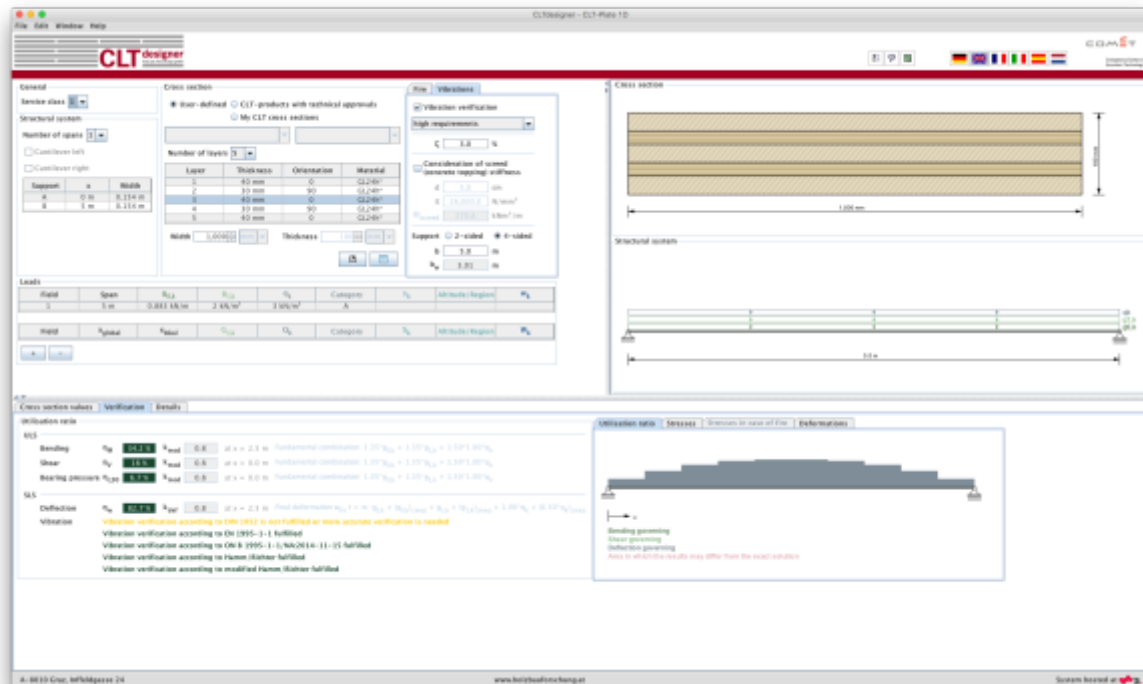


Module "CLT-Plate 1D - Continuous beam"

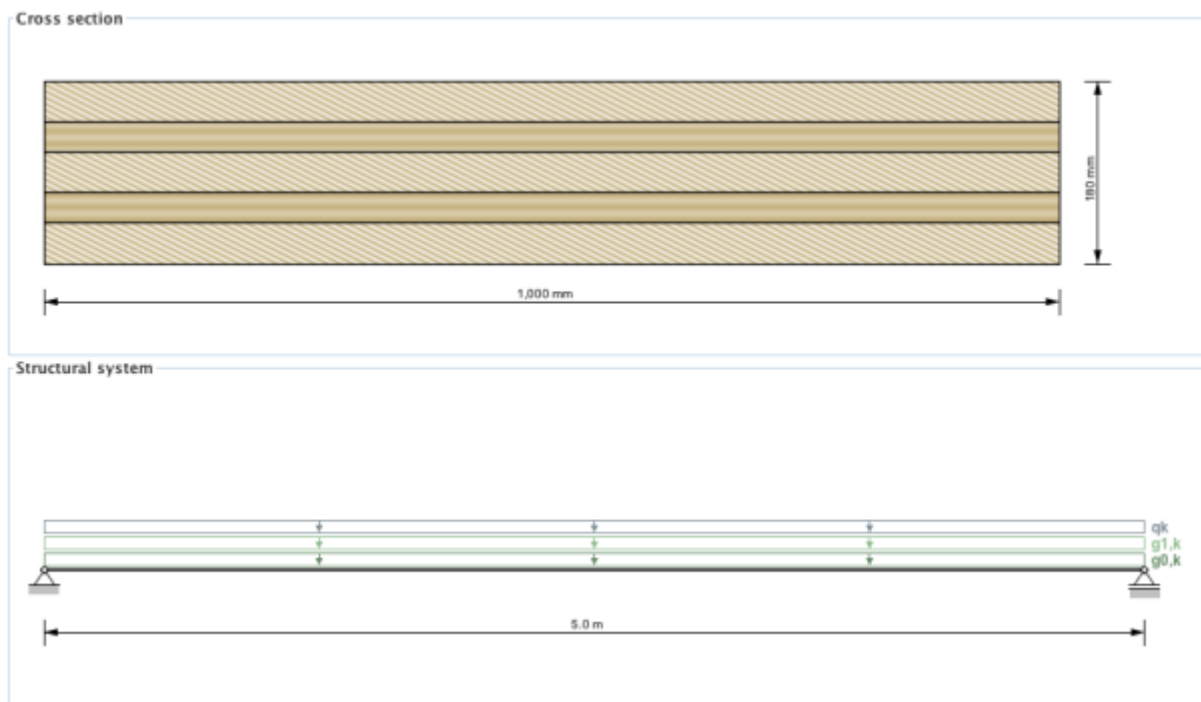


Input data

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.

General

Service class
1
▼

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.

Structural system

Number of spans

☐ Cantilever left

☐ Cantilever right

Support	x	Width
A	0 m	0.154 m
B	5 m	0.154 m

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.

Cross section

☒ User-defined
 ☐ CLT-products with technical approvals

☐ My CLT cross sections

Number of layers

Layer	Thickness	Orientation	Material
1	40 mm	0	GL24h*
2	20 mm	90	GL24h*
3	40 mm	0	GL24h*
4	20 mm	90	GL24h*
5	40 mm	0	GL24h*

Width Thickness

Ratio board thickness / width t/a


Beta! Optimise cross section...

The width of the CLT plate strips can be also defined in this field. The default value is set to 1 m. The

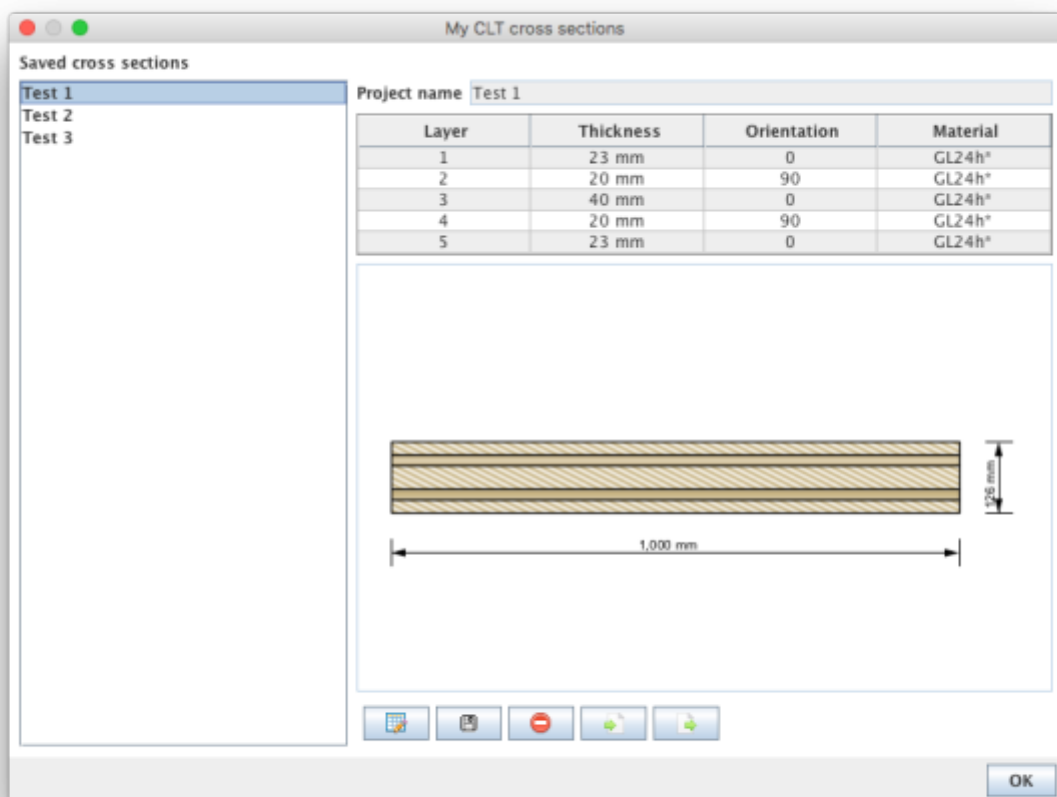
thickness of the CLT plate is calculated automatically based on the thickness of the single layers.






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 α_1 to α_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.

Property	Value	Unit
bending strength	24	N/mm ²
tensile strength parallel	16.5	N/mm ²
tensile strength perpendicular	0.5	N/mm ²
compressive strength parallel	24	N/mm ²
compressive strength perpendicular	2.7	N/mm ²
shear strength	3	N/mm ²
rolling shear strength	1.25	N/mm ²
Youngs modulus parallel	11,600	N/mm ²
5%-quantile from Youngs modulus parallel	9,667	N/mm ²
Youngs modulus perpendicular	0	N/mm ²
shear modulus	720	N/mm ²
rolling shear modulus	72	N/mm ²
density	380	kg/m ³
density mean value	500	kg/m ³
in plane shear strength	5.5	N/mm ²
torsional strength	2.5	N/mm ²
bending strength in-plane	21	N/mm ²

- 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

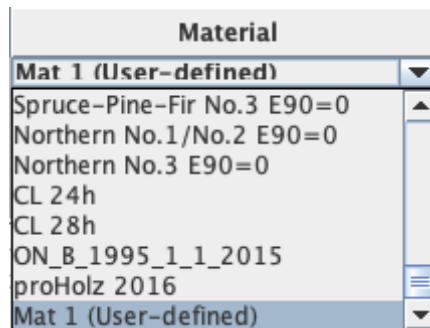
1. row: description of the parameters
 2. row: units of the parameters
 3. row: value
- delimiter: ";"



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;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.



Optimization of layup

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/m^3 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/m ²	1.2 kN/m ²	A			
2	4 m	0.55 kN/m	0.58 kN/m ²	1.2 kN/m ²	A			
3	4.25 m	0.55 kN/m	0.58 kN/m ²	1.2 kN/m ²	A			

Field	x_{global}	x_{local}	$G_{1,k}$	Q_k	Category	s_k	Altitude/Region	w_k
<div> <input type="button" value="+"/> <input type="button" value="-"/> </div>								

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.

Fire

Vibrations

☐ Fire above

☒ Fire below

Fire duration minutes

☒ Fire protection system

☒ below

t_{ch} minutes

t_f minutes ☒ $t_f = t_{ch}$

k_2

k_3

☐ Heat resistant adhesive

☒ consider falling off of charred layers

☐ Without gaps or with bonded edges

k_{fire}

d_0 mm

Charring rate mm/min

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.

Fire
Vibrations

☒ **Vibration verification**

normal requirements
▼

ζ %

☒ **Consideration of screed (concrete topping) stiffness**

d

6.0

cm

E

26,000.0

N/mm²

EI_{screed}

468

kNm²/m

Support ☐ 2-sided ☒ 4-sided

b

5.0

m

b_w

3.13

m

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.

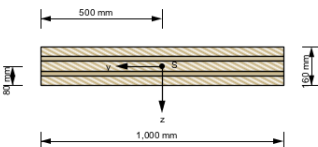
Results and output

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.

Full cross section



EA_{ef}

1,392,000,000

N

El_{ef}

3,526,400,000,000

N·mm²

GA_{ef}

24,272,685

N

y_S

500

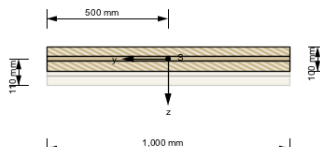
mm

z_S

80

mm

Charred cross section



EA_{ef}

928,000,000

N

El_{ef}

958,933,333,333

N·mm²

GA_{ef}

14,445,094

N

y_S

500

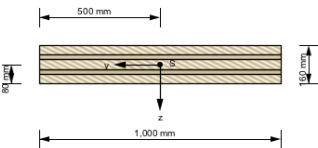
mm

z_S

110

mm

Full cross section



EA

1,392,000,000

N

El_{yy,A}

185,600,000,000

N·mm²

El_{yy,B}

3,340,800,000,000

N·mm²

El_{yy}

3,526,400,000,000

N·mm²

GA_{z,A}

∞

N

GA_{z,B}

21,600,000

N

GA_z

21,600,000

N

y_S

500

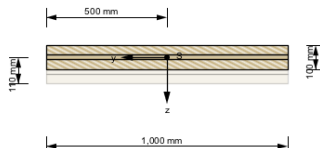
mm

z_S

80

mm

Charred cross section



EA

928,000,000

N

El_{yy,A}

123,733,333,333

N·mm²

El_{yy,B}

835,200,000,000

N·mm²

El_{yy}

958,933,333,333

N·mm²

GA_{z,A}

∞

N

GA_{z,B}

10,800,000

N

GA_z

10,800,000

N

y_S

500

mm

z_S

110

mm

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.

Cross section values

Verification

Details

Utilisation ratio

ULS

Bending

η_M

28.3 %

k_{mod}

0.8

at x = 7.5 m

Fundamental combination: $1.35 \cdot q_{0,k} + 1.35 \cdot q_{1,k} + 1.50 \cdot 1.00 \cdot q_k$

Shear

η_V

13 %

k_{mod}

0.8

at x = 7.5 m

Fundamental combination: $1.35 \cdot q_{0,k} + 1.35 \cdot q_{1,k} + 1.50 \cdot 1.00 \cdot q_k$

Bearing pressure

$\eta_{c,90}$

5 %

k_{mod}

0.8

at x = 7.5 m

Fundamental combination: $1.35 \cdot q_{0,k} + 1.35 \cdot q_{1,k} + 1.50 \cdot 1.00 \cdot q_k$

SLS

Deflection

η_w

75.8 %

k_{def}

0.85

at x = 9.83 m

Final deformation $w_{tot,fin} \overset{!}{=} \infty: q_{0,k} + (q_{0,k})_{creep} + q_{1,k} + (q_{1,k})_{creep} + 1.00 \cdot q_k + (0.30 \cdot q_k)_{creep}$

Vibration

Vibration verification according to DIN 1052 fulfilled

Vibration verification according to EN 1995-1-1 fulfilled

Vibration verification according to ON B 1995-1-1/NA:2009-07 fulfilled

Vibration verification according to Hamm/Richter fulfilled

Vibration verification according to modified Hamm/Richter fulfilled

Utilisation ratio in case of fire

ULS

Bending

$\eta_{M,fi}$

15.7 %

k_{mod}

1.0

at x = 7.5 m

Accidental combination: $q_{0,k} + q_{1,k} + 0.30 \cdot q_k$

Shear

$\eta_{V,fi}$

6.1 %

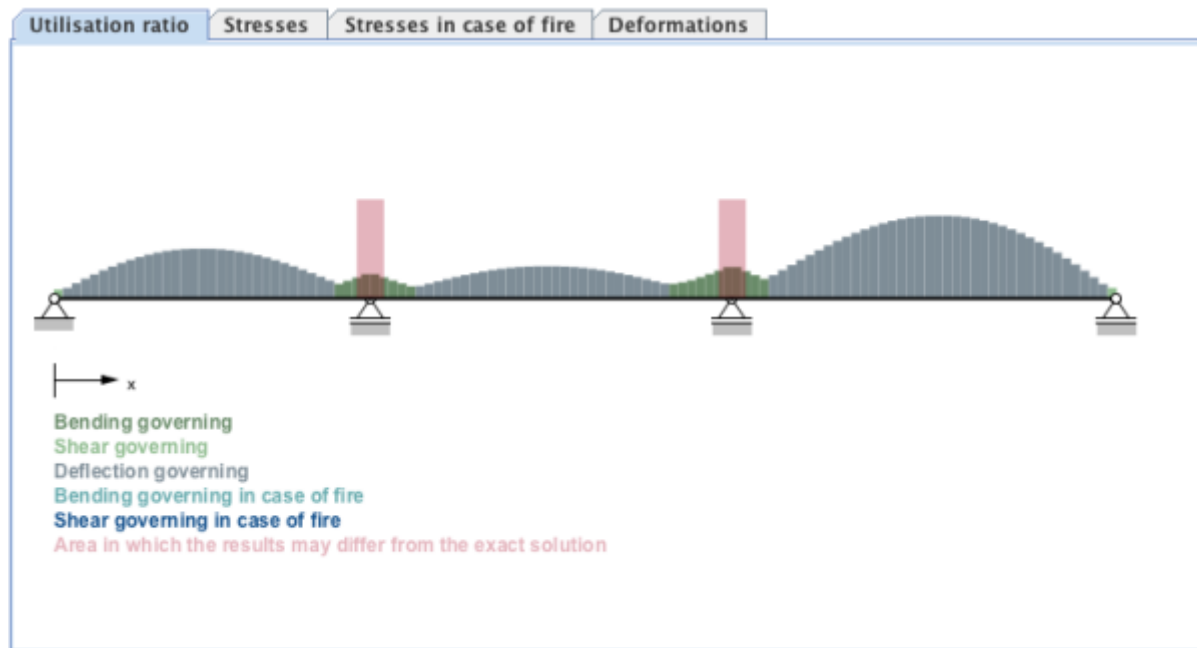
k_{mod}

1.0

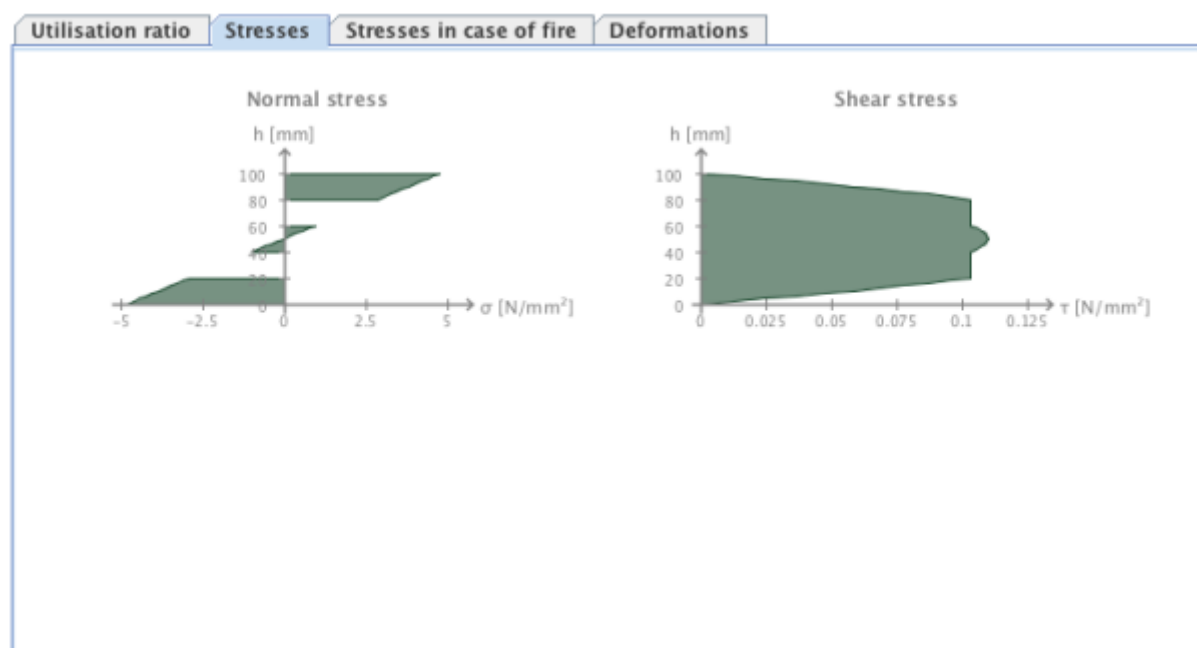
at x = 7.5 m

Accidental combination: $q_{0,k} + q_{1,k} + 0.30 \cdot q_k$

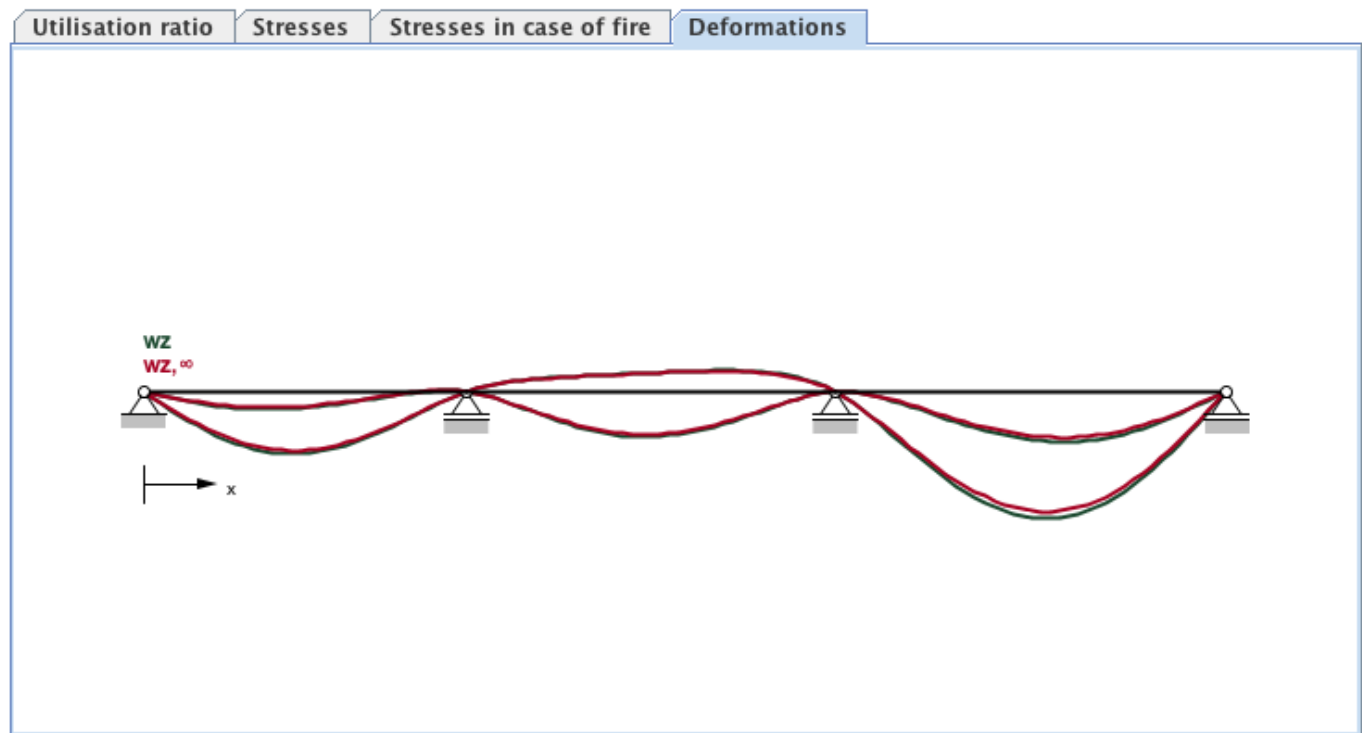
The tab "Utilisation" shows the distribution of the governing utilisation ratios along the beam. Areas in which the results may differ from the exact solution are marked here.



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.

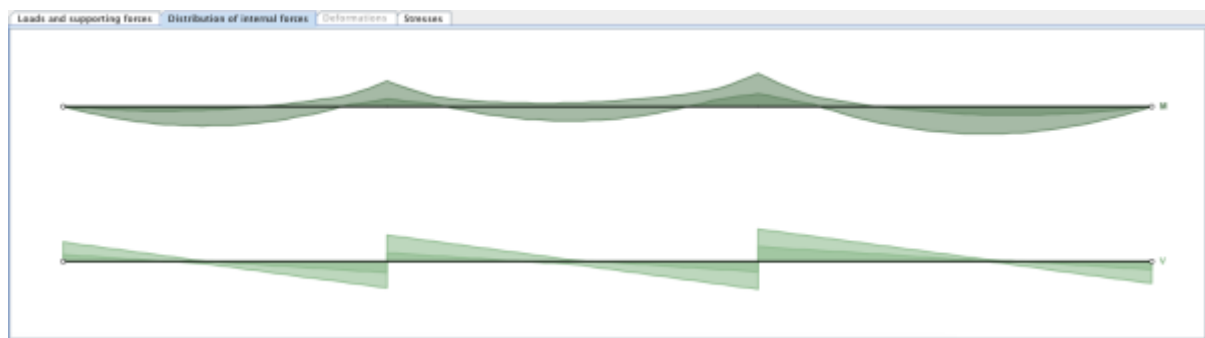
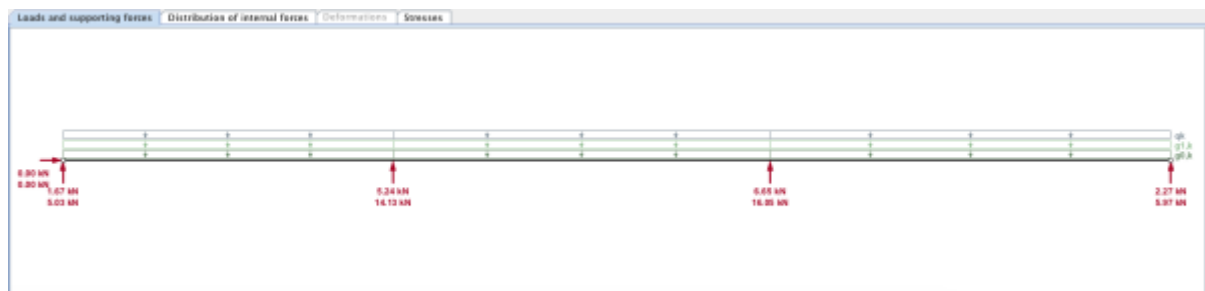
Cross section values **Verification** **Details**

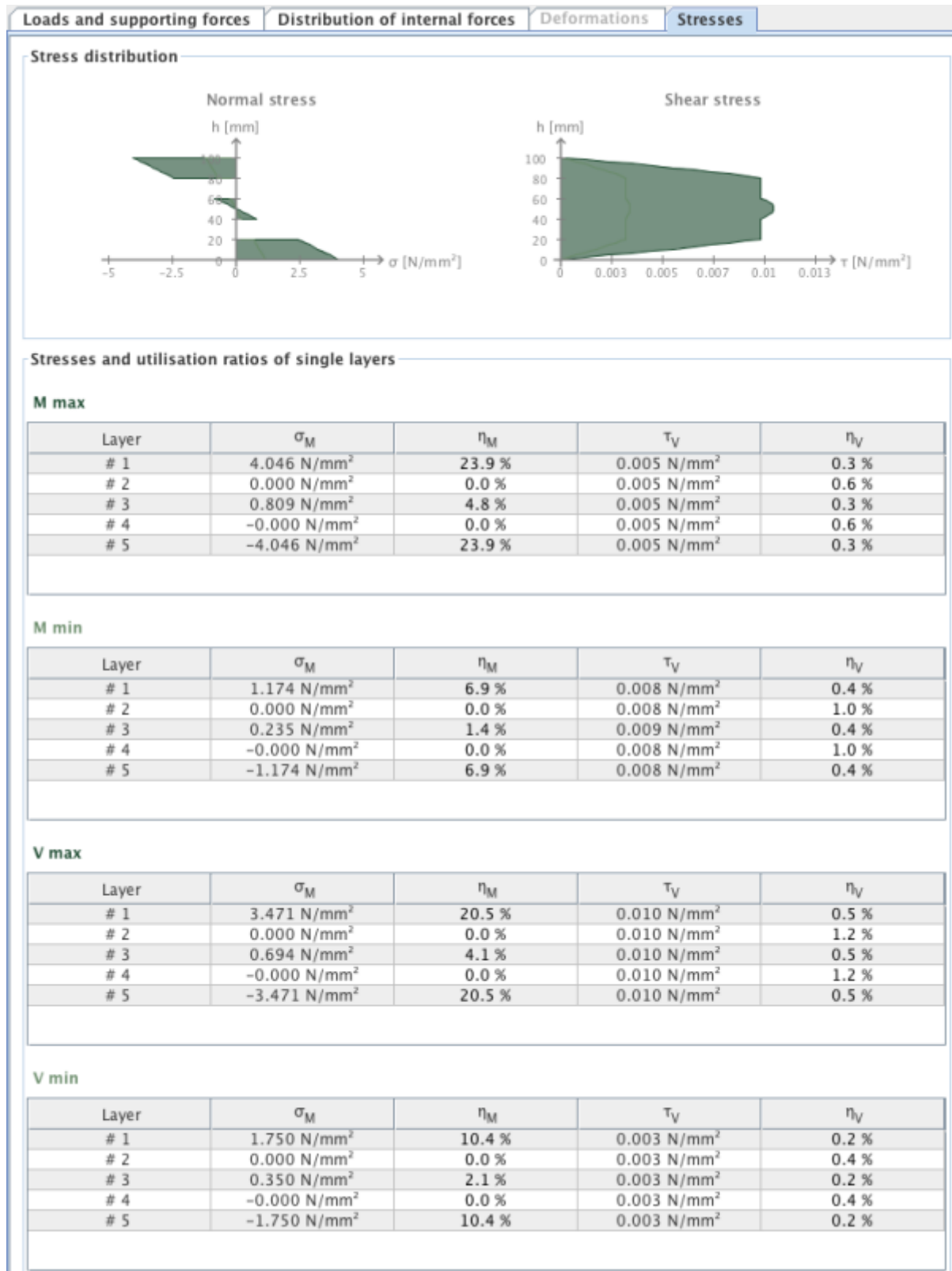
- Load cases**
 - $g_{0,k}$
 - $g_{0,k}$
 - $g_{0,k}$
 - $g_{0,k}$
 - $g_{1,k}$
 - $g_{1,k}$
 - $g_{1,k}$
 - $g_{1,k}$
 - q_k
 - q_k
 - q_k
 - q_k
- Combinations**
 - ULS**
 - Fundamental combination**
 - $k_{mod} = 0.6$
 - $1.35 \cdot g_{0,k} + 1.35 \cdot g_{1,k}$
 - $g_{0,k} + g_{1,k}$
 - $k_{mod} = 0.7$
 - $k_{mod} = 0.8$
 - $1.35 \cdot g_{0,k} + 1.35 \cdot g_{1,k} + 1.50 \cdot 1.00 \cdot q_k$
 - $g_{0,k} + g_{1,k} + 1.50 \cdot 1.00 \cdot q_k$
 - $k_{mod} = 0.9$
 - $k_{mod} = 1.0$
 - $k_{mod} = 1.1$
 - Accidental combination**
 - $g_{0,k} + g_{1,k}$
 - $g_{0,k} + g_{1,k} + 0.30 \cdot q_k$
 - SLS**
 - Eurocode interpretative document – EN 1995-1-1:2009**
 - Instantaneous deformation $w_{inst} \ t = 0$**
 - $g_{0,k} + g_{1,k} + 1.00 \cdot q_k$
 - Final deformation $w_{fin} \ t = \infty$**
 - $g_{0,k} + (g_{0,k})_{creep} + g_{1,k} + (g_{1,k})_{creep} + 1.00 \cdot q_k + (0.30 \cdot q_k)_{creep}$
 - Final deformation $w_{net,fin} \ t = \infty$**
 - $g_{0,k} + (g_{0,k})_{creep} + g_{1,k} + (g_{1,k})_{creep} + 1.00 \cdot q_k + (0.30 \cdot q_k)_{creep}$
 - National Annex – ON B 1995-1-1/NA:2009-07**
 - Characteristic combination $t = 0$**
 - $1.00 \cdot q_k$
 - Characteristic combination $t = \infty$**
 - $g_{0,k} + g_{1,k} + 1.00 \cdot q_k + 0.30 \cdot q_k$
 - Quasi-permanent combination**
 - $g_{0,k} + g_{1,k} + 0.30 \cdot q_k$

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 kNm	1.87 kNm		-0.00 kNm	5.03 kNm		-0.00 kNm	5.03 kNm		-0.00 kNm	1.87 kNm	
1	0.1 m	0.49 kNm	4.70 kNm		0.38 kNm	1.51 kNm		0.49 kNm	4.70 kNm		0.38 kNm	1.51 kNm	
1	0.2 m	0.94 kNm	4.37 kNm		0.30 kNm	1.98 kNm		0.94 kNm	4.37 kNm		0.30 kNm	1.98 kNm	
1	0.3 m	1.36 kNm	4.03 kNm		0.41 kNm	1.21 kNm		1.36 kNm	4.03 kNm		0.41 kNm	1.21 kNm	
1	0.4 m	1.75 kNm	3.70 kNm		0.54 kNm	1.05 kNm		1.75 kNm	3.70 kNm		0.54 kNm	1.05 kNm	
1	0.5 m	2.10 kNm	3.37 kNm		0.64 kNm	0.90 kNm		2.10 kNm	3.37 kNm		0.64 kNm	0.90 kNm	
1	0.6 m	2.42 kNm	3.04 kNm		0.72 kNm	0.75 kNm		2.42 kNm	3.04 kNm		0.72 kNm	0.75 kNm	
1	0.7 m	2.71 kNm	2.70 kNm		0.79 kNm	0.60 kNm		2.71 kNm	2.70 kNm		0.79 kNm	0.60 kNm	
1	0.8 m	2.86 kNm	2.37 kNm		0.84 kNm	0.44 kNm		2.86 kNm	2.37 kNm		0.84 kNm	0.44 kNm	
1	0.9 m	3.16 kNm	2.04 kNm		0.88 kNm	0.29 kNm		3.16 kNm	2.04 kNm		0.88 kNm	0.29 kNm	
1	1.0 m	3.37 kNm	1.71 kNm		0.90 kNm	0.14 kNm		3.37 kNm	1.71 kNm		0.90 kNm	0.14 kNm	
1	1.1 m	3.52 kNm	1.37 kNm		0.91 kNm	-0.01 kNm		3.52 kNm	1.37 kNm		0.91 kNm	-0.01 kNm	
1	1.2 m	3.64 kNm	1.04 kNm		0.90 kNm	-0.17 kNm		3.64 kNm	1.04 kNm		0.90 kNm	-0.17 kNm	
1	1.3 m	3.73 kNm	0.71 kNm		0.88 kNm	-0.32 kNm		3.73 kNm	0.71 kNm		0.88 kNm	-0.32 kNm	
1	1.4 m	3.79 kNm	0.38 kNm		0.84 kNm	-0.47 kNm		3.79 kNm	0.38 kNm		0.84 kNm	-0.47 kNm	
1	1.5 m	3.81 kNm	0.04 kNm		0.78 kNm	-0.62 kNm		3.81 kNm	0.04 kNm		0.78 kNm	-0.62 kNm	
1	1.6 m	3.79 kNm	-0.29 kNm		0.71 kNm	-0.78 kNm		3.67 kNm	-0.57 kNm		0.69 kNm	-0.89 kNm	
1	1.7 m	3.75 kNm	-0.62 kNm		0.63 kNm	-0.93 kNm		3.63 kNm	-0.93 kNm		0.63 kNm	-1.22 kNm	
1	1.8 m	3.67 kNm	-0.95 kNm		0.53 kNm	-1.08 kNm		3.51 kNm	-1.08 kNm		0.51 kNm	-1.56 kNm	
1	1.9 m	3.56 kNm	-1.29 kNm		0.41 kNm	-1.23 kNm		3.36 kNm	-1.23 kNm		0.41 kNm	-1.89 kNm	
1	2.0 m	3.41 kNm	-1.62 kNm		0.28 kNm	-1.39 kNm		3.16 kNm	-1.39 kNm		0.28 kNm	-2.22 kNm	
1	2.1 m	3.21 kNm	-1.95 kNm		0.13 kNm	-1.54 kNm		2.91 kNm	-1.54 kNm		0.13 kNm	-2.55 kNm	
1	2.2 m	3.02 kNm	-2.28 kNm		-0.03 kNm	-1.69 kNm		2.66 kNm	-1.69 kNm		-0.03 kNm	-2.89 kNm	
1	2.3 m	2.78 kNm	-2.62 kNm		-0.21 kNm	-1.84 kNm		2.41 kNm	-1.84 kNm		-0.21 kNm	-3.22 kNm	
1	2.4 m	2.50 kNm	-2.95 kNm		-0.40 kNm	-1.99 kNm		2.15 kNm	-1.99 kNm		-0.40 kNm	-3.55 kNm	
1	2.5 m	2.19 kNm	-3.29 kNm		-0.60 kNm	-2.13 kNm		1.90 kNm	-2.13 kNm		-0.60 kNm	-3.88 kNm	
1	2.6 m	1.84 kNm	-3.61 kNm		-0.83 kNm	-2.30 kNm		1.64 kNm	-2.30 kNm		-0.83 kNm	-4.22 kNm	
1	2.7 m	1.46 kNm	-3.93 kNm		-1.06 kNm	-2.45 kNm		1.38 kNm	-2.45 kNm		-1.06 kNm	-4.55 kNm	
1	2.8 m	1.05 kNm	-4.28 kNm		-1.32 kNm	-2.61 kNm		1.11 kNm	-2.61 kNm		-1.32 kNm	-4.88 kNm	
1	2.9 m	0.61 kNm	-4.61 kNm		-1.59 kNm	-2.76 kNm		0.84 kNm	-2.76 kNm		-1.59 kNm	-5.21 kNm	
1	3.0 m	0.13 kNm	-4.94 kNm		-1.87 kNm	-2.91 kNm		0.56 kNm	-2.91 kNm		-1.87 kNm	-5.55 kNm	
1	3.1 m	-0.30 kNm	-5.26 kNm		-2.25 kNm	-3.06 kNm		0.28 kNm	-3.06 kNm		-2.25 kNm	-5.88 kNm	
1	3.2 m	-0.56 kNm	-5.61 kNm		-2.65 kNm	-3.21 kNm		-0.06 kNm	-3.21 kNm		-2.65 kNm	-6.21 kNm	
1	3.3 m	-0.81 kNm	-5.94 kNm		-3.06 kNm	-3.36 kNm		-0.31 kNm	-3.36 kNm		-3.06 kNm	-6.54 kNm	
1	3.4 m	-1.11 kNm	-6.30 kNm		-3.48 kNm	-3.51 kNm		-0.56 kNm	-3.51 kNm		-3.48 kNm	-6.88 kNm	
1	3.5 m	-1.41 kNm	-6.67 kNm		-3.91 kNm	-3.66 kNm		-0.81 kNm	-3.66 kNm		-3.91 kNm	-7.21 kNm	
2	3.6 m	-1.41 kNm	2.38 kNm		-3.91 kNm	6.92 kNm		-0.81 kNm	6.92 kNm		-3.91 kNm	2.38 kNm	
2	3.8 m	-1.20 kNm	2.01 kNm		-3.75 kNm	6.58 kNm		-0.79 kNm	6.58 kNm		-3.75 kNm	2.01 kNm	
2	3.7 m	-1.01 kNm	1.88 kNm		-3.53 kNm	6.25 kNm		-0.55 kNm	6.25 kNm		-3.53 kNm	1.88 kNm	
2	3.6 m	-0.83 kNm	1.71 kNm		-3.24 kNm	5.92 kNm		-0.54 kNm	5.92 kNm		-3.24 kNm	1.71 kNm	
2	3.9 m	-0.67 kNm	1.55 kNm		-2.36 kNm	5.59 kNm		-0.36 kNm	5.59 kNm		-2.36 kNm	1.55 kNm	
2	4.0 m	-0.46 kNm	4.15 kNm		-1.88 kNm	2.51 kNm		-1.82 kNm	5.25 kNm		-1.82 kNm	1.40 kNm	
2	4.1 m	-0.07 kNm	3.81 kNm		-1.63 kNm	2.38 kNm		-1.31 kNm	4.92 kNm		-0.39 kNm	1.25 kNm	
2	4.2 m	0.10 kNm	3.48 kNm		-1.40 kNm	2.20 kNm		-0.84 kNm	4.59 kNm		-0.27 kNm	1.10 kNm	

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.





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