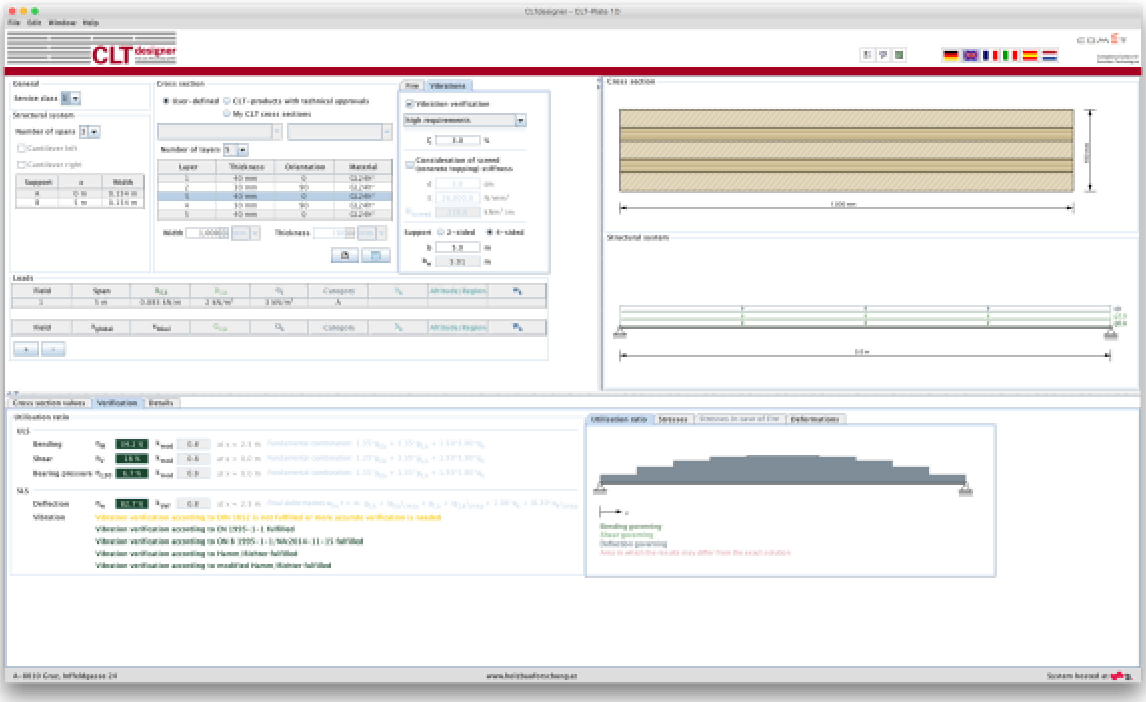
# Module "CLT-Plate 1D - Continuous beam"

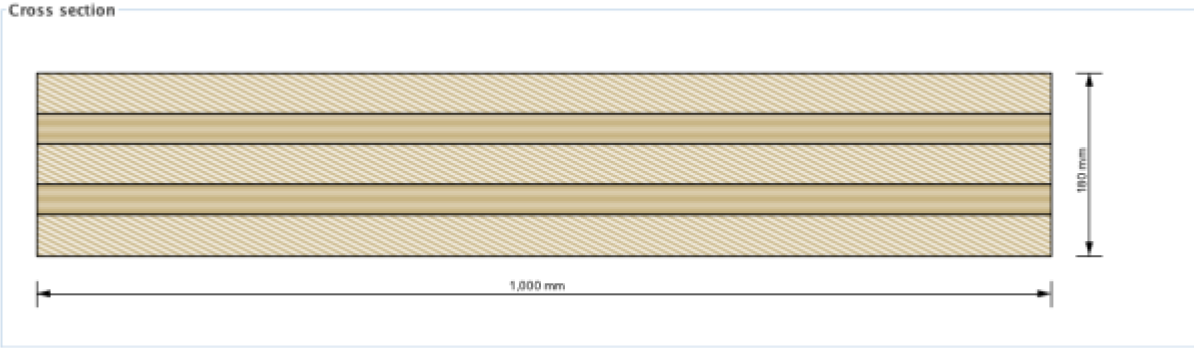


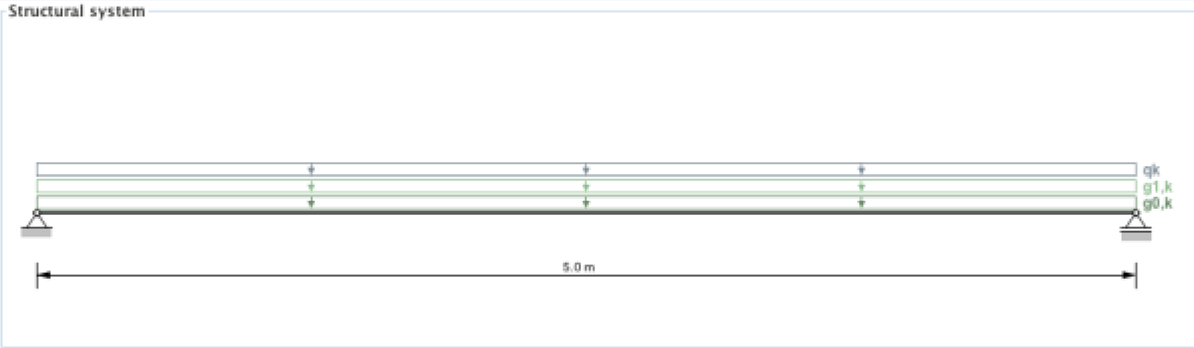
## Input data

The input is divided into:

- general information about the project and the considered structural element
- definitions of the structural system
- definitions of the cross section
- input of the loads
- informations about fire and vibration parameters

A graphical representation of the input data is shown on the right side. This offers the possibility for a fast check of the input data.



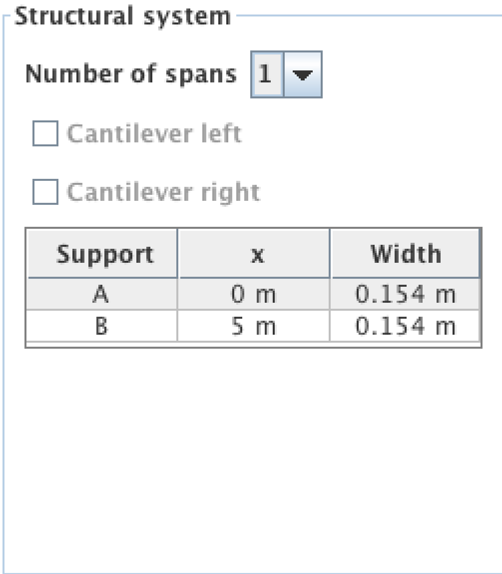

## General

The input field "General" defines the service class. It is only allowed to use CLT elements in areas of service class 1 and 2.

- Service class 1 (interior service condition) is in general consistent with a common utilisation of living spaces.
- Service class 2 (protected exterior service condition) is generally used for open but roofed structures.


## Structural system

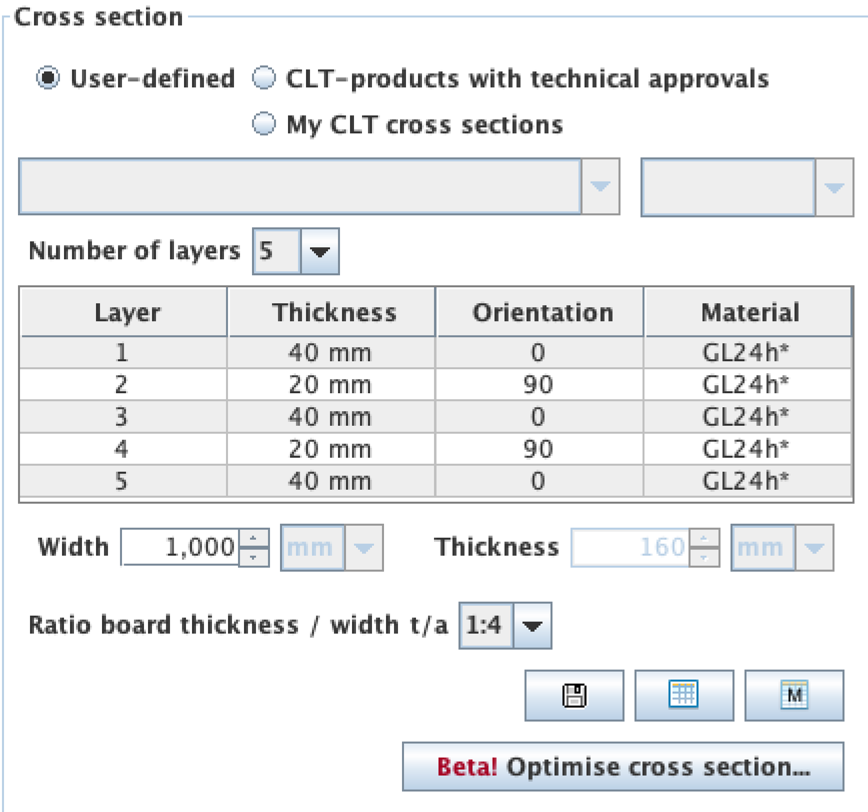
In the current version a continuous beam with a maximum of 7 spans including a cantilever on the left and right side can be analysed. The supporting width and span of field (via x-value in the table) can be defined within this input field.




## Cross section

The cross section can be defined by the user or by choosing a typical cross section of a proprietary CLT product. There is also the possibility to save own CLT cross sections in a library. The elements are subdivided by the number of layers.

If a user-defined cross section is entered, the thickness and orientation of each layer can be changed. Furthermore, the material can be changed for all layers. The thickness of each layer has to be within the range of 6.0 mm to 45 mm. In the case of proprietary CLT products, the strength class of lumber and the orientation can be changed. If the orientation is changed, the whole cross section is rotated.



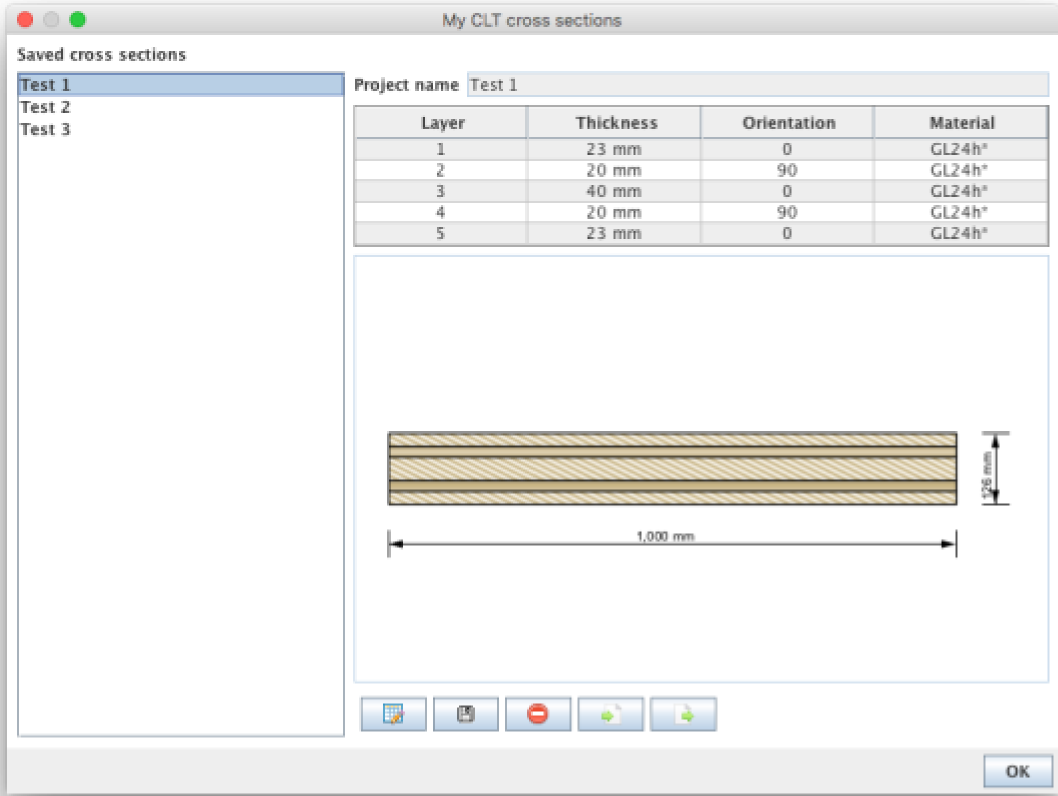

The width of the CLT plate strips can be also defined in this field. The default value is set to 1 m. The thickness of the CLT plate is calculated automatically based on the thickness of the single layers.

The ratio of board thickness to board width can also be changed here. The default setting is 1:4.

### My CLT cross sections

By clicking the button the current cross section can be stored in the library and be retrieved by selecting "My CLT cross sections" later on.

The library can be displayed with the button .




- The edit mode can be entered by clicking on . Currently, only the name of the stored cross section can be changed.
- With the changes are saved.
- With the chosen cross section in the sidebar can be removed from the library.
- With cross sections from a csv file can be imported.
- With the cross sections from the library can be exported to a csv file.

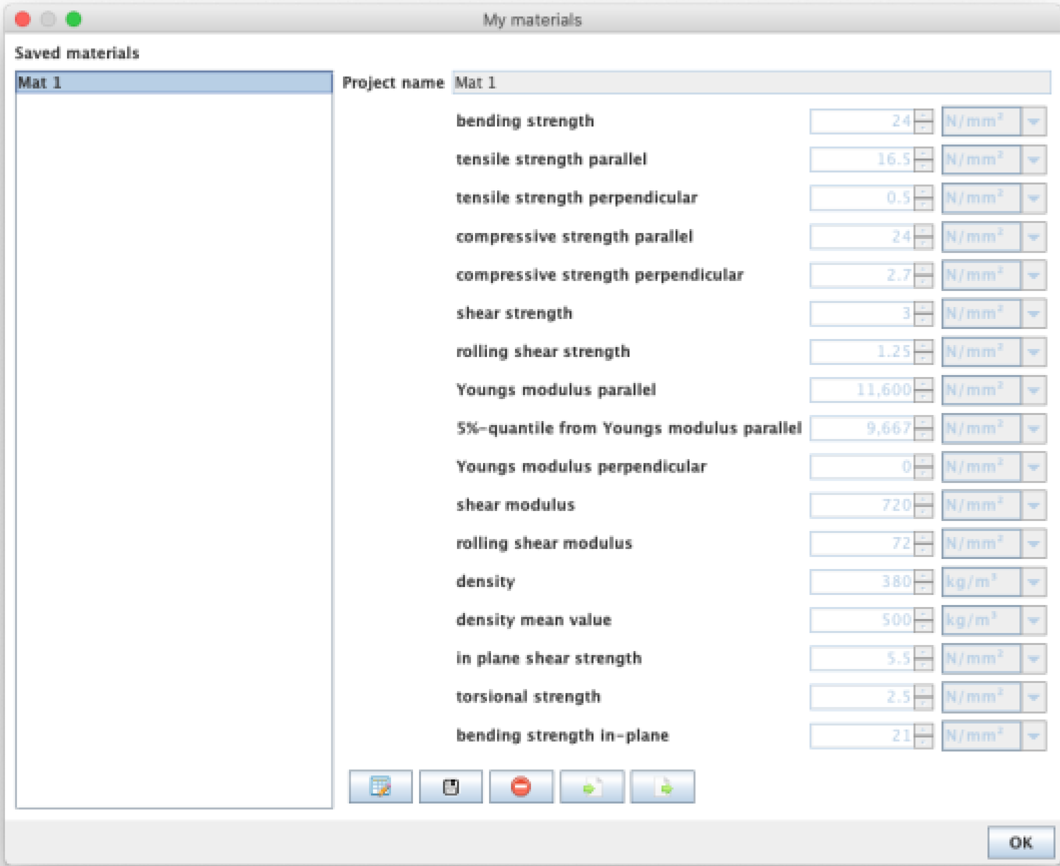
**Syntax of the csv file**

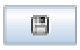
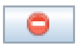
name;number of layers n;layer thickness in [m] $t_1$ to $t_n$;orientation of the layers $o_1$ to $o_n$ (0 or 90);name of material

Example:
Test layup;5;0.03;0.02;0.02;0.02;0.03;90;0;90;0;90;GL24h*

## My materials

With the button  the material library can be displayed.




- With  the edit mode can be entered.
- With  the changes are saved.
- With  the chosen material in the sidebar can be removed from the library.
- With  materials from a csv file can be imported.
- With  the materials from the library can be exported to a csv file.

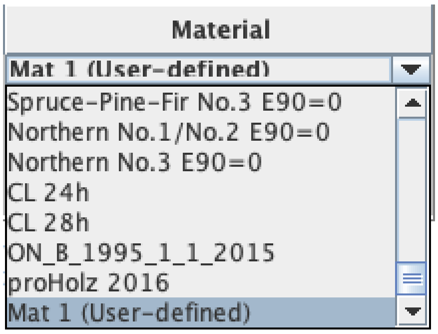
**Syntax of the csv file**

1. row: description of the parameters
2. row: units of the parameters
3. row: value

delimiter: ";"

Example:
Name;f_m,k;f_t,0,k;f_t,90,k;f_c,k;f_c,90,k;f_v,k;f_r,k;E_0;E_0,05;E_90;G;G_r;rho_k;rho_mean;f_v,k,IP;f_T,k;f_m,k,IP
;N/mm2;N/mm2;N/mm2;N/mm2;N/mm2;N/mm2;N/mm2;N/mm2;N/mm2;N/mm2;N/mm2;N/mm2;kg/m3;kg/m3;N/mm2;N/mm2;N/mm2
Mat 1;24;16.5;0.5;24;2.7;3;1.25;11600;9667;0;720;72;380;500;5.5;2.5;21

The user-defined materials are then displayed in the material selection list.




## Loads

The loads are divided into the dead load (weight of the plate) ($g_{0,k}$), permanent loads ($g_{1,k}$), imposed load ($q_k$), snow load ($s_k$) and wind load ($w_k$). This classification is necessary to automatically carry out calculations for different load case combinations.

The plate weight is calculated automatically. The calculation method can be selected in the settings/preferences window. The default calculation method is in accordance with ON B 1991-1-1. A unit weight of 5.5 kN/m³ is assumed in the calculation. However, the unit weight may also be calculated using:

- calculation based on the mean value of density of the chosen material
- calculation based on a user-defined density

When entering the imposed loads, one of the following categories has to be chosen:

- A: Areas for domestic and residential activities
- B: Office areas
- C: Areas where people may congregate (with the exception of areas defined under category A, B and D)
- D: Shopping areas
- E: Areas for storage and industrial activities
- F: Traffic and parking areas for light-duty vehicles
- G: Traffic and parking areas for medium-duty vehicles
- H: Roofs

When entering the snow load, the country code or an altitude above sea level where the structure will be located has to be specified:

- < 1000 m
- > 1000 m
- FIN, IS, N, S

The span of each field can also be modified in the table of distributed loads.

Concentrated loads can be entered in the second table. The position can be defined whether by the local or global x-coordinate.

Loads

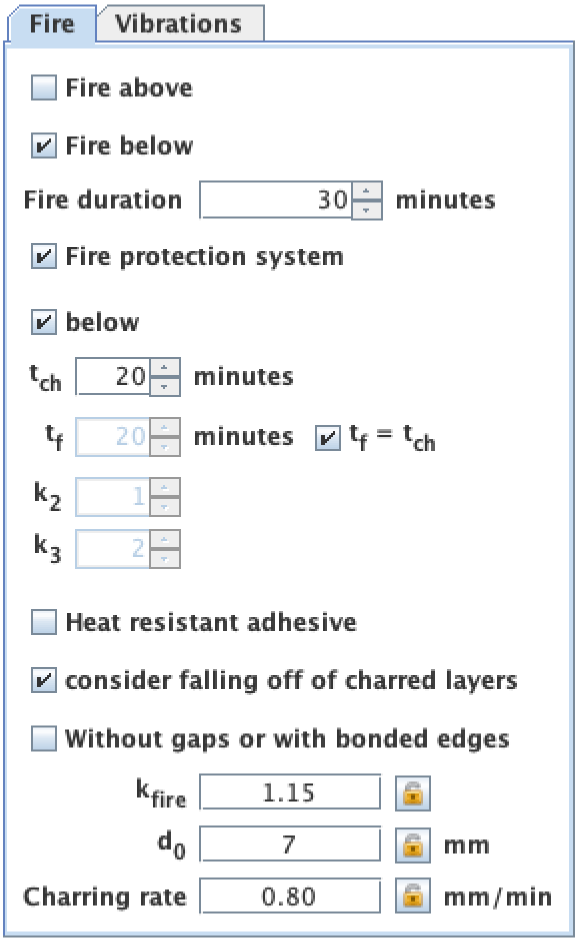
| Field | Span | $g_{0,k}$ | $g_{1,k}$ | $q_k$ | Category | $s_k$ | Altitude/Region | $w_k$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 3.5 m | 0.55 kN/m | 0.58 kN/m² | 1.2 kN/m² | A | | | |
| 2 | 4 m | 0.55 kN/m | 0.58 kN/m² | 1.2 kN/m² | A | | | |
| 3 | 4.25 m | 0.55 kN/m | 0.58 kN/m² | 1.2 kN/m² | A | | | |

| Field | $x_{global}$ | $x_{lokal}$ | $G_{1,k}$ | $Q_k$ | Category | $S_k$ | Altitude/Region | $W_k$ |
|---|---|---|---|---|---|---|---|---|

+ -

## Fire

By choosing "Fire above" and/or "Fire below" in the tab "Fire" a structural fire design has to be carried out. The "Fire duration" is specified in minutes and can be increased (or decreased) by increments of 30 minutes by pressing the up (or down) arrows, or defined by entering a specific duration between 0 minutes and 240 minutes in the allotted box. By ticking the box next to "Fire protection" a layer of fire protection is added to the plate, but the effective protection time of the protection layer needs to be defined.

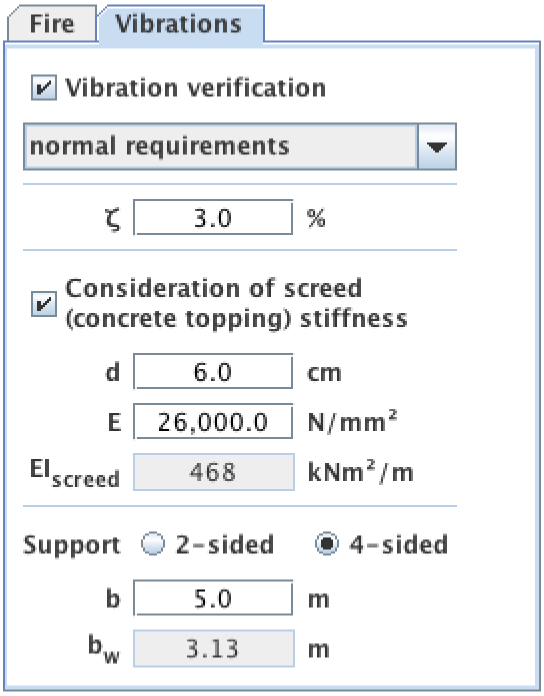



For a user-defined cross section, options are given for specifying heat resistant adhesives, presence of grooves, and whether the layers are edge-glued. For proprietary CLT products both values are set automatically and they cannot be changed.

The values $k_{fire}$ (conversion factor 20%-quantiles) and $d_0$ (layer thickness to take into consideration the influence of temperature exposure) are pre-set and cannot be changed. The charring rate is dependent on the option edge glued or without groove. For a user-defined cross section this value can be changed.

## Vibrations

The tab "Vibrations" allows for vibration verification.




For the vibration verification the following specifications are of importance:

- high or normal requirements? This choice will have an influence on the limit values.
- modal damping factor
- consideration of the screed (concrete topping) stiffness
  - thickness of the screed (concrete topping)
  - modulus of elasticity of the screed (concrete topping)
- support (2-sided or 4-sided)
- room width b perpendicular to the load carrying direction

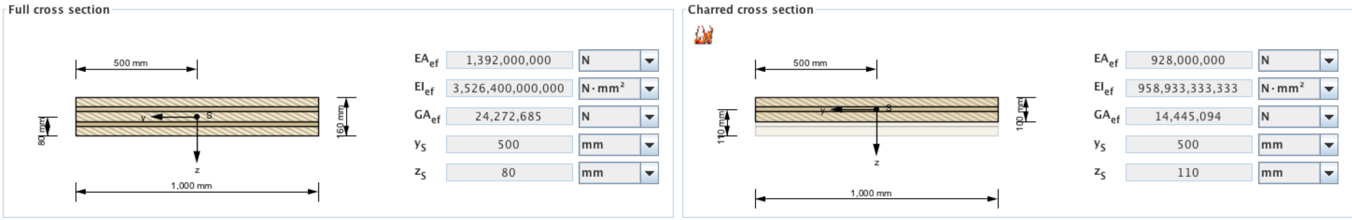
The effective width $b_w$ of the chosen cross section used by the stiffness criteria will be specified.

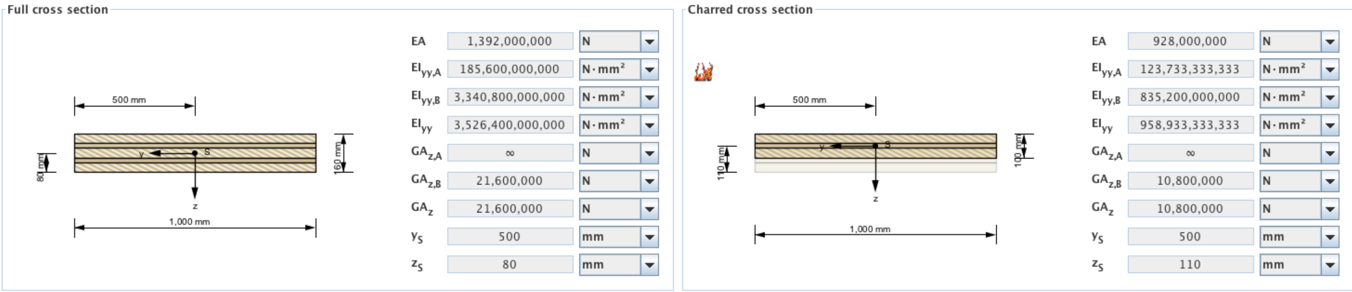
# Results and output

Load combinations are compiled based on the input loads entered in the "Loads" field. The respective $k_{mod}$- and $k_{def}$-values can be determined automatically based on the classification of loads (plate weight, wind load, etc.).

## Cross section values

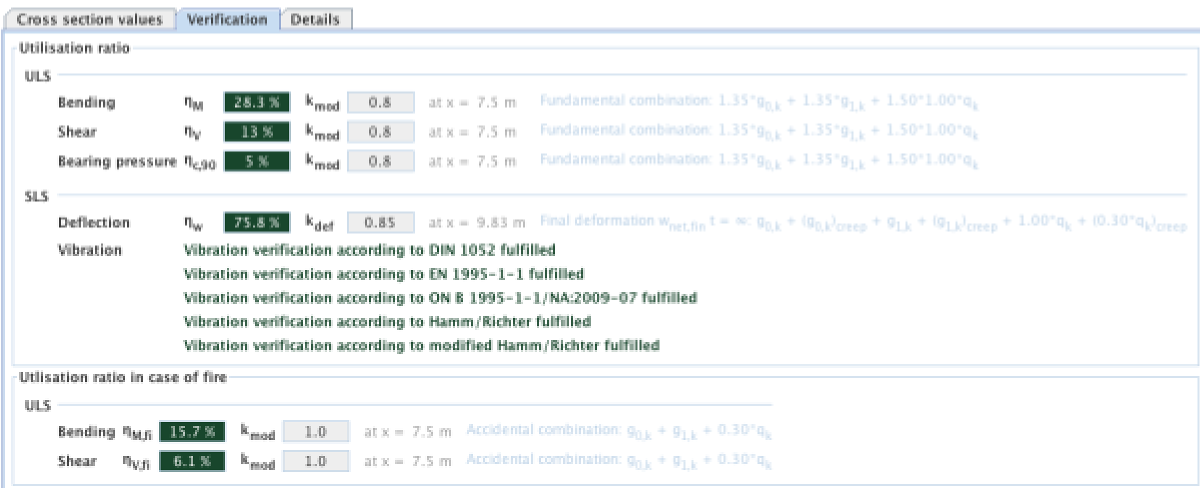
Output values generated in the tab "Cross section values" field include the effective stiffness (depending on the chosen calculation method), the position of the centre of mass for the full cross section and also for the charred cross section in case of structural fire design.



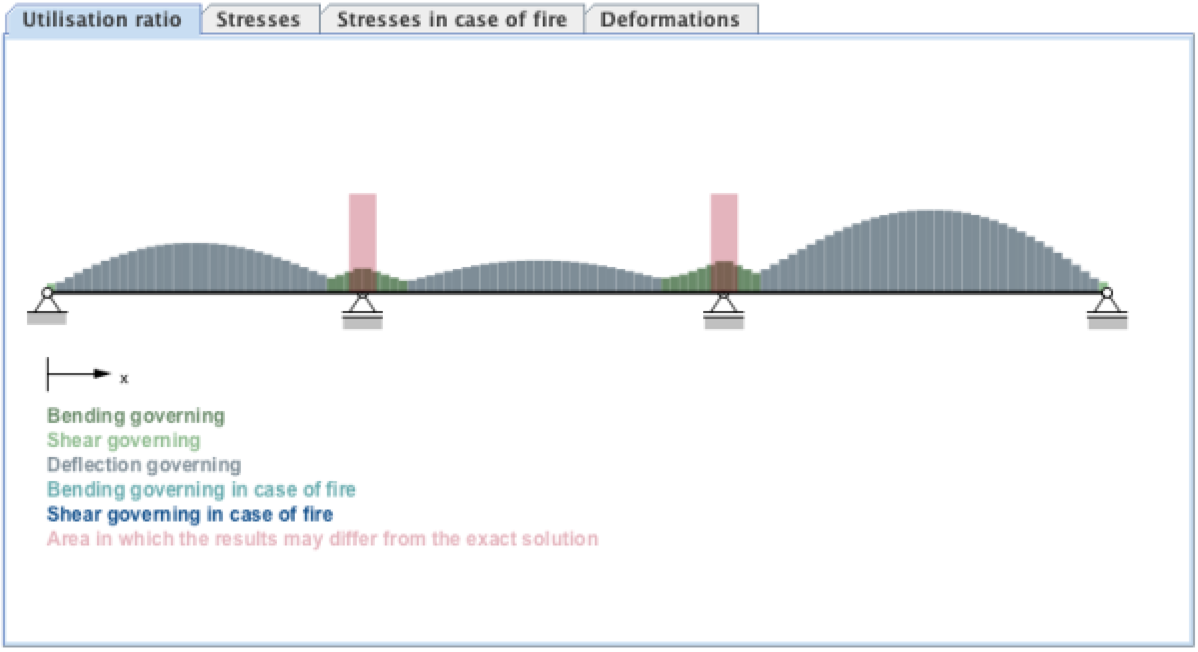




## Summary of the results

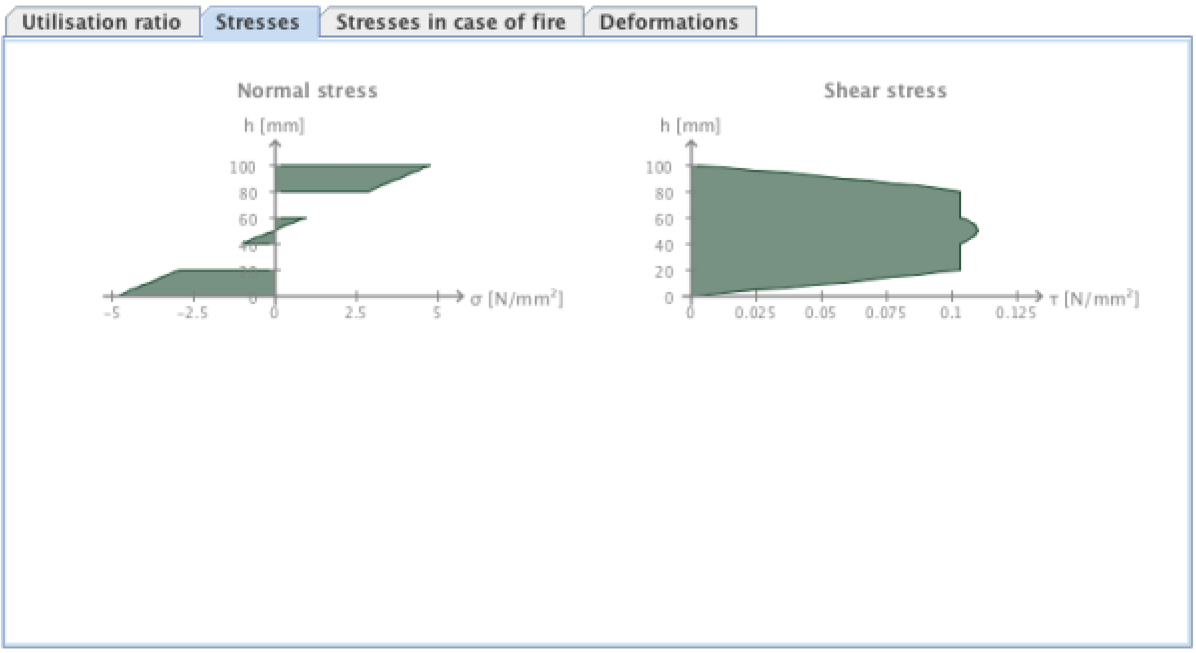
A summary of the verifications can be retrieved via the tab "Verifications". The utilisation ratios for various limit states are colour-coded indicating if the verification is fulfilled (green), not fulfilled (red) or a more accurate verification is needed (yellow). The locations of the maximum utilisation ratio and the governing combinations are compiled in the same way.



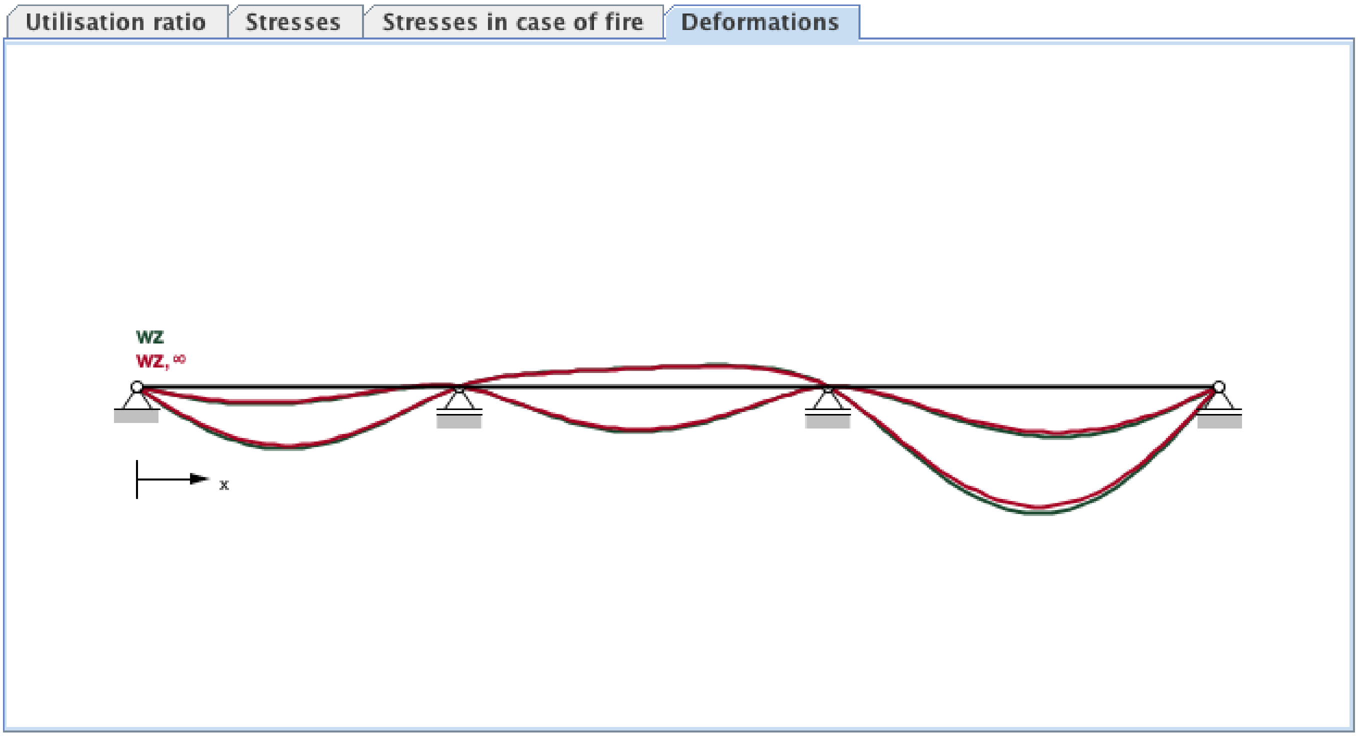

The tab "Utilisation" shows the distribution of the governing utilisation ratios along the beam. Areas in which the results may differ from the exact solution are marked here.




The tab "Stresses" shows the governing stresses resulting from the ULS verification. If a structural fire design was carried out, the governing stresses in case of fire are shown in the tab "Stresses in case of fire"

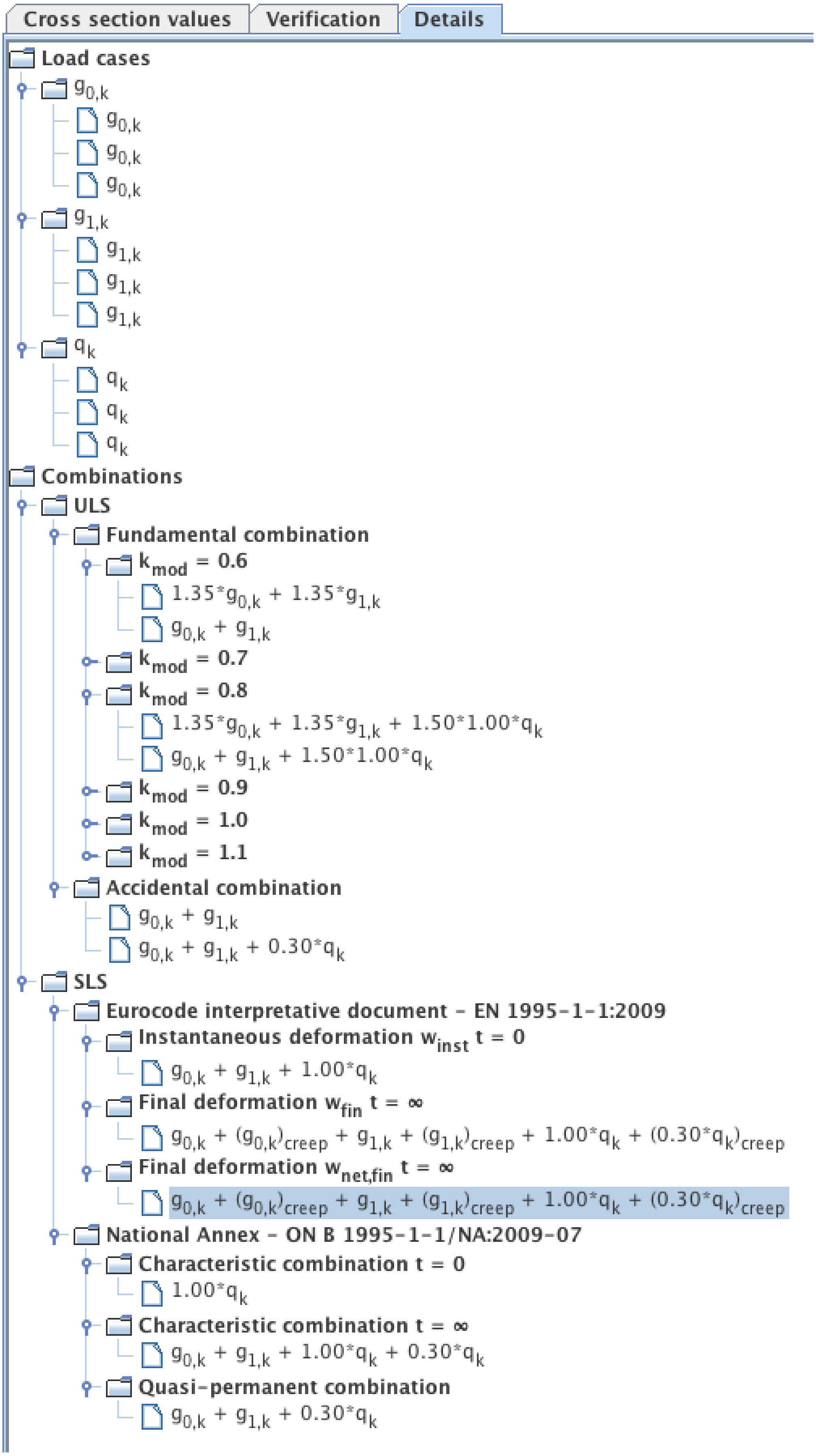



The tab "Deformations" shows the deformed system or the envelope given by the minimum and maximum deformation resulting from the governing SLS verification.




## Detailed results

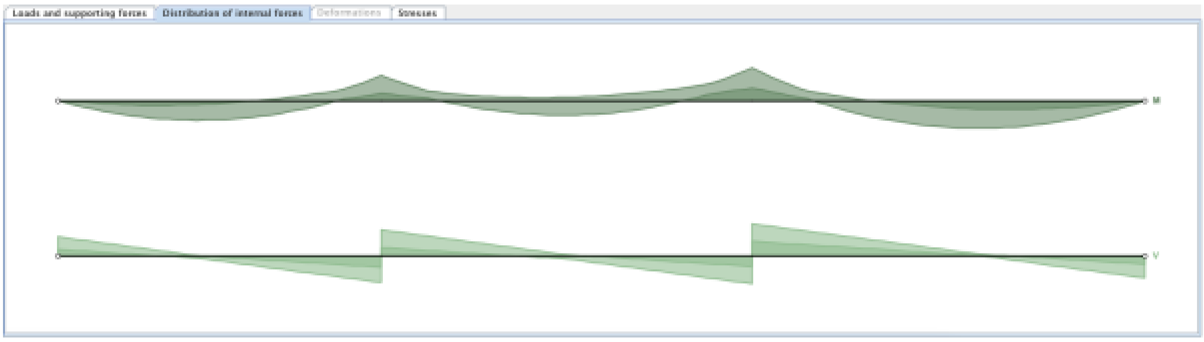
The detailed results can be retrieved in the tab "Details". The "tree" on the left side offers the possibility to choose the respective load case or combination.




The results of this choice (internal forces, deformations) are then shown for each of the calculation sections of each field (number depending on the information in the settings) in the table on the top right.

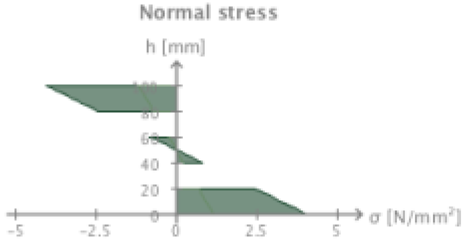
| Field | x | $M_{max}$ | M | V | $M_{min}$ | M | V | $V_{max}$ | M | V | $V_{min}$ | M | V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0 m | | -0.00 kN·m | 1.67 kN | | -0.00 kN·m | 5.03 kN | | -0.00 kN·m | 5.03 kN | | -0.00 kN·m | 1.67 kN |
| 1 | 0.1 m | | 0.49 kN·m | 4.70 kN | | 0.16 kN·m | 1.51 kN | | 0.49 kN·m | 4.70 kN | | 0.16 kN·m | 1.51 kN |
| 1 | 0.2 m | | 0.94 kN·m | 4.37 kN | | 0.30 kN·m | 1.36 kN | | 0.94 kN·m | 4.37 kN | | 0.30 kN·m | 1.36 kN |
| 1 | 0.3 m | | 1.36 kN·m | 4.03 kN | | 0.43 kN·m | 1.21 kN | | 1.36 kN·m | 4.03 kN | | 0.43 kN·m | 1.21 kN |
| 1 | 0.4 m | | 1.75 kN·m | 3.70 kN | | 0.54 kN·m | 1.05 kN | | 1.75 kN·m | 3.70 kN | | 0.54 kN·m | 1.05 kN |
| 1 | 0.5 m | | 2.10 kN·m | 3.37 kN | | 0.64 kN·m | 0.90 kN | | 2.10 kN·m | 3.37 kN | | 0.64 kN·m | 0.90 kN |
| 1 | 0.6 m | | 2.42 kN·m | 3.04 kN | | 0.72 kN·m | 0.75 kN | | 2.42 kN·m | 3.04 kN | | 0.72 kN·m | 0.75 kN |
| 1 | 0.7 m | | 2.71 kN·m | 2.70 kN | | 0.79 kN·m | 0.60 kN | | 2.71 kN·m | 2.70 kN | | 0.79 kN·m | 0.60 kN |
| 1 | 0.8 m | | 2.96 kN·m | 2.37 kN | | 0.84 kN·m | 0.44 kN | | 2.96 kN·m | 2.37 kN | | 0.84 kN·m | 0.44 kN |
| 1 | 0.9 m | | 3.18 kN·m | 2.04 kN | | 0.88 kN·m | 0.29 kN | | 3.18 kN·m | 2.04 kN | | 0.88 kN·m | 0.29 kN |
| 1 | 1.0 m | | 3.37 kN·m | 1.71 kN | | 0.90 kN·m | 0.14 kN | | 3.37 kN·m | 1.71 kN | | 0.90 kN·m | 0.14 kN |
| 1 | 1.1 m | | 3.52 kN·m | 1.37 kN | | 0.91 kN·m | -0.01 kN | | 3.52 kN·m | 1.37 kN | | 0.91 kN·m | -0.01 kN |
| 1 | 1.2 m | | 3.64 kN·m | 1.04 kN | | 0.90 kN·m | -0.17 kN | | 3.64 kN·m | 1.04 kN | | 0.90 kN·m | -0.17 kN |
| 1 | 1.3 m | | 3.73 kN·m | 0.71 kN | | 0.88 kN·m | -0.32 kN | | 3.73 kN·m | 0.71 kN | | 0.88 kN·m | -0.32 kN |
| 1 | 1.4 m | | 3.79 kN·m | 0.38 kN | | 0.84 kN·m | -0.47 kN | | 3.79 kN·m | 0.38 kN | | 0.84 kN·m | -0.47 kN |
| 1 | 1.5 m | | 3.81 kN·m | 0.04 kN | | 0.78 kN·m | -0.62 kN | | 3.81 kN·m | 0.04 kN | | 0.78 kN·m | -0.62 kN |
| 1 | 1.6 m | | 3.79 kN·m | -0.29 kN | | 0.71 kN·m | -0.78 kN | | 1.67 kN·m | -0.17 kN | | 2.83 kN·m | -0.89 kN |
| 1 | 1.7 m | | 3.75 kN·m | -0.62 kN | | 0.63 kN·m | -0.93 kN | | 1.65 kN·m | -0.33 kN | | 2.73 kN·m | -1.22 kN |
| 1 | 1.8 m | | 3.67 kN·m | -0.95 kN | | 0.53 kN·m | -1.08 kN | | 1.61 kN·m | -0.48 kN | | 2.59 kN·m | -1.56 kN |
| 1 | 1.9 m | | 3.56 kN·m | -1.29 kN | | 0.41 kN·m | -1.23 kN | | 1.55 kN·m | -0.63 kN | | 2.41 kN·m | -1.89 kN |
| 1 | 2.0 m | | 3.41 kN·m | -1.62 kN | | 0.28 kN·m | -1.39 kN | | 1.48 kN·m | -0.78 kN | | 2.21 kN·m | -2.22 kN |
| 1 | 2.1 m | | 3.23 kN·m | -1.95 kN | | 0.13 kN·m | -1.54 kN | | 1.40 kN·m | -0.94 kN | | 1.97 kN·m | -2.55 kN |
| 1 | 2.2 m | | 3.02 kN·m | -2.28 kN | | -0.03 kN·m | -1.69 kN | | 1.30 kN·m | -1.09 kN | | 1.70 kN·m | -2.89 kN |
| 1 | 2.3 m | | 2.78 kN·m | -2.62 kN | | -0.21 kN·m | -1.84 kN | | 1.18 kN·m | -1.24 kN | | 1.39 kN·m | -3.22 kN |
| 1 | 2.4 m | | 2.50 kN·m | -2.95 kN | | -0.40 kN·m | -2.00 kN | | 1.05 kN·m | -1.39 kN | | 1.05 kN·m | -3.55 kN |
| 1 | 2.5 m | | 2.19 kN·m | -3.28 kN | | -0.60 kN·m | -2.15 kN | | 0.90 kN·m | -1.55 kN | | 0.68 kN·m | -3.88 kN |
| 1 | 2.6 m | | 1.84 kN·m | -3.61 kN | | -0.83 kN·m | -2.30 kN | | 0.74 kN·m | -1.70 kN | | 0.28 kN·m | -4.22 kN |
| 1 | 2.7 m | | 1.46 kN·m | -3.95 kN | | -1.06 kN·m | -2.45 kN | | 0.58 kN·m | -1.85 kN | | -0.16 kN·m | -4.55 kN |
| 1 | 2.8 m | | 1.05 kN·m | -4.28 kN | | -1.32 kN·m | -2.61 kN | | 0.37 kN·m | -2.00 kN | | -0.63 kN·m | -4.88 kN |
| 1 | 2.9 m | | 0.61 kN·m | -4.61 kN | | -1.59 kN·m | -2.76 kN | | 0.16 kN·m | -2.16 kN | | -1.14 kN·m | -5.21 kN |
| 1 | 3.0 m | | 0.13 kN·m | -4.94 kN | | -1.87 kN·m | -2.91 kN | | -0.06 kN·m | -2.31 kN | | -1.67 kN·m | -5.55 kN |
| 1 | 3.1 m | | -0.30 kN·m | -2.46 kN | | -2.25 kN·m | -5.88 kN | | -0.30 kN·m | -2.46 kN | | -2.25 kN·m | -5.88 kN |
| 1 | 3.2 m | | -0.56 kN·m | -2.61 kN | | -2.85 kN·m | -6.21 kN | | -0.56 kN·m | -2.61 kN | | -2.85 kN·m | -6.21 kN |
| 1 | 3.3 m | | -0.83 kN·m | -2.77 kN | | -3.49 kN·m | -6.54 kN | | -0.83 kN·m | -2.77 kN | | -3.49 kN·m | -6.54 kN |
| 1 | 3.4 m | | -1.11 kN·m | -2.92 kN | | -4.16 kN·m | -6.88 kN | | -1.11 kN·m | -2.92 kN | | -4.16 kN·m | -6.88 kN |
| 1 | 3.5 m | | -1.41 kN·m | -3.07 kN | | -4.86 kN·m | -7.21 kN | | -1.41 kN·m | -3.07 kN | | -4.86 kN·m | -7.21 kN |
| 2 | 3.5 m | | -1.41 kN·m | 2.16 kN | | -4.86 kN·m | 6.92 kN | | -4.86 kN·m | 6.92 kN | | -1.41 kN·m | 2.16 kN |
| 2 | 3.6 m | | -1.20 kN·m | 2.01 kN | | -4.19 kN·m | 6.58 kN | | -4.19 kN·m | 6.58 kN | | -1.20 kN·m | 2.01 kN |
| 2 | 3.7 m | | -1.01 kN·m | 1.86 kN | | -3.55 kN·m | 6.25 kN | | -3.55 kN·m | 6.25 kN | | -1.01 kN·m | 1.86 kN |
| 2 | 3.8 m | | -0.83 kN·m | 1.71 kN | | -2.94 kN·m | 5.92 kN | | -2.94 kN·m | 5.92 kN | | -0.83 kN·m | 1.71 kN |
| 2 | 3.9 m | | -0.67 kN·m | 1.55 kN | | -2.36 kN·m | 5.59 kN | | -2.36 kN·m | 5.59 kN | | -0.67 kN·m | 1.55 kN |
| 2 | 4.0 m | | -0.46 kN·m | 4.15 kN | | -1.88 kN·m | 2.51 kN | | -1.82 kN·m | 5.25 kN | | -0.52 kN·m | 1.40 kN |
| 2 | 4.1 m | | -0.07 kN·m | 3.81 kN | | -1.63 kN·m | 2.36 kN | | -1.31 kN·m | 4.92 kN | | -0.39 kN·m | 1.25 kN |
| 2 | 4.2 m | | 0.30 kN·m | 3.48 kN | | -1.40 kN·m | 2.20 kN | | -0.84 kN·m | 4.59 kN | | -0.27 kN·m | 1.10 kN |

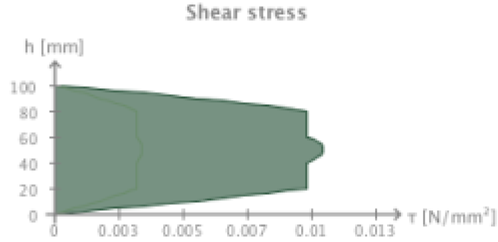
By choosing the desired calculation section in the table, the loads and supporting forces, the distribution of internal forces and the deformations as well as the calculated stresses are shown under different tabs on the bottom right.

Loads and supporting forces | Distribution of internal forces | Deformations | Stresses

### Stress distribution




### Stresses and utilisation ratios of single layers

**M max**

| Layer | $\sigma_M$ | $\eta_M$ | $\tau_V$ | $\eta_V$ |
|---|---|---|---|---|
| # 1 | 4.046 N/mm² | 23.9 % | 0.005 N/mm² | 0.3 % |
| # 2 | 0.000 N/mm² | 0.0 % | 0.005 N/mm² | 0.6 % |
| # 3 | 0.809 N/mm² | 4.8 % | 0.005 N/mm² | 0.3 % |
| # 4 | -0.000 N/mm² | 0.0 % | 0.005 N/mm² | 0.6 % |
| # 5 | -4.046 N/mm² | 23.9 % | 0.005 N/mm² | 0.3 % |

**M min**

| Layer | $\sigma_M$ | $\eta_M$ | $\tau_V$ | $\eta_V$ |
|---|---|---|---|---|
| # 1 | 1.174 N/mm² | 6.9 % | 0.008 N/mm² | 0.4 % |
| # 2 | 0.000 N/mm² | 0.0 % | 0.008 N/mm² | 1.0 % |
| # 3 | 0.235 N/mm² | 1.4 % | 0.009 N/mm² | 0.4 % |
| # 4 | -0.000 N/mm² | 0.0 % | 0.008 N/mm² | 1.0 % |
| # 5 | -1.174 N/mm² | 6.9 % | 0.008 N/mm² | 0.4 % |

**V max**

| Layer | $\sigma_M$ | $\eta_M$ | $\tau_V$ | $\eta_V$ |
|---|---|---|---|---|
| # 1 | 3.471 N/mm² | 20.5 % | 0.010 N/mm² | 0.5 % |
| # 2 | 0.000 N/mm² | 0.0 % | 0.010 N/mm² | 1.2 % |
| # 3 | 0.694 N/mm² | 4.1 % | 0.010 N/mm² | 0.5 % |
| # 4 | -0.000 N/mm² | 0.0 % | 0.010 N/mm² | 1.2 % |
| # 5 | -3.471 N/mm² | 20.5 % | 0.010 N/mm² | 0.5 % |

**V min**

| Layer | $\sigma_M$ | $\eta_M$ | $\tau_V$ | $\eta_V$ |
|---|---|---|---|---|
| # 1 | 1.750 N/mm² | 10.4 % | 0.003 N/mm² | 0.2 % |
| # 2 | 0.000 N/mm² | 0.0 % | 0.003 N/mm² | 0.4 % |
| # 3 | 0.350 N/mm² | 2.1 % | 0.003 N/mm² | 0.2 % |
| # 4 | -0.000 N/mm² | 0.0 % | 0.003 N/mm² | 0.4 % |
| # 5 | -1.750 N/mm² | 10.4 % | 0.003 N/mm² | 0.2 % |