k_0	is the factor according to Table 4.1;
$d_{char,n}$	is the notional design charring depth according to Eq. (3.2);
β_n	is the notional charring rate according to Chapter 3.4.2 (2).

Under fire conditions the cross-section checks described below use the strengths defined in EN 1995-1-2, Eq. (2.1).

Note:

Alternatively to the described method with reduced cross-section, the check can be performed in accordance with EN 1995-1-2, Chapter 4.4, using the '*Advanced calculation method*'. For more information on this, refer to section '*Structural Analysis for Fire Scenarios*' of the manual.

Cross-Section Checks

In accordance with EN 1995-1-1, Chapter 6.1.1 the orientation of the grains are assumed to be parallel to the beam axis. The check of tensile and compressive stresses is limited to this fiber direction. The system strength factor according to Chapter 6.6 is assumed to be $k_{sys} = 1$.

Design Values of Strengths

Normal temperature

The strengths at normal temperature result from EN 1995-1-1, Eq. (2.14):

$$f_d = k_{mod} \cdot f_k / \gamma_M \qquad (2.14)$$

where

f_d is the design value of strength at normal temperature;

k_{mod} is the modification factor for load duration and moisture content as per Chapter 3.1.3;

f_k is the characteristic strength according to EN 338 and EN 14080;

γ_M is the partial safety factor for timber according to Table 2.3.

Fire conditions

The strengths in fire are defined in EN 1995-1-2, Eq. (2.1):

$$f_{d,fi} = k_{mod,fi} \cdot f_{20} / \gamma_{M,fi} \qquad (2.1)$$

where

$f_{d,fi}$ is the design strength in fire;

$k_{mod,fi}$ is the modification factor for fire, which is assumed to be $k_{mod,fi} = 1$ for the check with reduced cross-section according to 4.2.2 (5);

f_{20} is the 20% fractile of a strength property at normal temperature with $f_{20} = k_{fi} \cdot f_k$ acc. to Eq. (2.4);

k_{fi} is the factor given in table 2.1;

f_k is the characteristic strength according to EN 338 and EN 14080;

$\gamma_{M,fi}$ is the partial safety factor for timber in fire which is assumed to be $\gamma_{M,fi} = 1$.

Tension Parallel to the Grain

In accordance with Chapter 6.1.2 the following expression shall be satisfied:

$$\sigma_{t,0,d} \le f_{t,0,d} \qquad (6.1)$$

where

$\sigma_{t,0,d}$ is the design tensile stress along the grain.

$f_{t,0,d}$ is the design tensile strength along the grain.

Compression Parallel to the Grain

In accordance with Chapter 6.1.4 the following expression shall be satisfied:

$$\sigma_{c,0,d} \le f_{c,0,d} \qquad (6.2)$$

where

$\sigma_{c,0,d}$ is the design compressive stress along the grain.

$f_{c,0,d}$ is the design compressive strength along the grain.

Bending

In accordance with Chapter 6.1.6 the following expressions shall be satisfied:

$$\sigma_{m,y,d} / f_{m,y,d} + k_m \cdot \sigma_{m,z,d} / f_{m,z,d} \leq 1 \quad (6.11)$$

$$k_m \cdot \sigma_{m,y,d} / f_{m,y,d} + \sigma_{m,z,d} / f_{m,z,d} \leq 1 \quad (6.12)$$

where

$\sigma_{m,y,d}$ and $\sigma_{m,z,d}$	are the design bending stresses about the principal axes.
$f_{m,y,d}$ and $f_{m,z,d}$	are the corresponding design bending strengths.

The factor k_m makes allowance for the inhomogeneities of the material in a cross-section and is assumed as follows according to Clause 6.1.6 (2):

k_m = 0.7	for rectangular sections made of solid timber, glued laminated timber and laminated veneer lumber.
k_m = 1.0	for other cross-sections and other wood-based structural products.

Combined Bending and Axial Tension

In accordance with Chapter 6.2.3 the following expressions shall be satisfied for the combined stresses from bending and tension:

$$\sigma_{t,0,d} / f_{t,0,d} + \sigma_{m,y,d} / f_{m,y,d} + k_m \cdot \sigma_{m,z,d} / f_{m,z,d} \leq 1 \quad (6.17)$$

$$\sigma_{t,0,d} / f_{t,0,d} + k_m \cdot \sigma_{m,y,d} / f_{m,y,d} + \sigma_{m,z,d} / f_{m,z,d} \leq 1 \quad (6.18)$$

For the factor k_m the value given for bending applies.

Combined Bending and Axial Compression

In accordance with Chapter 6.2.4 the following expressions shall be satisfied for the combined stresses from bending and compression:

$$(\sigma_{c,0,d} / f_{c,0,d})^2 + \sigma_{m,y,d} / f_{m,y,d} + k_m \cdot \sigma_{m,z,d} / f_{m,z,d} \leq 1 \quad (6.19)$$

$$(\sigma_{c,0,d} / f_{c,0,d})^2 + k_m \cdot \sigma_{m,y,d} / f_{m,y,d} + \sigma_{m,z,d} / f_{m,z,d} \leq 1 \quad (6.20)$$

For the factor k_m the value given for bending applies.

Shear

In accordance with Chapter 6.1.7 the following expression shall be satisfied:

$$\tau_d \leq f_{v,d} \tag{6.13}$$

The check is performed in case of biaxial bending for $\tau_d = \sqrt{\tau_{y,d}^2 + \tau_{z,d}^2}$ and in all other cases for τ_d = max ($\tau_{y,d}$; $\tau_{z,d}$).

where

$\tau_{y,d}$, $\tau_{z,d}$ are the design shear stresses of the lateral forces in the y and z direction of the cross-section.

$f_{v,d}$ is the design shear strength.

DIN EN 1995-1-1:
The following expression shall be satisfied for biaxial bending at rectangular sections:

$$(\tau_{y,d} / f_{v,d})^2 + (\tau_{z,d} / f_{v,d})^2 \leq 1 \tag{NA.55}$$

The effect of cracks on structural members stressed by bending shall be taken into account using the effective width b_{ef} of the member according to Clause 6.1.7 (2):

$$b_{ef} = k_{cr} \cdot b \tag{6.13a}$$

The reduction factor k_{cr} is assumed as follows:

$k_{cr} = 0.67$ for solid timber and glued laminated timber

$k_{cr} = 1.0$ for other wood-based structural products

DIN EN 1995-1-1:
The following factors apply:

$k_{cr} = 0.67$ for solid timber made of hardwood

$k_{cr} = 2.0 / f_{v,k}$ for solid timber and glued laminated beams made of softwood

$k_{cr} = 2.5 / f_{v,k}$ for glued laminated timber with $f_{v,k}$ in N/mm²

For beams made from softwood timber, the values for k_{cr} may be increased by 30 % in areas at least 1.50 m from the end-grain of the wood.

OENORM B 1995-1-1:
The following factors apply:

$k_{cr} = 0.67$ for solid timber and glued laminated timber made of hardwood

$k_{cr} = 1.00$ for other wood-based structural products made of hardwood

$k_{cr} = 1.00$ for solid timber, glued laminated timber and other wood-based structural products made of softwood. This value is applied for solid timber on the assumption of a characteristic shear strength $f_{v,k}$ = 2.3 N/mm² and for glued laminated timber on the assumption of $f_{v,k}$ = 2.5 N/mm².

SS EN 1995-1-1:
The following factors apply:

$k_{cr} = 0.67$ for solid timber and glued laminated timber fully or partially exposed to precipitation and solar radiation. The program assumes these prerequisites for service class 3.

$k_{cr} = 3.0 / f_{v,k}$ for solid timber and glued laminated timber in all other cases.

Torsion

In accordance with Chapter 6.1.8 the following expression shall be satisfied for torsional stresses:

$$\tau_{tor,d} \leq k_{shape} \cdot f_{v,d} \qquad (6.14)$$

with

$$k_{shape} = \begin{cases} 1.2 & \text{for a circular cross-section} \\ \min(1+0.05 \cdot h/b;\ 1.3) & \text{for a rectangular cross-section} \end{cases} \qquad (6.15)$$

where

$\tau_{tor,d}$ is the design torsional stress.

$f_{v,d}$ is the design shear strength.

k_{shape} is a factor depending on the shape of the cross-section.

h is the larger cross-sectional dimension.

b is the smaller cross-sectional dimension.

Combined Shear and Torsion

DIN EN 1995-1-1 und OENORM B 1995-1-1:

The following expression shall be satisfied for the combination of shear from lateral force and torsion:

$$\tau_{tor,d} / (k_{shape} \cdot f_{v,d}) + (\tau_{y,d} / f_{v,d})^2 + (\tau_{z,d} / f_{v,d})^2 \leq 1 \qquad \text{(NA.56)} \ \text{(NA.6.15-E1)}$$

For the factor k_{shape} the value given for torsion applies.

Buckling Check With Equivalent Beam Method

For the usage of the equivalent beam method the stability of structural members subjected to combined compression and bending is to be checked according to EN 1995-1-1, Chapter 6.3.2. Thereby the relative slenderness ratio should be taken as:

$$\lambda_{rel,y} = \frac{\lambda_y}{\pi}\sqrt{\frac{f_{c,0,k}}{E_{0.05}}} \qquad (6.21)$$

and

$$\lambda_{rel,z} = \frac{\lambda_z}{\pi}\sqrt{\frac{f_{c,0,k}}{E_{0.05}}} \qquad (6.22)$$

where

λ_y, $\lambda_{rel,y}$ are the slenderness ratios for buckling about the y-axis;

λ_z, $\lambda_{rel,z}$ are the slenderness ratios for buckling about the z-xis;

$\lambda = l_{ef} / i$

l_{ef} is the equivalent beam length;

i is the radius of gyration.

In accordance with 6.3.2 (2) if $\lambda_{rel,y} \le 0.3$ or $\lambda_{rel,z} \le 0.3$ the compression and bending stresses are checked according to Eq. (6.19) or (6.20). Otherwise the following equations are used:

$$(\sigma_{c,0,d} / (k_{c,y} \cdot f_{c,0,d}) + \sigma_{m,y,d} / (k_m \cdot f_{m,y,d}) + k_m \cdot \sigma_{m,z,d} / f_{m,z,d} \le 1 \qquad (6.23)$$

$$(\sigma_{c,0,d} / (k_{c,z} \cdot f_{c,0,d}) + k_m \cdot \sigma_{m,y,d} / (k_m \cdot f_{m,y,d}) + \sigma_{m,z,d} / f_{m,z,d} \le 1 \qquad (6.24)$$

where

$$k_{c,y} = \frac{1}{k_y + \sqrt{k_y^2 - \lambda_{rel,y}^2}} \qquad (6.25)$$

$$k_{c,z} = \frac{1}{k_z + \sqrt{k_z^2 - \lambda_{rel,z}^2}} \qquad (6.26)$$

$$k_y = 0.5 \cdot \left(1 + \beta_c\left(\lambda_{rel,y} - 0.3\right) + \lambda_{rel,y}^2\right) \qquad (6.27)$$

$$k_z = 0.5 \cdot \left(1 + \beta_c\left(\lambda_{rel,z} - 0.3\right) + \lambda_{rel,z}^2\right) \qquad (6.28)$$

β_c is a factor for imperfections defined in Section 10;

$\beta_c = 0.2$ for solid timber; (6.29)

0.1 for glued laminated timber and LVL;

k_m is a factor according to 6.1.6 (2).

After the check is activated in the settings dialog it will be carried out for all beams with defined equivalent beam length.

Serviceability Limit States

Design Combinations

In accordance with EN 1990 (Eurocode 0), Chapter 6.5.3, the following combinations are taken into account in the serviceability limit states:

- Combination for characteristic situations

$$\sum_{j\geq 1} G_{k,j} \text{ "+" } P \text{ "+" } Q_{k,1} \text{ "+" } \sum_{i>1} \psi_{0,i} \cdot Q_{k,i} \tag{6.14b}$$

- Combination for frequent situations

$$\sum_{j\geq 1} G_{k,j} \text{ "+" } P \text{ "+" } \psi_{1,1} \cdot Q_{k,1} \text{ "+" } \sum_{i>1} \psi_{2,i} \cdot Q_{k,i} \tag{6.15b}$$

- Combination for quasi-continuous situations

$$\sum_{j\geq 1} G_{k,j} \text{ "+" } P \text{ "+" } \sum_{i>1} \psi_{2,i} \cdot Q_{k,i} \tag{6.16b}$$

Limiting Deformations

In accordance with EN 1995-1-1, Chapter 7.2, the deformations of beams should not exceed the values in Table 7.2.

DIN EN 1995-1-1:

The limits given in table NA.13 apply.

OENORM B 1995-1-1:

The limits given in table NA.7.2 apply.

SS EN 1995-1-1:

In accordance with Article 8 the limitation values for the deflection are determined in every individual case depending on the respective circumstances.

The deformation check is selected in the analysis settings. The instantaneous deformation is calculated according to Chapter 2.2.3 (2) for the characteristic design situation. Deviating from the procedure in EN 1995-1-1, the final deformation is always calculated according DIN EN 1995-1-1, Chapter 2.2.3 (NA.8), Equation (NA.1). It is based on the quasi-continuous design situation.

$$u_{net,fin} = \left(u_{inst,G} + \sum_{i\geq 1} \psi_{2,i} \cdot u_{inst,Q,i} \right) \cdot \left(1 + k_{def}\right) - u_c \tag{NA.1}$$

OENORM B 1995-1-1:

The equation (NA.7.2) corresponding to the above equation is used.

For this purpose, the characteristic and quasi-continuous design situations are to be defined in the action dialog. The deformation coefficient k_{def} is determined automatically according to EN 1995-1-1, Table 3.2, depending on the timber material and the service class, defined in the cross section. An elevation of the component is not considered.

The deformations can be found in the folder *Beam deformations* > *Timber checks* of the result tree.

Results

The extremal values for internal forces, support reactions, deformations, soil pressures and stresses are saved for all check situations. The detailed log also lists the decisive combination internal forces of all design situations for each result location.

Stresses

σ_x, σ_y	Extremal normal stresses from bending and normal force.
σ_{xy}	Extremal shear stresses from torsional moment and shear force.
τ_{xy}, τ_{xz}	Extremal shear stresses from lateral force and torsion.
σ_v	Maximum comparison stress.
σ_1, σ_2	Extremal principal stresses.

All stresses are given in [MN/m²].

Utilizations

The utilization is defined as the ratio between the action E_d and the resistance R_d of a cross-section. In the folder *Stresses/ Timber Checks* of the result tree the following results are available:

- Utilization of the beams for each situation.
- Maximal utilization of the beams of all situations.
- Maximal utilization of the sections of all situations.

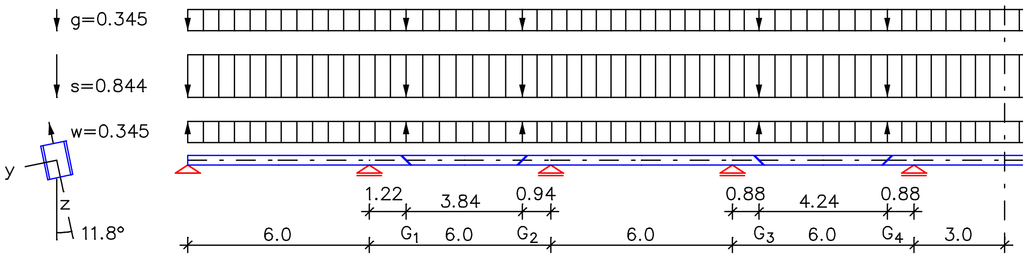
Examples

Timber Checks on a Purlin With Joints

The example was chosen inspired by the book

Gerhard Werner; Karlheinz Zimmer.
Holzbau 2 - Dach- und Hallentragwerke nach DIN 1052 (neu 2008) und Eurocode 5.
4., neu bearbeitete Auflage. Springer-Verlag, Berlin 2010.

A framework analysis and also timber checks are performed for the purlin illustrated below. The axes of the structure formed by a purlin with joints run parallel to the eave resp. the roof surface. Therefore the cross-section is rotated by 11.8 degrees. The inner spans of the purlin up to joint G_1 are assigned to section 1 (rectangle 100/160). The outer spans of the purlin up to joint G_1 are of section 2 (rectangle 120/160). Both sections are made of softwood of strength class C24 and assigned to service class 2.



Static system, dimensions [m] and loads [kN/m]

Sum of installed loads and support reactions

LC.	Label	Fx [kN]	Fy [kN]	Fz [kN]
1	Dead load and roof cladding	0.000	0.000	9.315
	Support reactions	0.000	0.000	9.315
2	Snow load (short-term)	0.000	0.000	22.788
	Support reactions	0.000	-0.000	22.788
3	Wind load (short-term)	0.000	1.905	-9.118
	Support reactions	0.000	1.905	-9.118

Loads are to be assigned to actions like described in the following log to perform the checks. The checking program carries out the necessary internal force combinations and checks the cross-section resistance and the deformations.

Design per EN 1995-1-1:2014

```
The check of the cross-section resistance is based on EN 1995-1-1, Chapter 6.1.
The system strength factor as per Chapter 6.6 is assumed to be ksys = 1.
The effect of member size on strength is considered as per Chapter 3.2 and 3.3.
The maximum cross-section dimension for the bending strength and the minimum for
the tensile strength are used as the decisive dimension for the factor kh.

The actions are combined acc. to EN 1990, Eq. (6.10), using the partial and
combination factors according to EN 1990:2021.
```

All variations of cooperation of the variable actions are examined.

Stress Calculation

```
The normal stresses and shear stresses are calculated for homogeneous
polygon sections from normal force, bending moments, lateral force and torsion.
The shear characteristics are calculated acc. to the Boundary-Element-Method.
The calculation points for all stresses are edge points of the cross-section.
```

Partial Safety Factors for Timber

```
                                    gamma.M
Permanent and temporary comb.         1.30 (Solid Timber)
                                      1.25 (Glued Laminated Timber)
Accidental combination                1.00
```

Characteristic Material Properties

```
Strength and density as per EN 338:2016 and EN 14080:2013 [MN/m², kg/m³].

Material          fmk    ft0k   fc0k    fvk   rhok
C24              24.0    14.5   21.0    4.0  350.0
```

Cross-Section Properties

```
Cl.       Service class
A         Sectional area [mm²]
d,h,b     Diameter, height, width [mm]
Iy..Iyz   Moments of inertia [m4]
```

Cross-section	Material	Cl.	A	d,h b	Iy Iz	Ix Iyz
1 Inner spans	C24	2	16000	160	3.4133e-05	3.2598e-05
				100	1.3333e-05	0.0000e+00
2 Outer span	C24	2	19200	160	4.0960e-05	4.9752e-05
				120	2.3040e-05	0.0000e+00

EN 1995-1-1 actions

Standard design group

G - Dead load

```
Gamma.sup / gamma.inf = 1.35 / 1

Load-duration: Permanent

Load cases
----------
1     Dead load and roof cladding
```

QS - Snow and ice load

```
Gamma.sup / gamma.inf = 1.5 / 0

Load-duration: Short-term

Combination coefficients for: Superstructures
Snow load - Places in CEN member states with less than 1000 m above sea level
Psi.0 / Psi.1 / Psi.2 = 0.5 / 0.2 / 0

Load cases 1. Variant, inclusive
--------------------------------
2     Snow load (short-term)
```

QW - Wind load

```
Gamma.sup / gamma.inf = 1.5 / 0

Load-duration: Short-term

Combination coefficients for: Superstructures
Wind loads
Psi.0 / Psi.1 / Psi.2 = 0.6 / 0.2 / 0

Load cases 1. Variant, exclusive
--------------------------------
3     Wind load (short-term)
```

1. Permanent and temporary situation

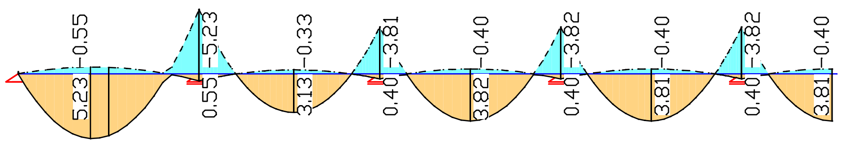
```
Final state

G  - Dead load
QS - Snow and ice load
QW - Wind load
```

1. Rare (characteristic) situation

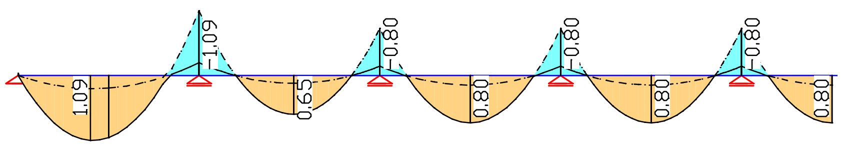
```
Final state

G  - Dead load
QS - Snow and ice load
QW - Wind load
```

1. Quasi-continuous situation

```
Final state

G  - Dead load
QS - Snow and ice load
QW - Wind load
```



Bending moment min/max M_y [kNm]

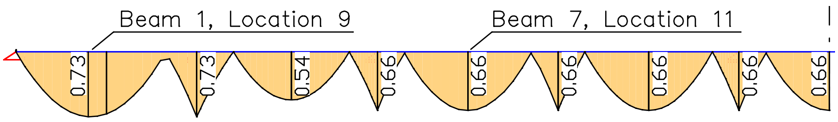


Bending moment min/max M_z [kNm]

Max. Cross-Section Utilization

```
Utilization Relation between the design values of stress and strength.
Tension     Tension parallel to the grain as per Eq. (6.1).
Compression Compression parallel to the grain as per Eq. (6.2).
Bending     Bending as per Eq. (6.11) and (6.12).
Bend.,Tens. Bending and axial tension as per Eq. (6.17) and (6.18).
Bend.,Comp. Bending and axial compression as per Eq. (6.19) and (6.20).
Shear       Shear as per Eq. (6.13).
Torsion     Torsion as per Eq. (6.14).
x           Distance from the beam startpoint [m].
PC          Permanent and temporary comb.
```

Cross-section	Material	Result	Beam	Loc.	x[m]	Comb.	Util.
1 Inner spans	C24	Tension			-.-	-.-	-.-
		Compression			-.-	-.-	-.-
		Bending	7	11	3.00	PC.1	0.66
		Bending, Tens.			-.-	-.-	-.-
		Bending, Comp.			-.-	-.-	-.-
		Shear	8	11	3.00	PC.1	0.26
		Torsion			-.-	-.-	-.-
2 Outer span	C24	Tension			-.-	-.-	-.-
		Compression			-.-	-.-	-.-
		Bending	1	9	2.40	PC.1	0.73
		Bending, Tens.			-.-	-.-	-.-
		Bending, Comp.			-.-	-.-	-.-
		Shear	2	11	3.00	PC.1	0.26
		Torsion			-.-	-.-	-.-



Utilization by check 'Bending'

The following pages contain excerpts from the detailed check log for beam 1 at location 9.

Check of the Cross-Section Resistance for Beams

```
The results represent the extrema of all combinations.

Utilization Relation between the design values of stress and strength.
kmod        Modif. factor for load-duration and moisture content, Eq. (2.17).
km          Reduction factor for the bending stress as per Chapter 6.1.6(2).
khy, khz    Increase factors for the bending strength as per Eq. (3.1), (3.2).
kht         Increase factor for the tensile strength as per Eq. (3.1), (3.2).
kcr         Reduction factor for the shear strength as per Eq. (6.13a).
kshape      Increase factor for the shear strength as per Eq. (6.14).
ft0d        Axial tensile strength = kmod · ft0k / gamma.M [MN/m²].
fc0d        Axial compressive strength = kmod · fc0k / gamma.M [MN/m²].
fmd         Bending strength = kmod · fmk / gamma.M [MN/m²].
fvd         Strength for lat. force & torsion = kmod · fvk / gamma.M [MN/m²].
x           Distance from the beam startpoint [m].
y, z        Location in the sectional polygon [m].
```

Location 9

```
Beam 1: x = 2.40 m (Beam Length 3.00 m)
Cross-section 2: Outer span, C24; Class 2; h/b=160/120 mm; A=19200 mm²
km=0.70; khy/khz/kht=1.00/1.00/1.05; kcr=0.67; kshape=1.07
```

1. Permanent and temporary comb. (PC.1): G+QS+QW

```
Relevant values from 10 sets of internal forces
Set      Nx[kN]    Qy[kN]    Qz[kN]    Mx[kNm]    My[kNm]    Mz[kNm] Load-dur. kmod
3    :     0.00      0.03      0.15      -0.00       5.23       1.09 Sho.-term 0.90

Load case combination for the relevant set of internal forces
Set     Combination
3    : 1.35*L1+1.50*L2
```

Check for Bending

```
Max. Utilization as per Equation (6.11) and (6.12) :  0.73
cor. Sigma.myd / (khy·fmd)      :  -10.217 / 16.615 :  0.61
     Sigma.mzd / (khz·fmd)      :   -2.846 / 16.615 :  0.17
     S.point y / z [m]          :    0.000 /  0.000
     Situation / Set            :     PC.1 /      3
```

Check for Shear

```
Max. Utilisation as per Equation (6.13)             :  0.01
cor. Tau.yd    / (kcr·fvd)      :    0.002 /  1.855 :  0.00
     Tau.zd    / (kcr·fvd)      :    0.011 /  1.855 :  0.01
     Tau.d     / (kcr·fvd)      :    0.012 /  1.855 :  0.01
     S.point y / z [m]          :    0.060 /  0.080
     Situation / Set            :     PC.1 /      3
```

Following is the detailed log of deformations to be detected for beam 1, location 10, the location with the maximum instantaneous and final deformation.

Check of beam deformations

```
The results represent the extrema of all combinations.

Class       Service class
kdef        Deformation factor acc. to Table 3.2.
L           User-defined length of the field (Figure 7.1) [m].
w.inst,     User-defined permitted deflection for the instantaneous, final
w.fin       deformation check.
Utilis.     Ratio of instantaneous, final deformation to permitted deflection.
Direction   Direction of deformation for the check acc. to user input.
            y; z; y,z    Local y, z direction or y and z direction.
            r            Direction of the resulting deformation.
u.max       Maximum deformation in selected check direction [mm].
u.per       Permitted deflection calculated with L and w.inst or w.fin [mm].
Sit./Set    Decisive situation and set of deformations for the check.
```

Beam 1

Location 10

```
Beam 1: x = 2.70 m (Beam Length 3.00 m)
Cross-section 2: Endfeld, C24; Class 2; kdef=0.80; L=6.00 m;
w.inst=L/300; w.fin=L/250; Direction=r;
```

1. Characteristic (rare) combination (CC.1): G+QS+QW

```
Decisive local Deformation
Set         uy[mm]     uz[mm]     ur[mm]
3    :        9.6       25.9       27.6

Load case combination of decisive set of deformations
Set    Combination
3    : L1+L2
```

1. Quasi-continuous combination (QC.1): G+QS+QW

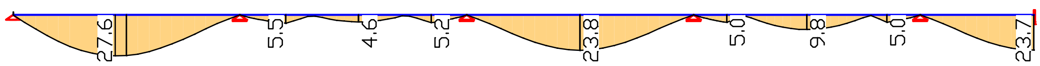
```
Decisive local Deformation
Set         uy[mm]     uz[mm]     ur[mm]
1    :        5.0       13.5       14.4

Load case combination of decisive set of deformations
Set    Combination
1    : L1
```

Check of Beam Deformations

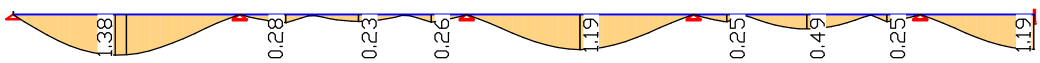
```
Instantaneous deformation [mm]:
Direct.  Sit./Set      u.max    u.per    Utilis.
   r     CC.1 / 3       27.6     20.0     1.38 >1

Final deformation [mm]:
Direct.  Sit./Set      u.max    u.per    Utilis.
   r     QC.1 / 1       14.4     24.0     0.60
```

The check of the instantaneous deformations exceeds the permissible deflection at several points. The literature example refers to DIN 1052, where only the deformations from traffic loads have to comply with the limit of L/300 when determining the initial deflection (load case 2, beam 1, location 10: u_r = 19.61 mm < 20 mm).

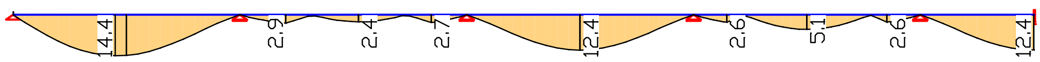
In the case of EN 1995-1-1, the deformation must be taken from the characteristic situation, i.e. in addition the deformation from permanent loads (load case 1, beam 1, location 10: u_r = 8.02 mm). By choosing a larger purlin cross-section this check can be satisfied.



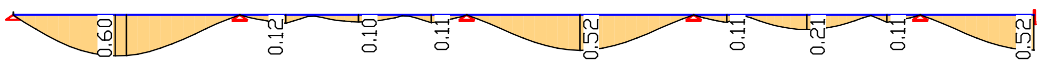
Instantaneous deformation in resulting direction [mm]



Utilization instantaneous deformation / perm. deflection



Final deformation in resulting direction [mm]

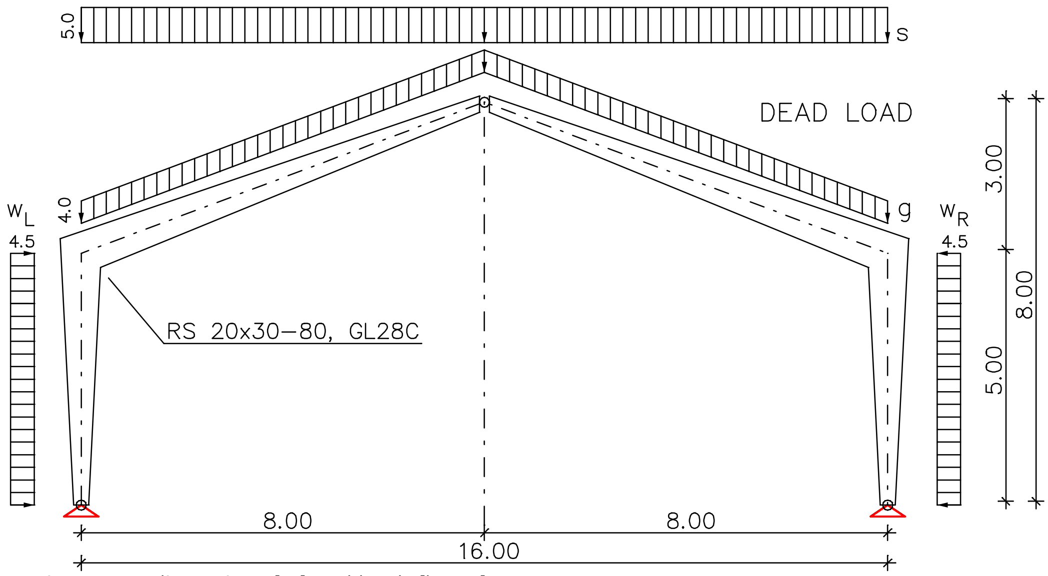


Utilization final deformation / perm. deflection

Three-Hinged Frame at Normal Temperature and Under Fire Conditions

This example shows the generation of a plane three-hinged frame made of timber with different cross-section heights at the beginning and the end of the beams and columns with corresponding loads. It also shows the process of the following calculations:

- Framework analysis according to the second-order theory
- Checks according to EN 1995-1-1 and EN 1995-1-2



Static system, dimensions [m] and loads [kN/m]

Cross-sections

At the hinges	Rectangle 20x30, GL28C, Service class 2
In the frame corners	Rectangle 20x80, GL28C, Service class 2

Settings for the check under fire conditions

Fire exposure	from three sides (left / right / bottom)
Duration of fire	30 min
Charring rate	0.7 mm/min

Load

Load case 1:	Permanent Loads, dead load and additional load 4.0 kN/m (see Fig.)
Load case 2:	Snow, projective line load 5.0 kN/m (load duration: medium-term) (see Fig.)
Load case 3, 4:	Wind, line load on columns 4.5 kN/m (load duration: short-term) (see Fig.)
Load case 11:	Stability check at normal temperature (see below)

Stability check at normal temperature

This load case has to be calculated according to the second-order theory. For the check in accordance with EN 1995-1-1 the results are checked against the characteristic material properties without further partial safety factors.

Load case 11 is described by the load type load group with the following settings:

Theory

Geometrical second-order theory

Selected load cases

Load case 1 with factor 1.35 (γ_G)

Load case 2 with factor 1.5 (γ_Q)

Additional global load factor

The actions have to be multiplied with the factors γ_G, γ_Q and γ_M = 1.25, because the safety factors have to be considered during the internal force calculation.

Predeformation

Is not taken into account in this example.

Design overview

To perform the checks the actions have to be assigned to the situations

- Permanent and temporary situation at normal temperature
- Special situation for the stability check at normal temperature
- Fire situation

as they are printed out in the following listing. The check program carries out the necessary internal force combinations and verifies the cross-section resistance.

Design per EN 1995-1-1:2014 and EN 1995-1-2:2009

The check of the cross-section resistance is based on EN 1995-1-1, Chapter 6.1.
The system strength factor as per Chapter 6.6 is assumed to be ksys = 1.
The effect of member size on strength is considered as per Chapter 3.2 and 3.3.
The maximum cross-section dimension for the bending strength and the minimum for the tensile strength are used as the decisive dimension for the factor kh.

For fire conditions unprotected surfaces throughout the time of fire exposure are assumed acc. to EN 1995-1-2, Chapter 3.4.2. The check is performed with reduced cross-sections as per Chapter 4.2.2 of the standard.

The actions are combined acc. to EN 1990, Eq. (6.10), using the partial and combination factors according to EN 1990:2021 and 1991-1-2:2009.
All variations of cooperation of the variable actions are examined.

Designing occurs for all possible combinations of actions.

Stress Calculation

The normal stresses and shear stresses are calculated for homogeneous polygon sections from normal force, bending moment and lateral force.
The shear characteristics are calculated acc. to the Boundary-Element-Method.
The calculation points for all stresses are edge points of the cross-section.

Partial Safety Factors for Timber

	gamma.M
Permanent and temporary comb.	1.30 (Solid Timber)
	1.25 (Glued Laminated Timber)
Accidental combination	1.00
Special combination	1.00
Fire combination	1.00

Characteristic Material Properties

Strength and density as per EN 338:2016 and EN 14080:2013 [MN/m², kg/m³].

Material	fmk	ft0k	fc0k	fvk	rhok
GL28C	28.0	19.5	24.0	3.5	390.0

Cross-Section Properties under Normal Temperature

Cl. Service class
A Sectional area [mm²]
d,h,b Diameter, height, width [mm]
Iy..Iyz Moments of inertia [m4]

Cross-section	Material	Cl.	A	d,h b	Iy Iz	Iyz
3 Rectangle	GL28C	2	62500	313	5.0863e-04	0.0000e+00
				200	2.0833e-04	
4 Rectangle	GL28C	2	67500	338	6.4072e-04	0.0000e+00
				200	2.2500e-04	
5 Rectangle	GL28C	2	72500	363	7.9391e-04	0.0000e+00
				200	2.4167e-04	
6 Rectangle	GL28C	2	77500	388	9.6976e-04	0.0000e+00
				200	2.5833e-04	
7 Rectangle	GL28C	2	82500	413	1.1698e-03	0.0000e+00
				200	2.7500e-04	
8 Rectangle	GL28C	2	87500	438	1.3957e-03	0.0000e+00
				200	2.9167e-04	
9 Rectangle	GL28C	2	92500	463	1.6489e-03	0.0000e+00
				200	3.0833e-04	
10 Rectangle	GL28C	2	97500	488	1.9310e-03	0.0000e+00
				200	3.2500e-04	
11 Rectangle	GL28C	2	102500	513	2.2435e-03	0.0000e+00
				200	3.4167e-04	
12 Rectangle	GL28C	2	107500	538	2.5881e-03	0.0000e+00
				200	3.5833e-04	
13 Rectangle	GL28C	2	112500	563	2.9663e-03	0.0000e+00
				200	3.7500e-04	
14 Rectangle	GL28C	2	117500	588	3.3797e-03	0.0000e+00
				200	3.9167e-04	
15 Rectangle	GL28C	2	122500	613	3.8297e-03	0.0000e+00
				200	4.0833e-04	
16 Rectangle	GL28C	2	127500	638	4.3181e-03	0.0000e+00
				200	4.2500e-04	
17 Rectangle	GL28C	2	132500	663	4.8463e-03	0.0000e+00
				200	4.4167e-04	
18 Rectangle	GL28C	2	137500	688	5.4159e-03	0.0000e+00
				200	4.5833e-04	
19 Rectangle	GL28C	2	142500	713	6.0284e-03	0.0000e+00
				200	4.7500e-04	
20 Rectangle	GL28C	2	147500	738	6.6855e-03	0.0000e+00
				200	4.9167e-04	
21 Rectangle	GL28C	2	152500	763	7.3887e-03	0.0000e+00
				200	5.0833e-04	
22 Rectangle	GL28C	2	157500	788	8.1396e-03	0.0000e+00
				200	5.2500e-04	

Cross-Section Properties under Fire Conditions

```
Cl.      Service class
Ar       Area of the residual cross-section as per EN 1995-1-2, Chapter 3.4 [mm²]
dr,hr,br Diameter, height, width of the residual cross-section [mm]
Iy..Iyz  Moments of inertia [m4]
t        Duration of the fire exposure as per EN 1995-1-2, Eq. (3.2) [min]
ßn       Design notional charring rate as per EN 1995-1-2, Table 3.1 [mm/min]
Side     Side exposed to fire: (L)eft, (R)ight, (T)op, (B)ottom, (A)ll sides
```

Cross-section	Material	Cl.	Ar	dr,hr br	Iy Iz	Iyz	t ßn	Side
3 Rectangle	GL28C	2	40968	285	2.7633e-04	0.0000e+00	30	LRB
				144	7.0793e-05		0.70	
4 Rectangle	GL28C	2	44568	310	3.5576e-04	0.0000e+00	30	LRB
				144	7.7014e-05		0.70	
5 Rectangle	GL28C	2	48168	334	4.4913e-04	0.0000e+00	30	LRB
				144	8.3234e-05		0.70	
6 Rectangle	GL28C	2	51768	360	5.5754e-04	0.0000e+00	30	LRB
				144	8.9455e-05		0.70	
7 Rectangle	GL28C	2	55368	384	6.8213e-04	0.0000e+00	30	LRB
				144	9.5676e-05		0.70	
8 Rectangle	GL28C	2	58968	410	8.2403e-04	0.0000e+00	30	LRB
				144	1.0190e-04		0.70	
9 Rectangle	GL28C	2	62568	435	9.8435e-04	0.0000e+00	30	LRB
				144	1.0812e-04		0.70	
10 Rectangle	GL28C	2	66168	459	1.1642e-03	0.0000e+00	30	LRB
				144	1.1434e-04		0.70	
11 Rectangle	GL28C	2	69768	484	1.3648e-03	0.0000e+00	30	LRB
				144	1.2056e-04		0.70	
12 Rectangle	GL28C	2	73368	509	1.5871e-03	0.0000e+00	30	LRB
				144	1.2678e-04		0.70	
13 Rectangle	GL28C	2	76968	535	1.8324e-03	0.0000e+00	30	LRB
				144	1.3300e-04		0.70	
14 Rectangle	GL28C	2	80568	560	2.1018e-03	0.0000e+00	30	LRB
				144	1.3922e-04		0.70	
15 Rectangle	GL28C	2	84168	585	2.3963e-03	0.0000e+00	30	LRB
				144	1.4544e-04		0.70	
16 Rectangle	GL28C	2	87768	609	2.7171e-03	0.0000e+00	30	LRB
				144	1.5166e-04		0.70	
17 Rectangle	GL28C	2	91368	635	3.0653e-03	0.0000e+00	30	LRB
				144	1.5788e-04		0.70	
18 Rectangle	GL28C	2	94968	660	3.4421e-03	0.0000e+00	30	LRB
				144	1.6410e-04		0.70	
19 Rectangle	GL28C	2	98568	685	3.8486e-03	0.0000e+00	30	LRB
				144	1.7033e-04		0.70	
20 Rectangle	GL28C	2	102168	710	4.2859e-03	0.0000e+00	30	LRB
				144	1.7655e-04		0.70	
21 Rectangle	GL28C	2	105768	734	4.7551e-03	0.0000e+00	30	LRB
				144	1.8277e-04		0.70	
22 Rectangle	GL28C	2	109368	760	5.2573e-03	0.0000e+00	30	LRB
				144	1.8899e-04		0.70	

All residual cross-sections fulfill Clause 4.3.5(2) of EN 1995-1-2.

EN 1995-1-1 actions

Standard design group

G - Dead load

```
Gamma.sup / gamma.inf = 1.35 / 1

Load-duration: Permanent

Load cases
----------
1    Dead load
```

QS - Snow and ice load

```
Gamma.sup / gamma.inf = 1.5 / 0

Load-duration: Medium-term

Combination coefficients for: Superstructures
Snow load - Places in CEN member states with less than 1000 m above sea level
Psi.0 / Psi.1 / Psi.2 = 0.5 / 0.2 / 0

Load cases 1. Variant, inclusive
--------------------------------
2    Snow
```

QW - Wind load

```
Gamma.sup / gamma.inf = 1.5 / 0

Load-duration: Short-term

Combination coefficients for: Superstructures
Wind loads
Psi.0 / Psi.1 / Psi.2 = 0.6 / 0.2 / 0

Load cases 1. Variant, exclusive
--------------------------------
3    Wind left
4    Wind right
```

Fd - Design values of actions

Load-duration: Medium-term

```
Load cases
----------
11   PT Th.2
```

1. Permanent and temporary situation

Final state

G - Dead load
QS - Snow and ice load
QW - Wind load

1. Special situation

Final state

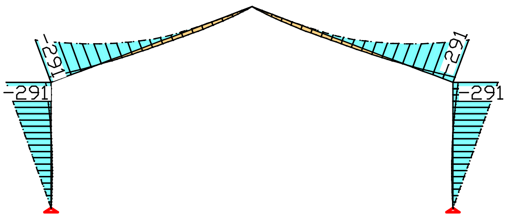
Fd - Design values of actions

1. Fire situation

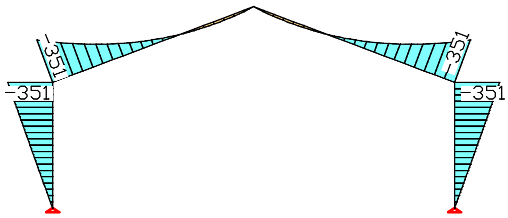
Final state

G - Dead load
QS - Snow and ice load
QW - Wind load

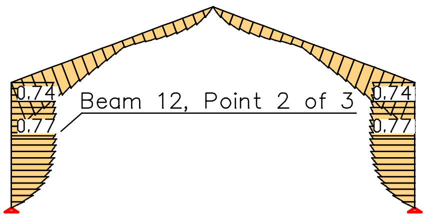
Results



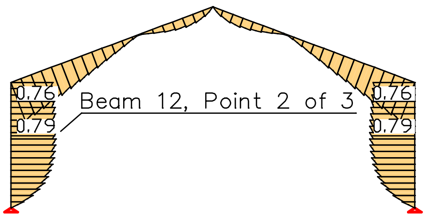
Bending moment min/max M (permanent c.) [kNm]



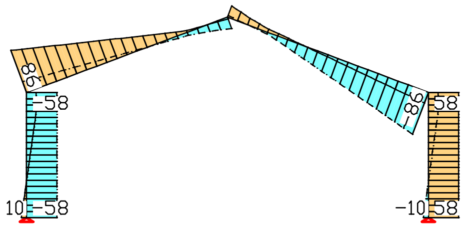
Bending moment min/max M (special c.) [kNm]



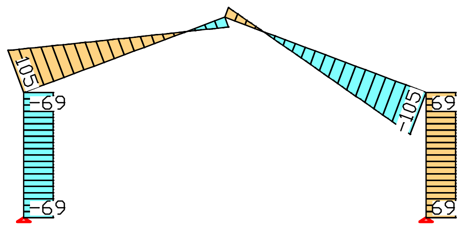
Maximum utilization due to bending (permanent c.)



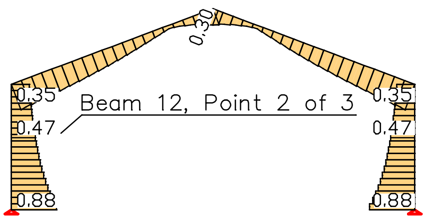
Maximum utilization due to bending (special c.)



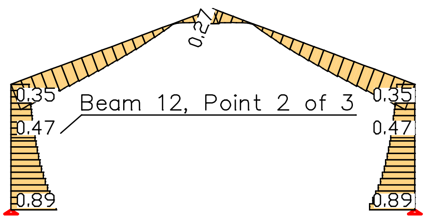
Lateral forces min/max Q (permanent c.) [kN]



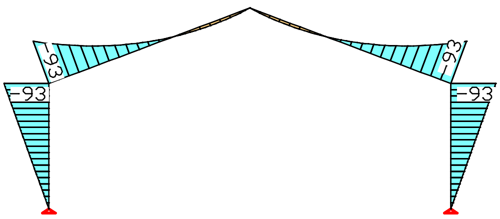
Lateral forces min/max Q (special c.) [kN]



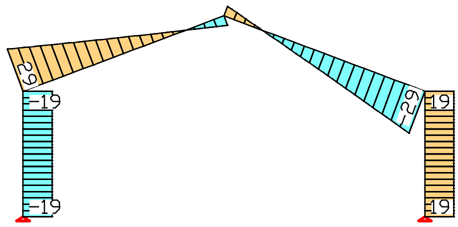
Maximum utilization due to shear (permanent c.)



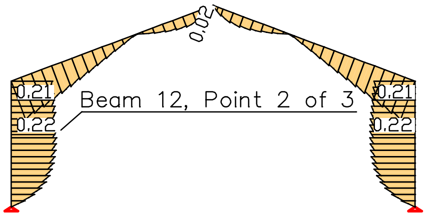
Maximum utilization due to shear (special c.)



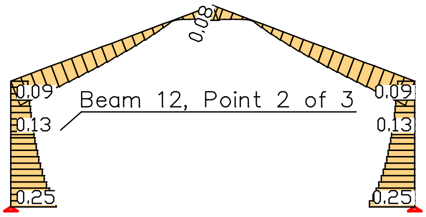
Bending moment min/max M (fire c.) [kNm]



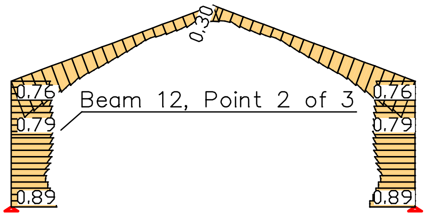
Lateral forces min/max Q (fire c.) [kN]



Maximum utilization due to bending (fire c.)



Maximum utilization due to shear (fire c.)



Maximum utilization due to all checks

Subsequently an additional extract of the detailed listing for beam 12, location 2 is printed.

Check of the Cross-Section Resistance for Beams under Normal Temperature

```
The results represent the extrema of all combinations.

Utilization Relation between the design values of stress and strength.
kmod         Modif. factor for load-duration and moisture content, Eq. (2.17).
km           Reduction factor for the bending stress as per Chapter 6.1.6(2).
khy          Increase factor for the bending strength as per Eq. (3.1), (3.2).
kht          Increase factor for the tensile strength as per Eq. (3.1), (3.2).
kcr          Reduction factor for the shear strength as per Eq. (6.13a).
ft0d         Axial tensile strength = kmod · ft0k / gamma.M [MN/m²].
fc0d         Axial compressive strength = kmod · fc0k / gamma.M [MN/m²].
fmd          Bending strength = kmod · fmk / gamma.M [MN/m²].
fvd          Shear strength for lateral force = kmod · fvk / gamma.M [MN/m²].
x            Distance from the beam startpoint [m].
y, z         Location in the sectional polygon [m].
```

Location 2

```
Beam 12: x = 0.13 m (Beam Length 0.25 m)
Cross-section 14: Rectangle, GL28C; Class 2; h/b=588/200 mm; A=117500 mm²
km=0.70; khy/kht=1.00/1.10; kcr=0.67
```

1. Permanent and temporary comb. (PC.1): G+QS+QW

```
No set of internal forces in this combination was relevant.
```

1. Special combination (SC.1): Fd

```
Relevant values from 1 set of internal forces
Set        Nx[kN]     Qz[kN]    My[kNm]  Load-dur. kmod
1     :  -140.38     -69.29    -204.14  Med.-term 0.80

Load case combination for the relevant set of internal forces
Set       Combination
1     : L11
```

Check for Compression parallel to the Grain

```
Max. Utilization as per Equation (6.2)                :  0.06
cor. Sigma.c0d / fc0d            :    -1.195 / 19.200 :  0.06
     Situation / Set             :     SC.1 /       1
```

Check for Bending

```
Max. Utilization as per Equation (6.11) and (6.12) :  0.79
cor. Sigma.myd / (khy·fmd)       :    17.743 / 22.447 :  0.79
     S.point y / z [m]           :     0.000 /  0.000
     Situation / Set             :     SC.1 /       1
```

Check for Bending and Axial Compression

```
Max. Utilization as per Equation (6.19) and (6.20) :  0.79
cor. Sigma.c0d / fc0d          :   -1.195 / 19.200 :  0.06
     Sigma.myd / (khy·fmd)     :   17.743 / 22.447 :  0.79
     S.point y / z [m]         :    0.000 /  0.000
     Situation / Set           :     SC.1 /      1
```

Check for Shear

```
Max. Utilisation as per Equation (6.13)            :  0.47
cor. Tau.yd    / (kcr·fvd)     :    0.000 /  1.876 :  0.00
     Tau.zd    / (kcr·fvd)     :   -0.885 /  1.876 :  0.47
     S.point y / z [m]         :    0.200 /  0.294
     Situation / Set           :     SC.1 /      1
```

Check of the Cross-Section Resistance for Beams under Fire Conditions

```
The results represent the extrema of all combinations.

Utilization Relation between the design values of stress and strength.
kmod,fi     Mod. factor for fire conditions as per EN 1995-1-2, Eq. (2.1).
kfi         Factor as per EN 1995-1-2, Table 2.1.
km          Reduction factor for the bending stress as per Chapter 6.1.6(2).
khy         Increase factor for the bending strength as per Eq. (3.1), (3.2).
kht         Increase factor for the tensile strength as per Eq. (3.1), (3.2).
kcr         Reduction factor for the shear strength as per Eq. (6.13a).
ft0d,fi     Axial tensile strength = kmod,fi · kfi · ft0k / gamma.M,fi.
fc0d,fi     Axial compressive strength = kmod,fi · kfi · fc0k / gamma.M,fi.
fmd,fi      Bending strength = kmod,fi · kfi · fmk / gamma.M,fi.
fvd,fi      Shear strength for lateral force = kmod,fi · kfi · fvk / gamma.M,fi.
x           Distance from the beam startpoint [m].
y, z        Location in the sectional polygon [m].
```

Location 2

```
Beam 12: x = 0.13 m (Beam Length 0.25 m)
Cross-section 14: Rectangle, GL28C, Class 2; hr/br=560/144 mm; Ar=80568 mm²
kmod,fi=1.00; kfi=1.15; km=0.70; khy/kht=1.01/1.10; kcr=0.67
```

1. Fire combination (FC.1): G+QS+QW

```
Relevant values from 1 set of internal forces
Set      Nx[kN]    Qz[kN]   My[kNm]
1    :   -38.74    -18.56    -53.37

Load case combination for the relevant set of internal forces
Set    Combination
1    : L1
```

Check for Compression parallel to the Grain

```
Max. Utilization as per Equation (6.2)             :  0.02
cor. Sigma.c0d / fc0d,fi       :   -0.481 / 27.600 :  0.02
     Situation / Set           :     FC.1 /      1
```

Check for Bending

```
Max. Utilization as per Equation (6.11) and (6.12) :  0.22
cor. Sigma.myd / (khy·fmd,fi)  :    7.104 / 32.426 :  0.22
     S.point y / z [m]         :    0.000 /  0.000
     Situation / Set           :     FC.1 /      1
```

Check for Bending and Axial Compression

```
Max. Utilization as per Equation (6.19) and (6.20) :  0.22
cor. Sigma.c0d / fc0d,fi       :   -0.481 / 27.600 :  0.02
     Sigma.myd / (khy·fmd,fi)  :    7.104 / 32.426 :  0.22
     S.point y / z [m]         :    0.000 /  0.000
     Situation / Set           :     FC.1 /      1
```

Check for Shear

```
Max. Utilisation as per Equation (6.13)            :  0.13
cor. Tau.yd    / (kcr·fvd,fi)  :    0.000 /  2.697 :  0.00
     Tau.zd    / (kcr·fvd,fi)  :   -0.346 /  2.697 :  0.13
     S.point y / z [m]         :    0.144 /  0.280
     Situation / Set           :     FC.1 /      1
```

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