X-Lam Designer

User manual

Version 2.2

TABLE OF CONTENTS

1 GENERAL

1.1 System requirements

- Java SE Runtime Environment (JRE 6)
  A free version of JRE can be downloaded from http://java.sun.com.

1.2 Design methods

Detailed information about the design methods implemented for CLT can be found in the CLThandbook | Solid timber structures made of cross laminated timber (CLT) | Verifications on the basis of the new European concept for construction standards (only available in German).

The CLThandbook (ISBN 978-3-85125-109-8; only available in German) can be ordered at lignum@tugraz.at.

1.3 Standards and guidelines used

The software is based on the European Technical Approval ETA-11/0189 and the European Standards (Eurocode) with its national annnexes for Germany and Austria.

Base documents:

- **DIN EN 1990:2010-12 and ON EN 1990:2003-03 respectively:**
  Basis of structural design
- **DIN EN 1991-1-1:2010-12 and ON EN 1991-1-1:2003-03 respectively:**
  Actions on structures
  Part 1-1: General actions – Densities, self-weight, imposed loads for buildings
- **DIN EN 1995-1-1:2010-12 and ON EN 1995-1-1:2009-07 respectively:**
  Design of timber structures
  Part 1-1: General - Common rules and rules for buildings
- **DIN EN 1995-1-2:2010-12 and ON EN 1995-1-2:2011-09:**
  Design of timber structures
  Part 1-2: General - Structural fire design

National Annexes:

- **DIN EN 1990/NA:2010-12 and ON B 1990-1:2004-05 respectively**
- **DIN EN 1991-1-1/NA:2010-12 and ON B 1991-1-1:2006-01 respectively**

- **DIN EN 1995-1-1/NA:2010-12 and ON B 1995-1-1:2010-08 respectively**
- **ON B 1995-1-2:2011-09**

1.4 Translations

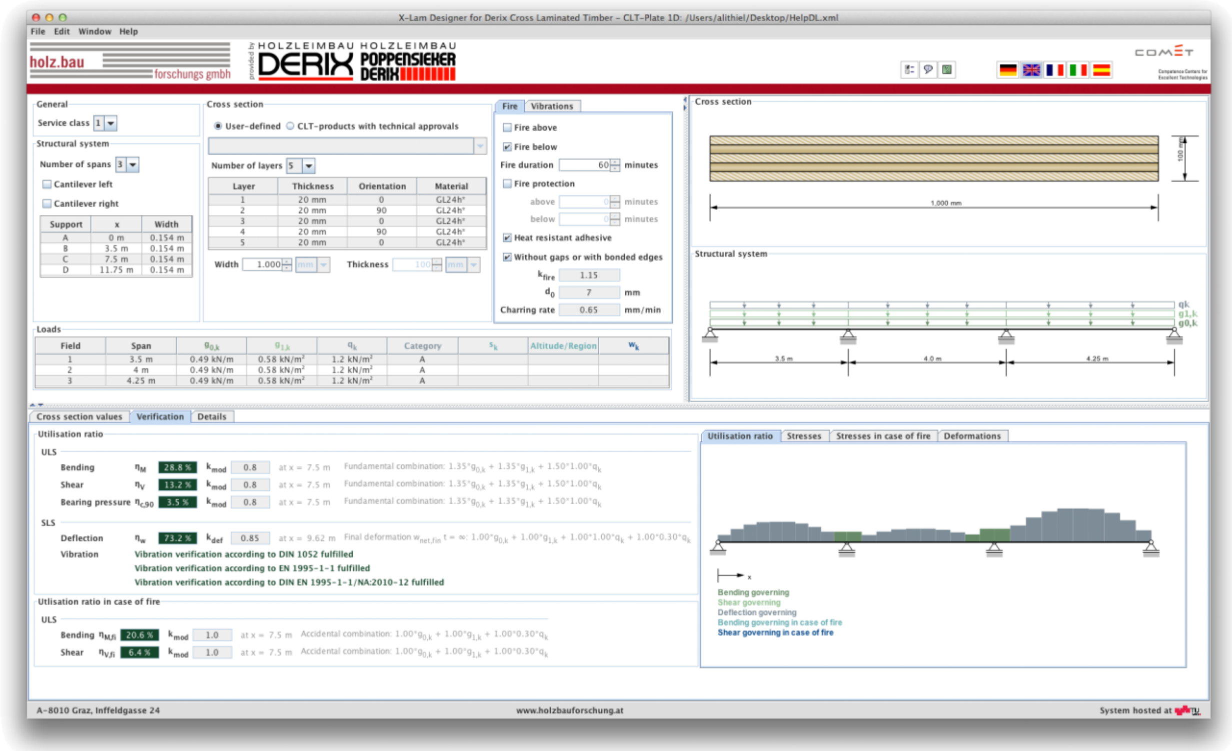
It is specifically stated that the versions of the X-Lam Designer in other languages are translations of the Austrian version. Therefore, any potential dissimilarities with engineering design standards in other countries cannot be ruled out. When differences due to translation are identified, the version in German shall take precedence.

2 GENERAL PROGRAM BUILD-UP

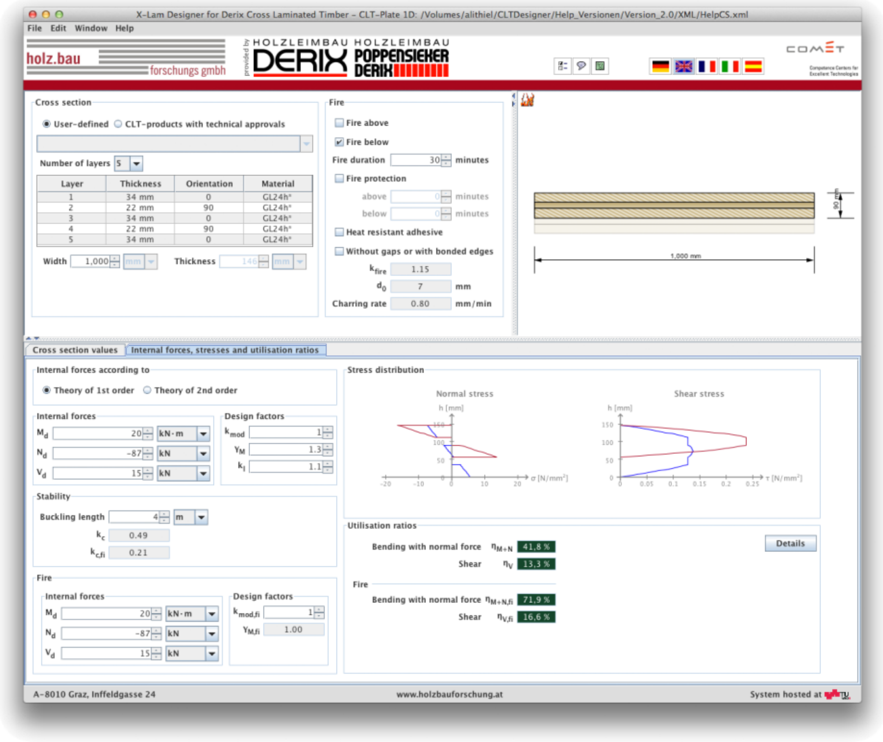
2.1 Modules

The program „X-Lam Designer“ consists of three modules.

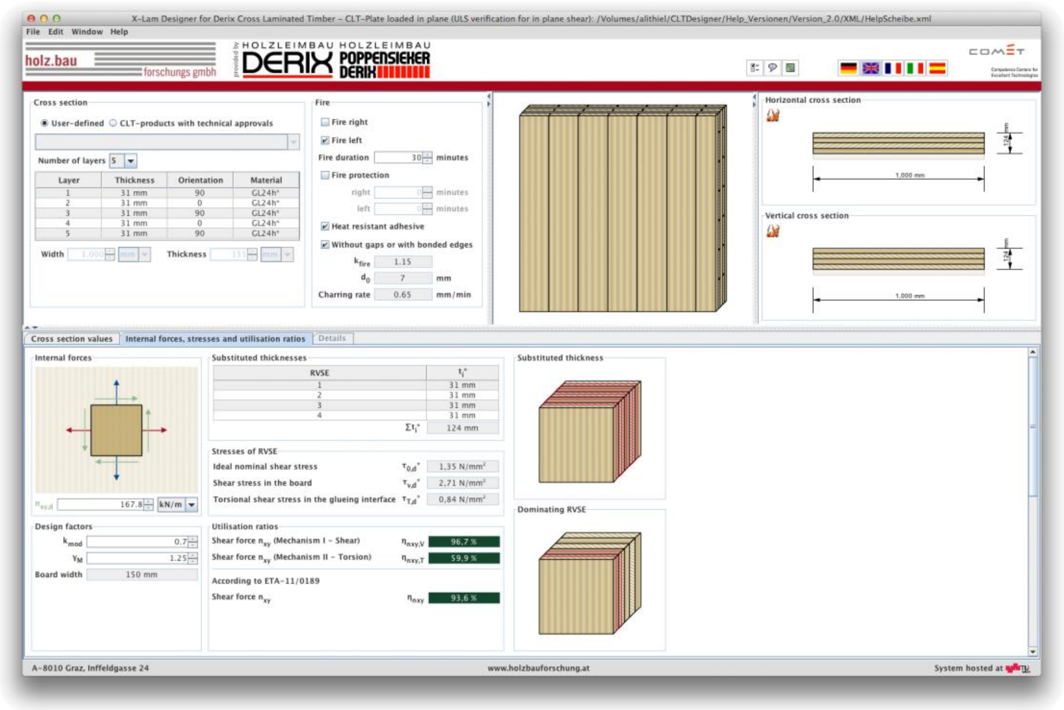
The module „CLT-Plate 1D – continuous beam” offers the required verifications for the ultimate limit state (ULS) with respect to bending and shear for permanent and transient loads as well as accidental (fire) design situations, and the verifications for the serviceability limit state with respect to deflection and vibrations according to EN 1990 or EN 1995 for continuous systems such as cross laminated timber plates.



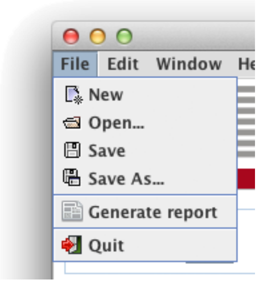
After specifying the internal forces and buckling lengths, the module “CLT-Plate 1D – Internal forces” carries out the required verifications of the ultimate limit state with respect to normal and shear forces for permanent and transient loads as well as accidental design situations.



The module “CLT-Plate loaded in plane” carries out the required shear stress verifications for a CLT cross-section in the ultimate limit state for permanent and transient loads as well as for accidental design situations based on a given shear force in plane per unit length.

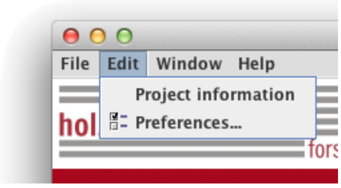


2.2 Menu bar

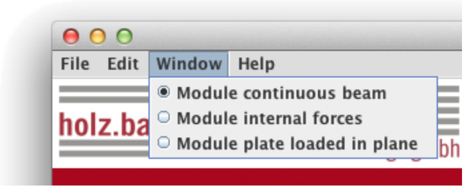


The menu item „File“ offers the following selections:

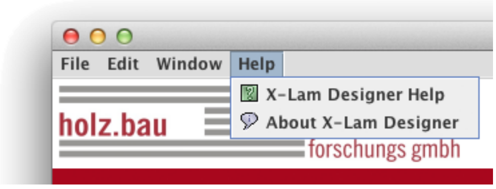
- New: Creates a new project
- Open and Save: Opens or saves a project
- Generate report: Compiles a pdf-format summary of specifications and results
- Quit: Closes the program



In the menu item „Edit“, the project information and settings can be entered or changed.



In the menu item „Window“, one can move between the two modules.

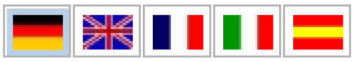


In the menu item „Help“, the user manual as well as further information concerning the X-Lam Designer can be accessed.

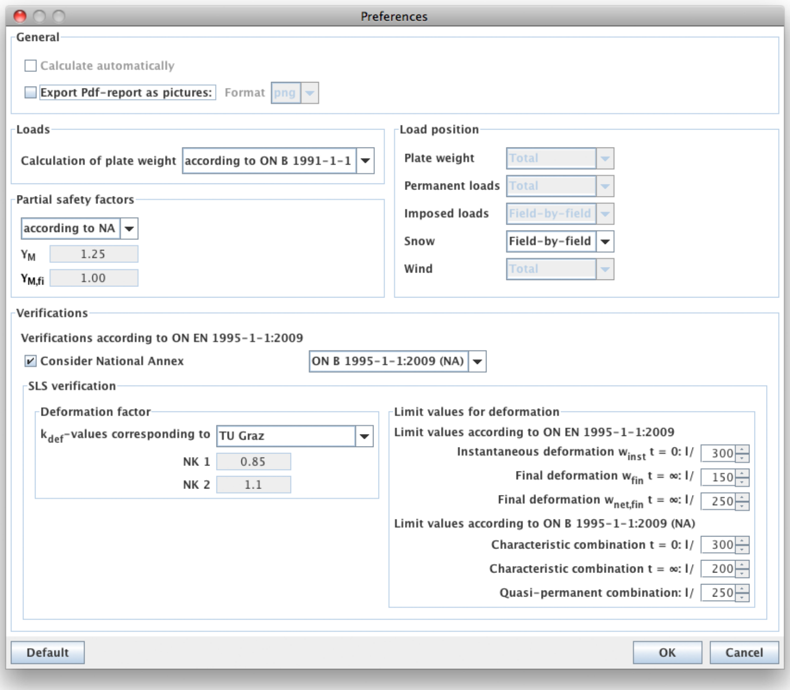
2.3 Buttons

A window with settings/preferences will open by clicking on the left button in the first series of buttons, another window with information about the X-Lam Designer will pop up by clicking on the middle, and help information can be accessed by clicking on the right button.

By clicking on one of the buttons in the second series of buttons shown in the following figure, the language can be changed. The current version offers German, English, French, Italian and Spanish translations.



2.4 Settings/Preferences



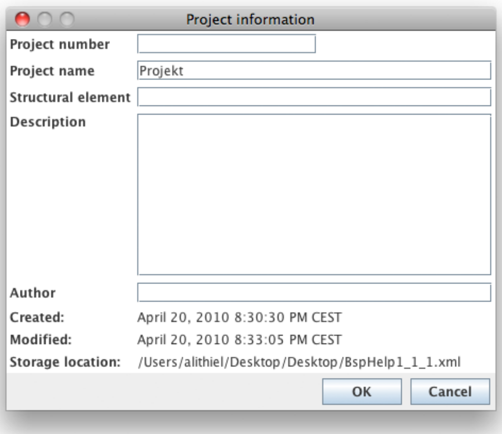
The calculation method for CLT plate weight, and the type and combination of structural loads can be changed via the settings/preferences. Furthermore, the partial safety factors and the deformation factor as well as the limits for the verification of deformation can be defined in this field.

2.5 Information

The information window includes the contact address, the terms of use, and a button for feedback.

2.6 Project information

Project information can be entered by clicking on „Edit | Project information“. Here, a project name and a description of the component to be examined can be inserted. Furthermore, the name of the author or a person in charge can be included. The date of creation, the date of the latest change in the project, as well as the storage location are created automatically.



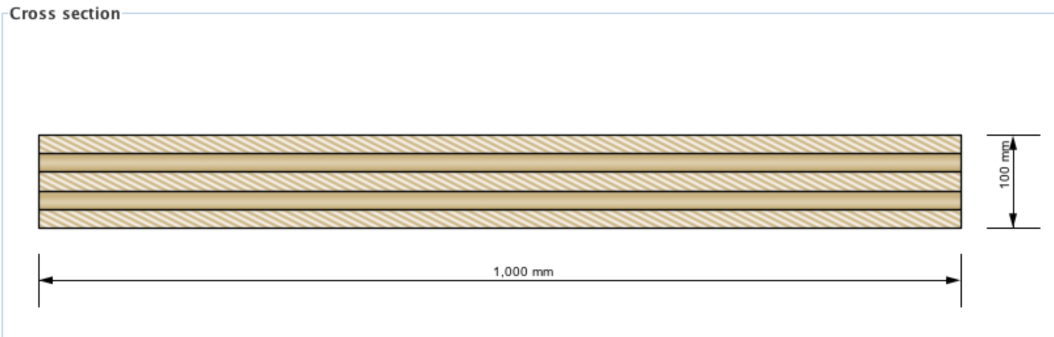
3 MODULE „CLT-PLATE 1D – CONTINUOUS BEAM“

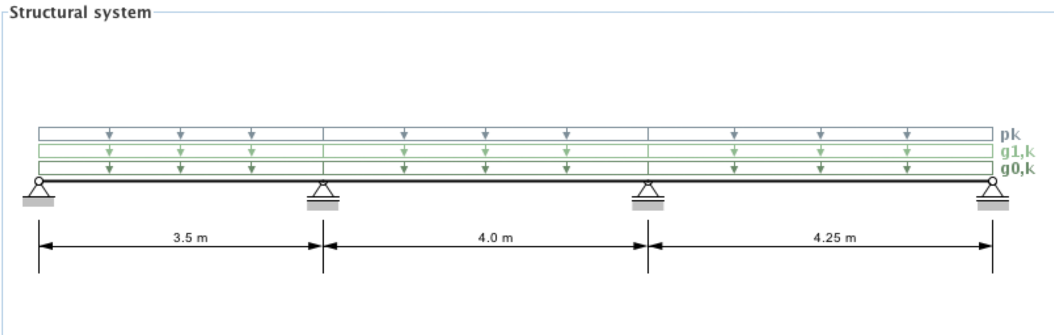
3.1 Input information

The input information entry is divided into several fields as follows:

- General: General information on the project and on the component to be examined
- Structural system: Description of the structural system
- Cross section: Description of the cross section
- Loads: Specification of the loads
- Fire / Vibration: Specification of parameters concerning structural fire design and vibrations

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.





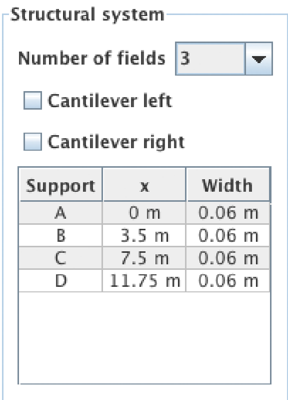
3.1.1 General

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.

3.1.2 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.

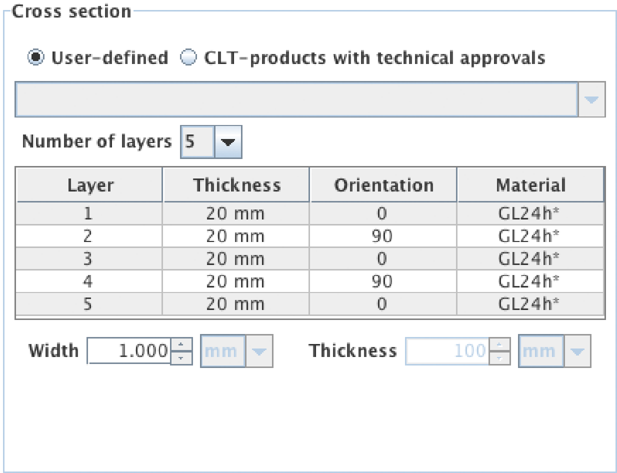


3.1.3 Cross section

The cross section can be defined by the user or by choosing a typical cross section of a proprietary CLT product. 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 thickness of each layer has to be within the range of 6.0 mm to 45 mm.

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.



3.1.4 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 based on the arithmetic average of density (ρ_{mean}) of the chosen material. However, the unit weight may also be calculated using:

- calculation in accordance with ON B 1991-1-1. A unit weight of 5.5 kN/m³ is assumed in the calculation.
- a user-defined density: 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 (Finland), IS (Iceland), N (Norway), S (Sweden)

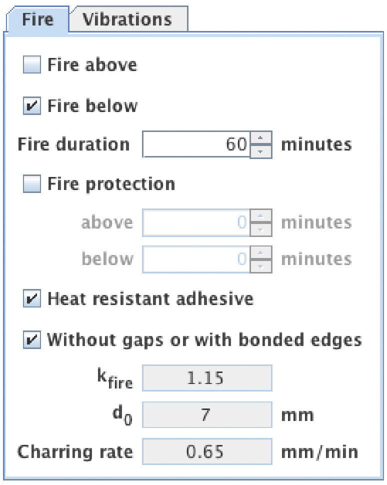
Loads

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			

The span of each field can also be modified in this table.

3.1.5 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.

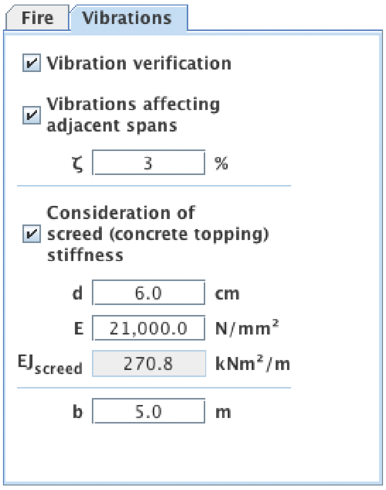


For a user-defined cross section, options are given for specifying heat resistant adhesives, presence of grooves, and whether the layers are edge-glued. For proprietary CLT products both values are set automatically and they cannot be changed.

The values k_{fire} (conversion factor 20%-quantiles) and d_0 (layer thickness to take into consideration the influence of temperature exposure) as well as the charring rate (dependent on the option edge glued or without groove) are pre-set and cannot be changed.

3.1.6 Vibrations

The tab „Vibrations“ allows for vibration verification.



For the vibration verification the following specifications are of importance:

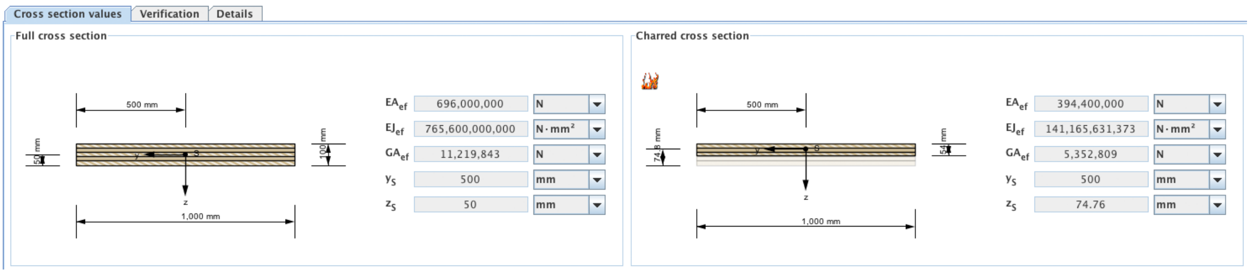
- Vibrations affecting adjacent span: Is it detrimental if vibrations are transferred to neighbouring fields?
- Modal damping factor ζ
- Consideration of the screed (concrete topping) stiffness: Is the stiffness of the screed (concrete topping) taken into consideration?
    - Thickness of the screed (concrete topping)
    - Modulus of elasticity of the screed (concrete topping)
- Plate width perpendicular to the direction of prestressing

3.2 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.). Each field / span is divided in ten sections and verifications are carried out for each section in each field / span.

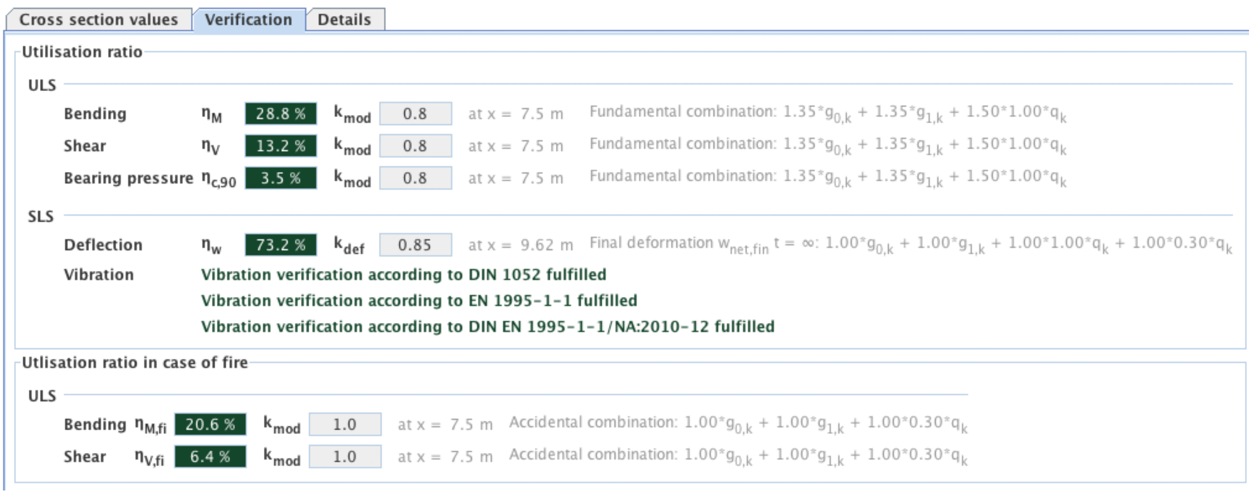
3.2.1 Cross section values

Output values generated in the tab “Cross section values” field include the effective stiffness, 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.

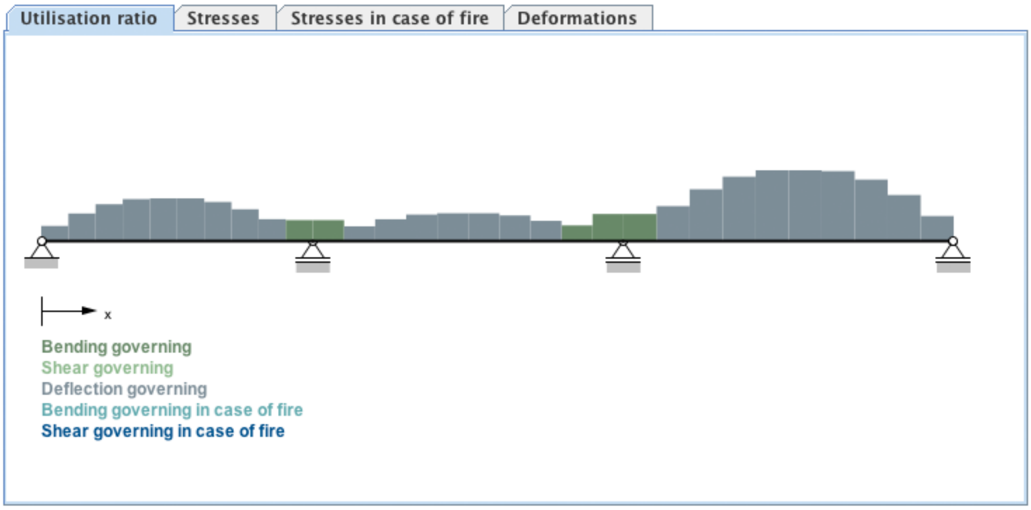


3.2.2 Summary of the results

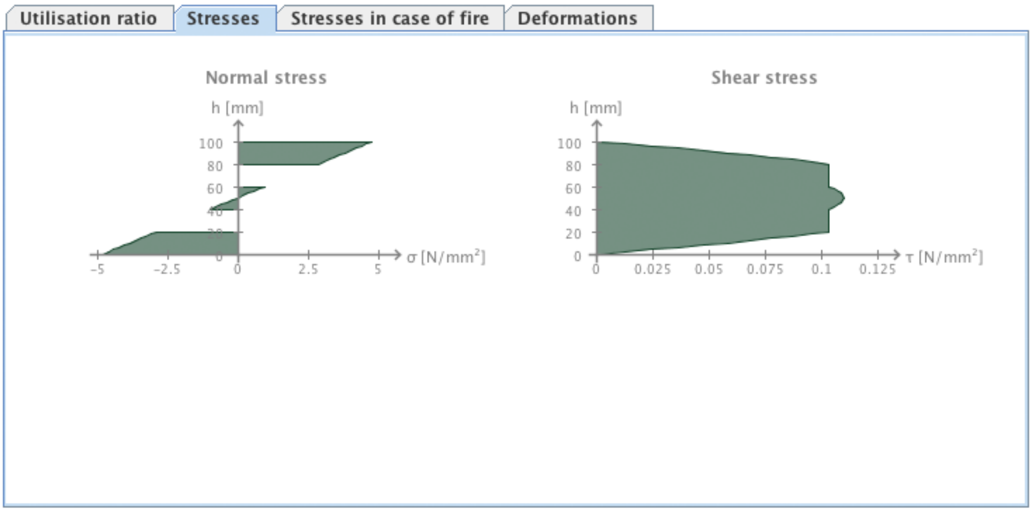
A summary of the verifications can be retrieved via the tab “Verifications”. The utilisation ratios for various limit states are colour-coded indicating if the verification is fulfilled (green) or not fulfilled (red). The locations of the maximum utilisation ratio and the governing combinations are compiled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



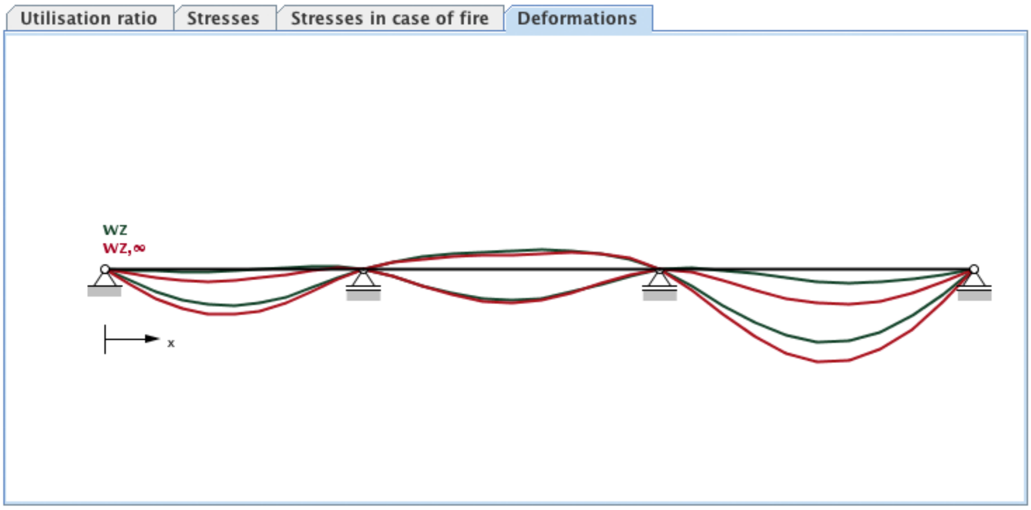
The tab “Utilisation” shows the distribution of the governing utilisation ratios along the beam.



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".

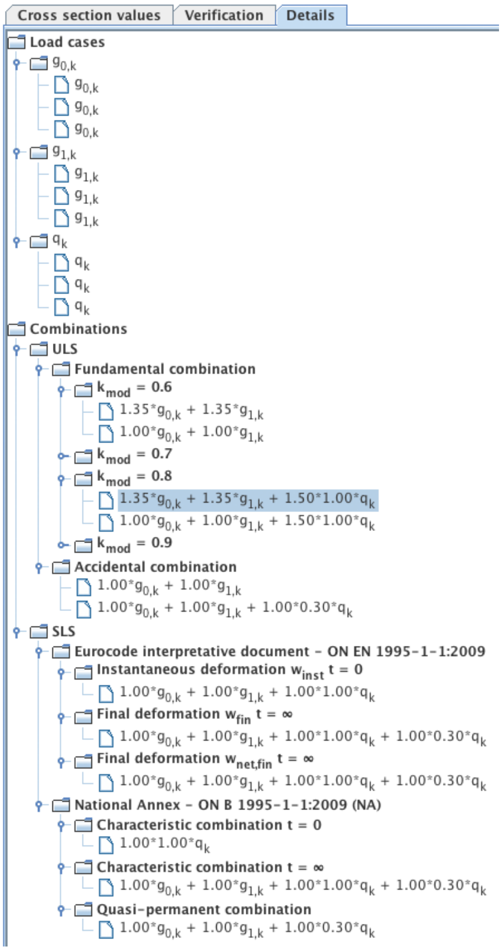


The tab "Deformations" shows the deformed system or the envelope given by the minimum and maximum deformation resulting from the governing SLS verification.



3.2.3 Detailed results

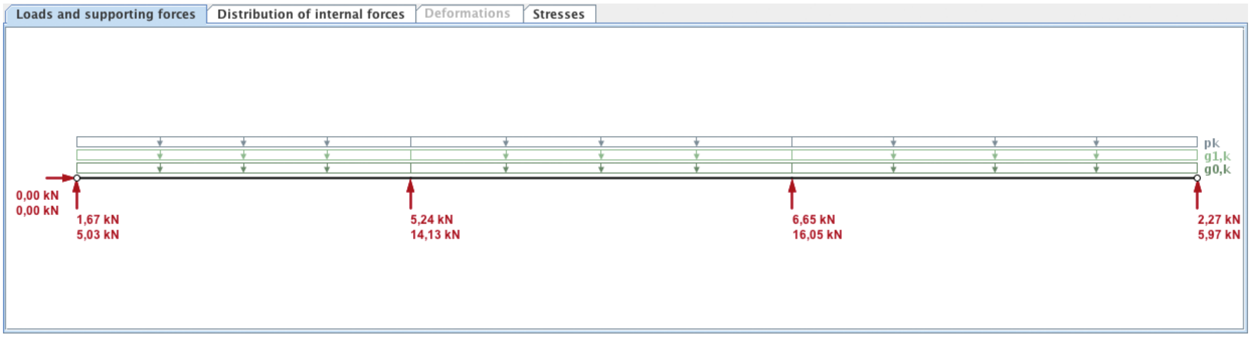
The detailed results can be retrieved in the tab “Details”. The “tree” on the left side offers the possibility to choose the respective load case or combination.

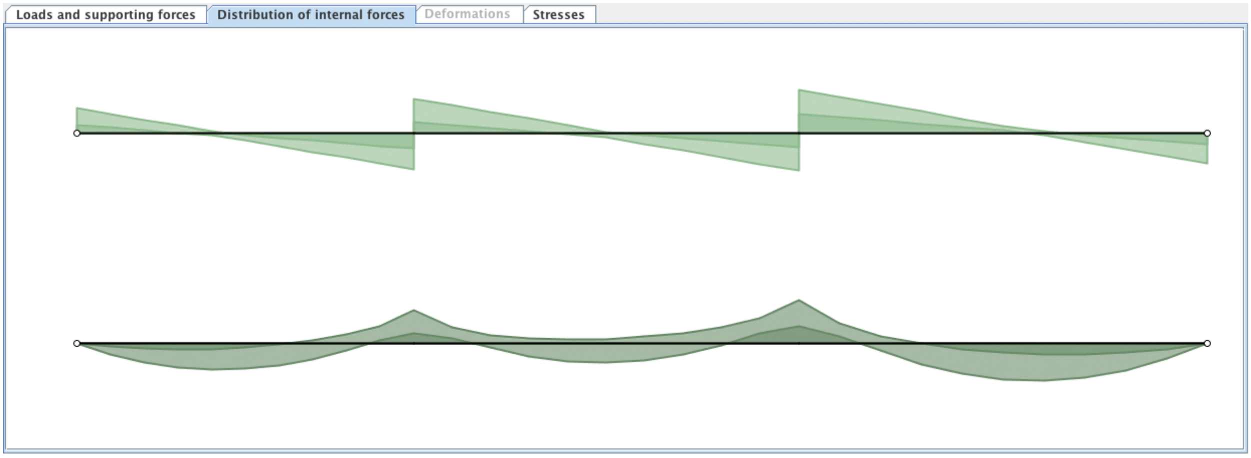


The results of this choice (internal forces, deformations) are then shown for each of the calculation sections of each field (ten sections / field) in the table on the top right.

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	4.59 kN		-0.00 kN·m	2.11 kN		-0.00 kN·m	5.03 kN		-0.00 kN·m	1.67 kN
1	0.35 m		1.56 kN·m	3.87 kN		0.49 kN·m	1.13 kN		1.56 kN·m	3.87 kN		0.49 kN·m	1.13 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	1.05 m		3.45 kN·m	1.54 kN		0.91 kN·m	0.06 kN		3.45 kN·m	1.54 kN		0.91 kN·m	0.06 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	1.75 m		3.71 kN·m	-0.79 kN		0.58 kN·m	-1.00 kN		1.63 kN·m	-0.40 kN		2.66 kN·m	-1.39 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	2.45 m		2.35 kN·m	-3.12 kN		-0.50 kN·m	-2.07 kN		0.98 kN·m	-1.47 kN		0.87 kN·m	-3.72 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	3.15 m		-0.43 kN·m	-2.54 kN		-2.54 kN·m	-6.05 kN		-0.43 kN·m	-2.54 kN		-2.54 kN·m	-6.05 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	3.9 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	4.3 m		0.63 kN·m	3.15 kN		-1.19 kN·m	2.05 kN		-0.40 kN·m	4.26 kN		-0.17 kN·m	0.94 kN
2	4.7 m		1.89 kN·m	2.51 kN		-0.76 kN·m	0.75 kN		1.04 kN·m	2.93 kN		0.09 kN·m	0.33 kN
2	5.1 m		2.63 kN·m	1.18 kN		-0.58 kN·m	0.14 kN		1.94 kN·m	1.60 kN		0.10 kN·m	-0.28 kN
2	5.5 m		2.83 kN·m	-0.15 kN		-0.65 kN·m	-0.47 kN		2.32 kN·m	0.26 kN		-0.13 kN·m	-0.89 kN
2	5.9 m		2.51 kN·m	-1.48 kN		-0.96 kN·m	-1.08 kN		0.14 kN·m	-0.39 kN		1.41 kN·m	-2.17 kN
2	6.3 m		1.65 kN·m	-2.81 kN		-1.51 kN·m	-1.69 kN		-0.14 kN·m	-1.00 kN		0.28 kN·m	-3.50 kN
2	6.7 m		0.26 kN·m	-4.14 kN		-2.31 kN·m	-2.30 kN		-0.66 kN·m	-1.61 kN		-1.39 kN·m	-4.83 kN
2	7.1 m		-1.43 kN·m	-2.22 kN		-3.59 kN·m	-6.16 kN		-1.43 kN·m	-2.22 kN		-3.59 kN·m	-6.16 kN
2	7.5 m		-2.44 kN·m	-2.83 kN		-6.32 kN·m	-7.49 kN		-2.44 kN·m	-2.83 kN		-6.32 kN·m	-7.49 kN
3	7.5 m		-2.44 kN·m	3.82 kN		-6.32 kN·m	8.55 kN		-6.32 kN·m	8.55 kN		-2.44 kN·m	3.82 kN
3	7.925 m		-0.96 kN·m	3.17 kN		-2.98 kN·m	7.14 kN		-2.98 kN·m	7.14 kN		-0.96 kN·m	3.17 kN
3	8.35 m		1.09 kN·m	5.33 kN		-1.09 kN·m	2.91 kN		-0.25 kN·m	5.73 kN		0.25 kN·m	2.52 kN
3	8.775 m		3.06 kN·m	3.92 kN		0.01 kN·m	2.27 kN		1.88 kN·m	4.31 kN		1.19 kN·m	1.87 kN
3	9.2 m		4.42 kN·m	2.51 kN		0.84 kN·m	1.62 kN		3.42 kN·m	2.90 kN		1.84 kN·m	1.22 kN
3	9.625 m		5.19 kN·m	1.09 kN		1.38 kN·m	0.97 kN		4.35 kN·m	1.49 kN		2.22 kN·m	0.57 kN
3	10.05 m		5.35 kN·m	-0.32 kN		1.66 kN·m	0.32 kN		1.66 kN·m	0.32 kN		5.35 kN·m	-0.32 kN
3	10.475 m		4.92 kN·m	-1.73 kN		1.66 kN·m	-0.33 kN		1.66 kN·m	-0.33 kN		4.92 kN·m	-1.73 kN
3	10.9 m		3.88 kN·m	-3.15 kN		1.38 kN·m	-0.98 kN		1.38 kN·m	-0.98 kN		3.88 kN·m	-3.15 kN
3	11.325 m		2.24 kN·m	-4.56 kN		0.83 kN·m	-1.62 kN		0.83 kN·m	-1.62 kN		2.24 kN·m	-4.56 kN
3	11.75 m		0.00 kN·m	-5.97 kN		0.00 kN·m	-2.27 kN		0.00 kN·m	-2.27 kN		0.00 kN·m	-5.97 kN

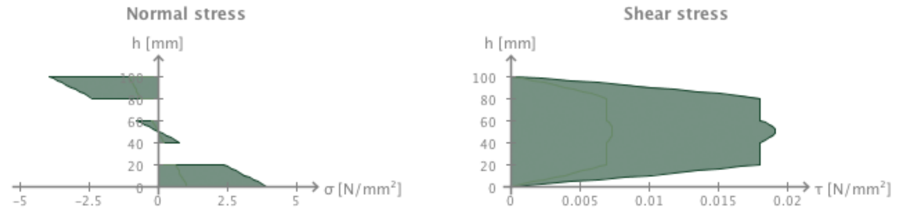
By choosing the desired calculation section in the table, the loads and supporting forces, the distribution of internal forces and the deformations as well as the calculated stresses are shown under different tabs on the bottom right.





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

Stress distribution



Stresses and utilisation ratios of single layers

M max

Layer	σ_M	η_M	τ_V	η_V
# 1	3.931 N/mm²	23.3 %	0.013 N/mm²	0.7 %
# 2	0.000 N/mm²	0.0 %	0.013 N/mm²	1.7 %
# 3	0.786 N/mm²	4.7 %	0.014 N/mm²	0.7 %
# 4	-0.000 N/mm²	0.0 %	0.013 N/mm²	1.7 %
# 5	-3.931 N/mm²	23.3 %	0.013 N/mm²	0.7 %

M min

Layer	σ_M	η_M	τ_V	η_V
# 1	1.049 N/mm²	6.2 %	0.012 N/mm²	0.6 %
# 2	0.000 N/mm²	0.0 %	0.012 N/mm²	1.5 %
# 3	0.210 N/mm²	1.2 %	0.012 N/mm²	0.7 %
# 4	-0.000 N/mm²	0.0 %	0.012 N/mm²	1.5 %
# 5	-1.049 N/mm²	6.2 %	0.012 N/mm²	0.6 %

4 MODULE „CLT-PLATE 1D – INTERNAL FORCES“

4.1 Input data

The input data include:

- Cross section: Definition of the cross section
- Fire: Specifications concerning structural fire design
- Internal forces: According to the theory (of 1st or 2nd order) on which the calculations are based on
- Design factors
- Stability: Specifications concerning stability

4.1.1 Cross section

See 3.1.3

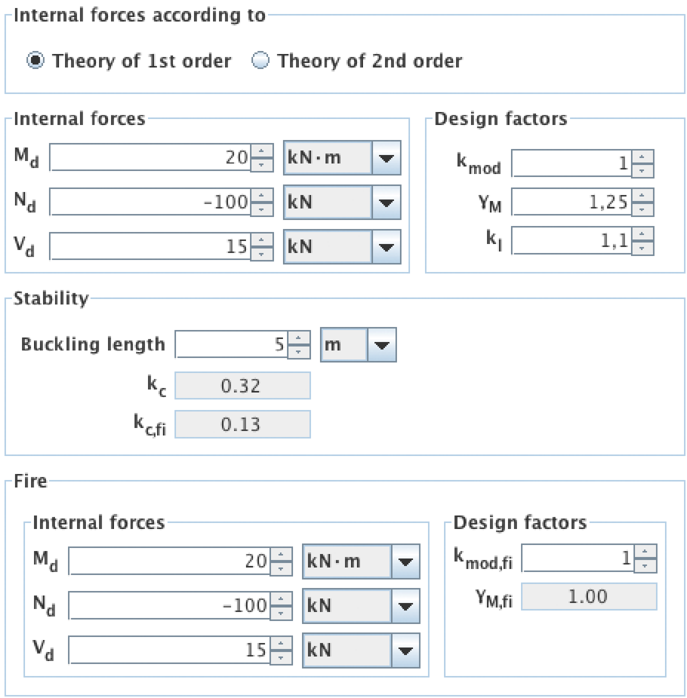
4.1.2 Fire

See 3.1.5

4.1.3 Type of calculation, internal forces, design factors and specifications concerning stability

The internal forces and the underlying type of calculation are defined in the tab „Internal forces, stresses and utilisation ratios“. Additionally, the design values are specified here.

If the internal forces result from a calculation based on a first order analysis a substitute buckling length has to be stated in case of a negative normal force („problem of stability“). Based on this buckling length and the respective cross section the required buckling factor k_c needed for the verification is calculated automatically.

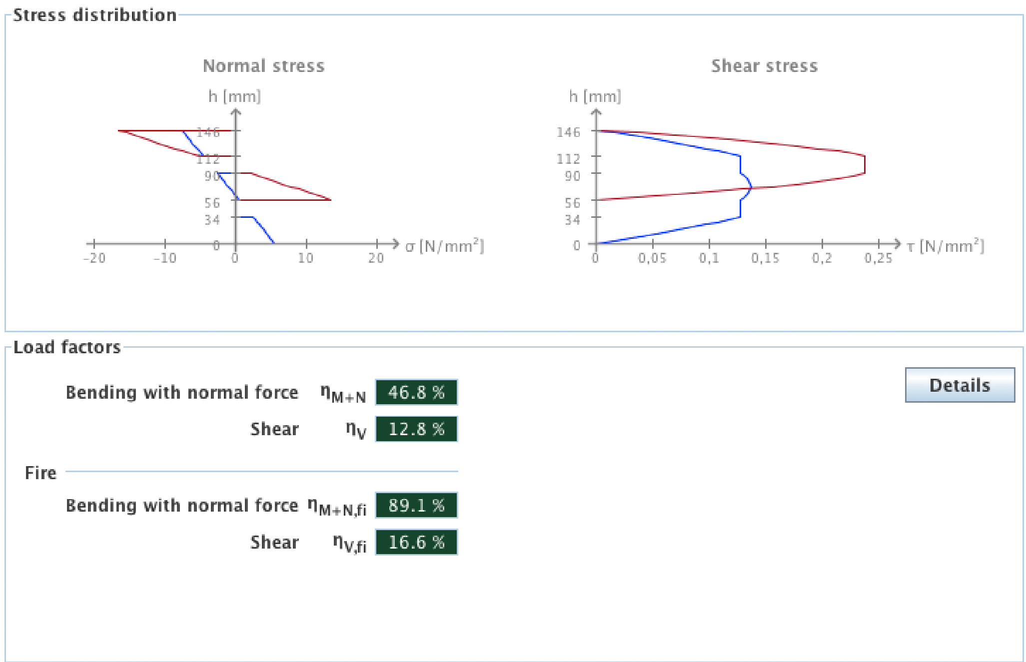


4.2 Results and output

4.2.1 Cross section values

See 3.2.1

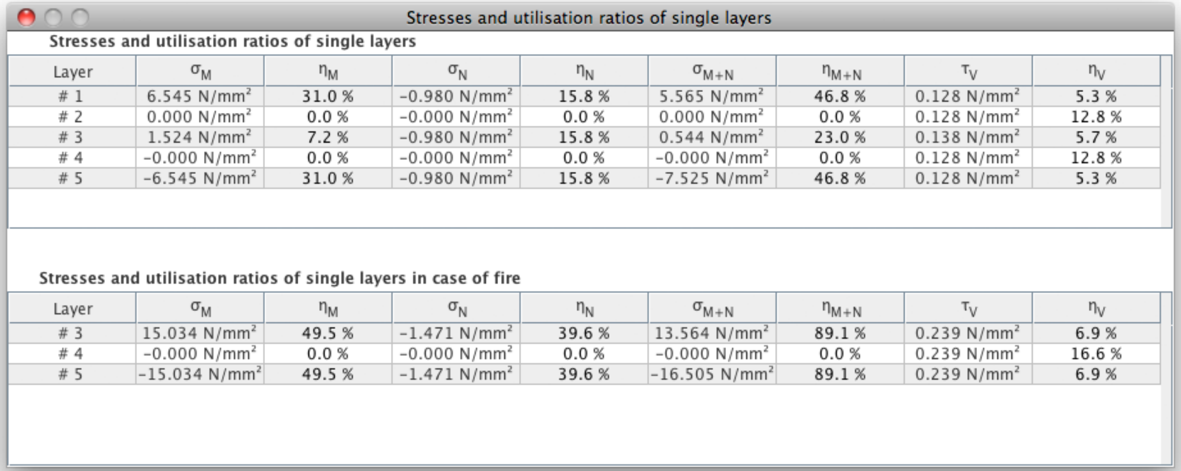
4.2.2 Summary of the results



The stress distributions and the governing utilisation ratios are shown in the tab „Internal forces, stresses and utilisation ratios".

4.2.3 Detailed results

Stresses and utilisation ratios of the single layers are shown when clicking on the "Details" button.



Stresses and utilisation ratios of single layers

Stresses and utilisation ratios of single layers

Layer	σ_M	η_M	σ_N	η_N	σ_{M+N}	η_{M+N}	τ_V	η_V
# 1	6.545 N/mm²	31.0 %	-0.980 N/mm²	15.8 %	5.565 N/mm²	46.8 %	0.128 N/mm²	5.3 %
# 2	0.000 N/mm²	0.0 %	-0.000 N/mm²	0.0 %	0.000 N/mm²	0.0 %	0.128 N/mm²	12.8 %
# 3	1.524 N/mm²	7.2 %	-0.980 N/mm²	15.8 %	0.544 N/mm²	23.0 %	0.138 N/mm²	5.7 %
# 4	-0.000 N/mm²	0.0 %	-0.000 N/mm²	0.0 %	-0.000 N/mm²	0.0 %	0.128 N/mm²	12.8 %
# 5	-6.545 N/mm²	31.0 %	-0.980 N/mm²	15.8 %	-7.525 N/mm²	46.8 %	0.128 N/mm²	5.3 %

Stresses and utilisation ratios of single layers in case of fire

Layer	σ_M	η_M	σ_N	η_N	σ_{M+N}	η_{M+N}	τ_V	η_V
# 3	15.034 N/mm²	49.5 %	-1.471 N/mm²	39.6 %	13.564 N/mm²	89.1 %	0.239 N/mm²	6.9 %
# 4	-0.000 N/mm²	0.0 %	-0.000 N/mm²	0.0 %	-0.000 N/mm²	0.0 %	0.239 N/mm²	16.6 %
# 5	-15.034 N/mm²	49.5 %	-1.471 N/mm²	39.6 %	-16.505 N/mm²	89.1 %	0.239 N/mm²	6.9 %

5 MODULE „CLT-PLATE LOADED IN PLANE“

5.1 Input information

The input information entry is divided into several fields as follows:

- Definition of the cross section
- Information concerning structural fire design
- Internal force variables
- Design factors

5.1.1 Cross section

See **Fehler! Verweisquelle konnte nicht gefunden werden.**

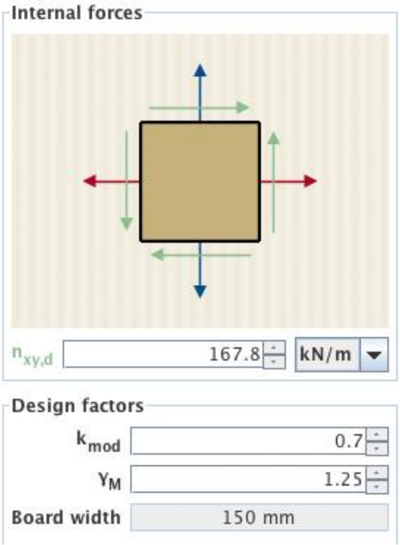
In this module it is not possible to change the cross sectional width.

5.1.2 Fire

See **Fehler! Verweisquelle konnte nicht gefunden werden.**

Fire left / right instead of fire above and below.

5.1.3 Internal forces and design factors



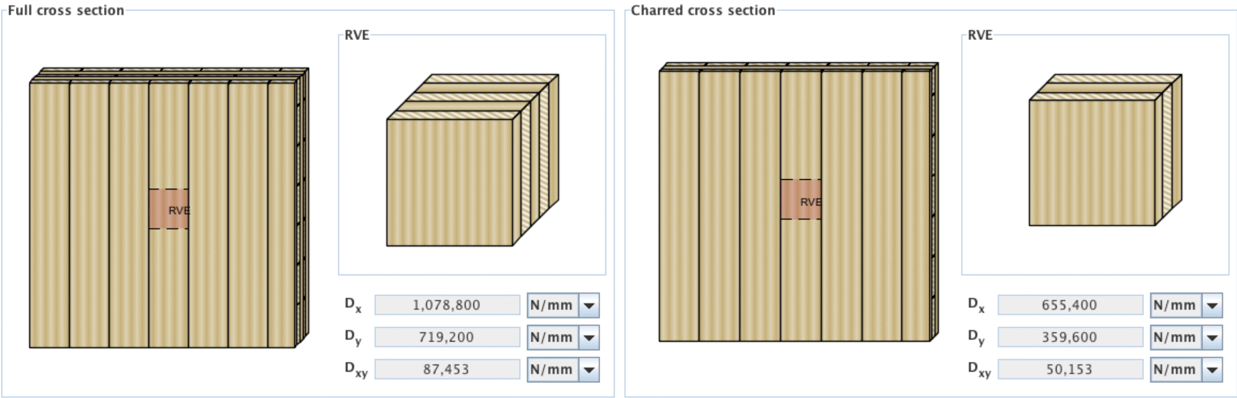
In the tab „internal forces, stresses and utilization ratio“ it is possible to define the shear force in plane per unit length $n_{xy,d}$, as well as the design factors. The design method is based on a board width of 150 mm.

5.2 Results and output

5.2.1 Cross section values

The effective stiffnesses of a plate loaded in plane are given in the tab „cross section values for the full cross section and in case of structural fire design for the charred cross section.

The small differences between the extensional stiffnesses D_x and D_y and the effective extensional stiffness EA_{ef} in the module CLT-plate 1D result from the negligence of the extensional stiffness of the cross layers in this module.



5.2.2 Summary of the results

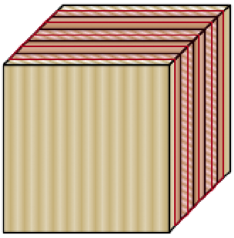
The calculated substituted thicknesses, stresses as well as utilization ratios of the two mechanisms (Mechanism I – shear and Mechanism II – torsion) are given in the tab „internal forces, stresses and utilization ratios“.

Furthermore, the utilization ratios, that were calculated based on ETA-11/0189 are given.

Substituted thicknesses

RVSE	t_i^*
1	31 mm
2	31 mm
3	31 mm
4	31 mm
Σt_i^*	124 mm

Substituted thickness



Stresses of RVSE

Ideal nominal shear stress	$\tau_{0,d}^*$	1,35 N/mm²
Shear stress in the board	$\tau_{v,d}^*$	2,71 N/mm²
Torsional shear stress in the glueing interface	$\tau_{T,d}^*$	0,84 N/mm²

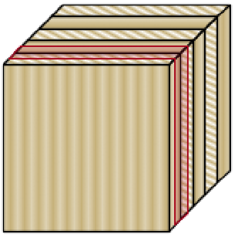
Utilisation ratios

Shear force n_{xy} (Mechanism I – Shear)	$\eta_{nxy,V}$	96,7 %
Shear force n_{xy} (Mechanism II – Torsion)	$\eta_{nxy,T}$	59,9 %

According to ETA-11/0189

Shear force n_{xy}	η_{nxy}	93,6 %

Dominating RVSE



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