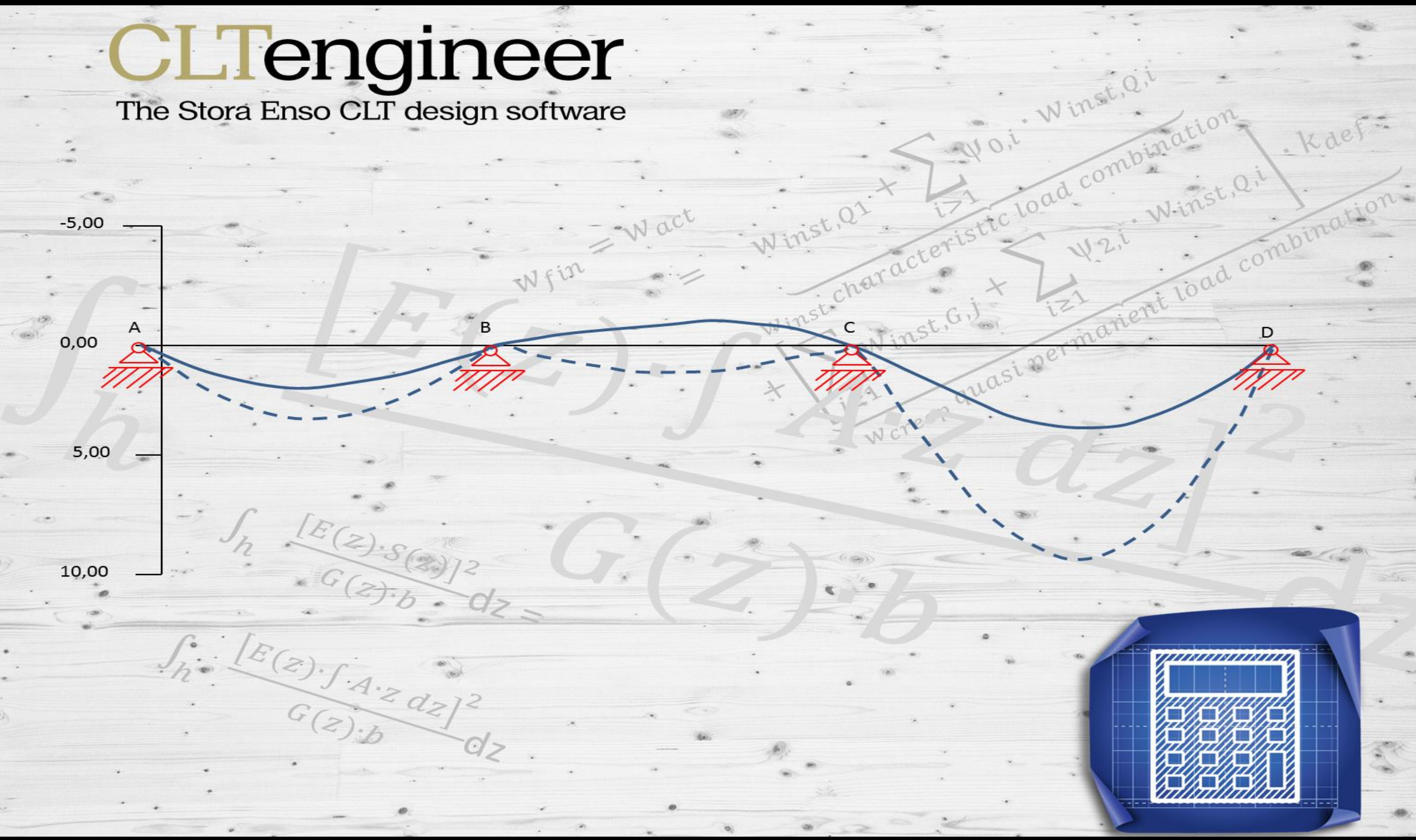


CLTengineer

The Stora Enso CLT design software

user manual

Date: 01.11.2015

DISCLAIMER & TERMS OF USE

1. Gerneral:
The Stora Enso CLTengineer ("software") is a technical design software for cross laminated timber (CLT). The technical design includes structural analysis and building physics. The software is an online software that can be operated through a web browser. No installation on a computer is required. To access the software, a registration process needs to be completed and the terms of use have to be accepted.

2. Intellectual property and copyright:
The software was created by Mursoft, Wörgötter, Kump OG (Graz, Austria) for Stora Enso Wood Products GmbH. All intellectual property rights in the software rest with Stora Enso Wood Products GmbH.

3. Registration
The use of the software requires an initial registration at the website of the software**. The use of the software shall be limited to the following countries: all member states of the European Union, Andorra, Iceland, Liechtenstein, Monaco, Norway, Switzerland and Australia.** The user is obligated to indicate true and correct data in the registration form. Stora Enso Wood Products GmbH is reserving and managing all licensing rights (rights to use the software). If a newly registered user will receive license rights, is subject to be decided by Stora Enso Wood Products GmbH. A registered user cannot claim to receive access to the software, unless given by Stora Enso Wood Products GmbH.

4. Accessibility:
The Stora Enso CLTengineer is an online software. Therefore it is dependent on the server that it is based on and the internet connection to the user´s computer. Server down time, any kind of network problems in the internet or connection problems at the user´s computer can cause a temporary inaccessibility of the software. Stora Enso Wood products GmbH cannot be held liable for the availability of the software at any time and the data entered by the user.
The Software was designed to run equally on Microsoft platforms, using Internet Explorer as web browser.
Due to the nature of the software it is likely that it will perform just as well on Macintosh platforms, using any other browser than Internet Explorer. The software might be operated from tablet computers (e.g.: iPad, etc.) in a similar way as through a desktop/laptop computer.
However, Stora Enso Wood Products GmbH does not guarantee compatibility with any computer system.

5. Accuracy and correctness
The software was programmed according to the current state of the art knowledge in structural analysis and building physics. Many local national regulations (Austria, Finland, France, Italy, Spain, Switzerland, United Kingdom and Australia) have been implemented in the software, such as national annexes of the Eurocode regulations. However, a complete coverage of all national and local regulations cannot be guaranteed.
The software was created to assist engineers in their daily business. The software is an engineering software that is dealing with a very complex matter of structural analysis and building physics analysis. Therefore, this software shall only be operated by skilled, experienced engineers, with a deep understanding of structural engineering and building physics related to timber structures. The user of the software is obliged to check all input values, no matter if they were given by the user or given by default by the software and all results for plausibility.
The use of the results of the software should not be relied upon as the basis for any decision or action. **Any use of results of the software is only allowed, if the results have been verified and approved regarding completeness and correctness by a project structural/building physics engineer.** The user has the possibility to make print-outs from the software. Any modification of those are not allowed.

6. Disclaimer of warranties and limitation of liability
The software of the CLTengineer on this website in provided "AS IS". Although the software has been developed with all due care Stora Enso cannot and does not give any warranties or representations or give any undertaking, either express or implied, about the accuracy, validity, timeliness or completeness of any information or data made available through the software and expressly disclaims any warranties of merchantability or fitness for a particular purpose. Stora Enso will not be liable to any party for any direct, indirect, special or other consequential damages caused by the use of the software, including without limitation any lost profits, business interruption or loss of programs or other data on the user´s information handling system, even if we are expressly advised of the possibility of such damages. Some jurisdictions do not allow the exclusion of implied warranties in which case the above will not apply in such jurisdictions.

Neither Stora Enso, nor any of its affiliates, directors, officers or employees, nor any third party vendor will be liable or have any responsibility of any kind for any loss or damage that you incur in the event of any failure or interruption of this website, or use of the website or its materials, whether or not the circumstances giving rise to such cause may have been within the control of Stora Enso. In no event will Stora Enso, its affiliates or any such parties be liable to you for any direct, special, indirect, consequential, incidental damages or any other damages of any kind even if Stora Enso or any other party have been advised of the possibility thereof.

The foregoing does not apply in case of mandatory liability.

7. Registration data
It is required to sign up at the website of the software in order to use the software. The collected data is being collected by Stora Enso Wood Products GmbH. The collected registration data will be held confidential. Stora Enso wood Products GmbH will use this data for marketing related purposes.

8. Privacy policy and confidentiality
All design data and project related data will be stored on the server that will host the software. The user will be able to choose, whether this data can be viewed by Stora Enso employees with administrator rights. In this case the user agrees that such information and material will be deemed to be non-confidential and non-proprietary. By submitting information or material you grant to Stora Enso and its affiliates a worldwide, perpetual, royalty-free, non-exclusive license to use, disclose, copy, modify, adapt, publicly display and translate all or any of such information or material for any purpose whatsoever without restrictions. Stora Enso reserves the right to, in its sole discretion and without notice, remove or delete any material submitted in connection with the use of the CLT engineer. Given Stora Enso the right to view the data could be helpful when giving support to software users.

Table of content

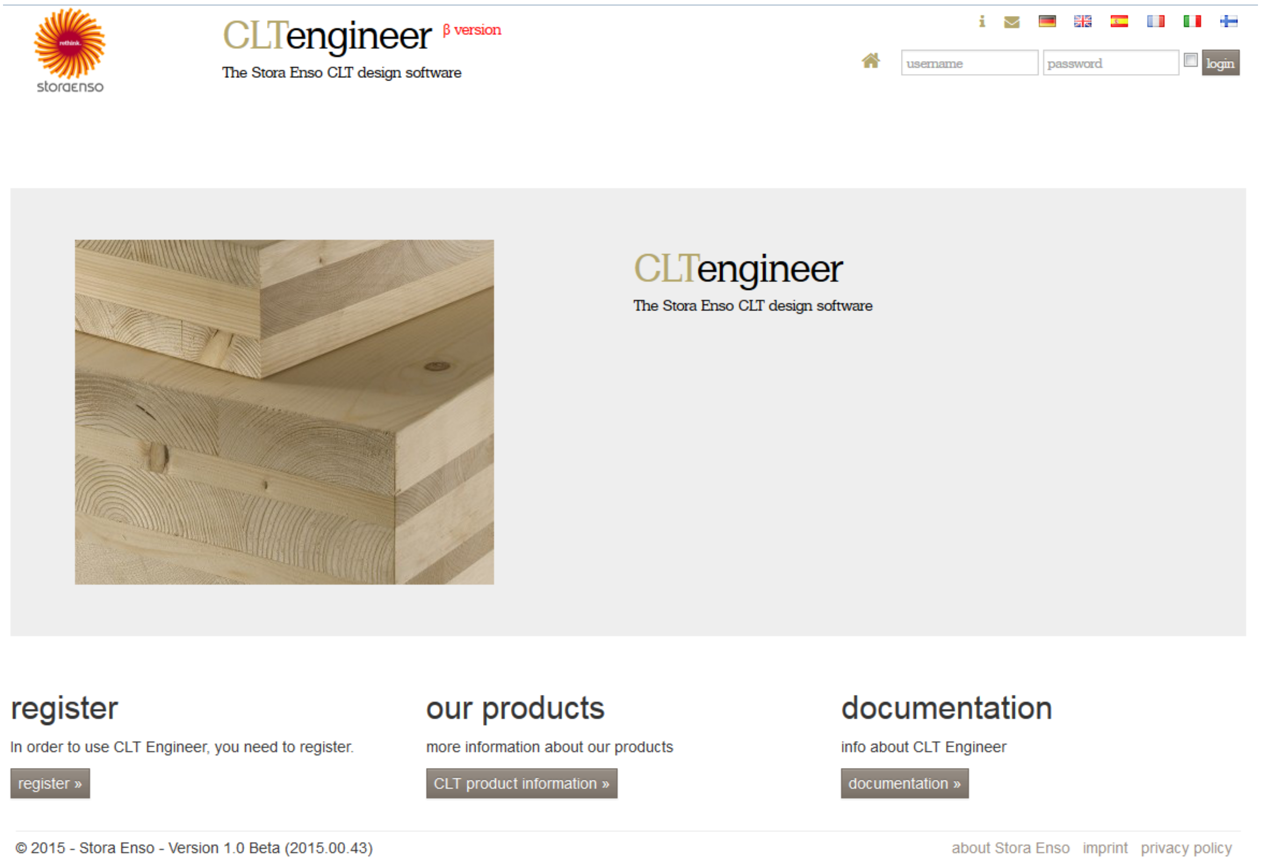
1. General

This document gives a quick introduction to the *CLTengineer*, the Stora Enso CLT design software. The *CLTengineer* is an online software and will gradually replace the existing MS-Excel based software.

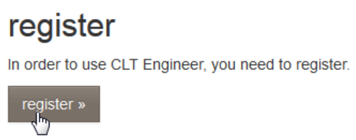
2. Getting started

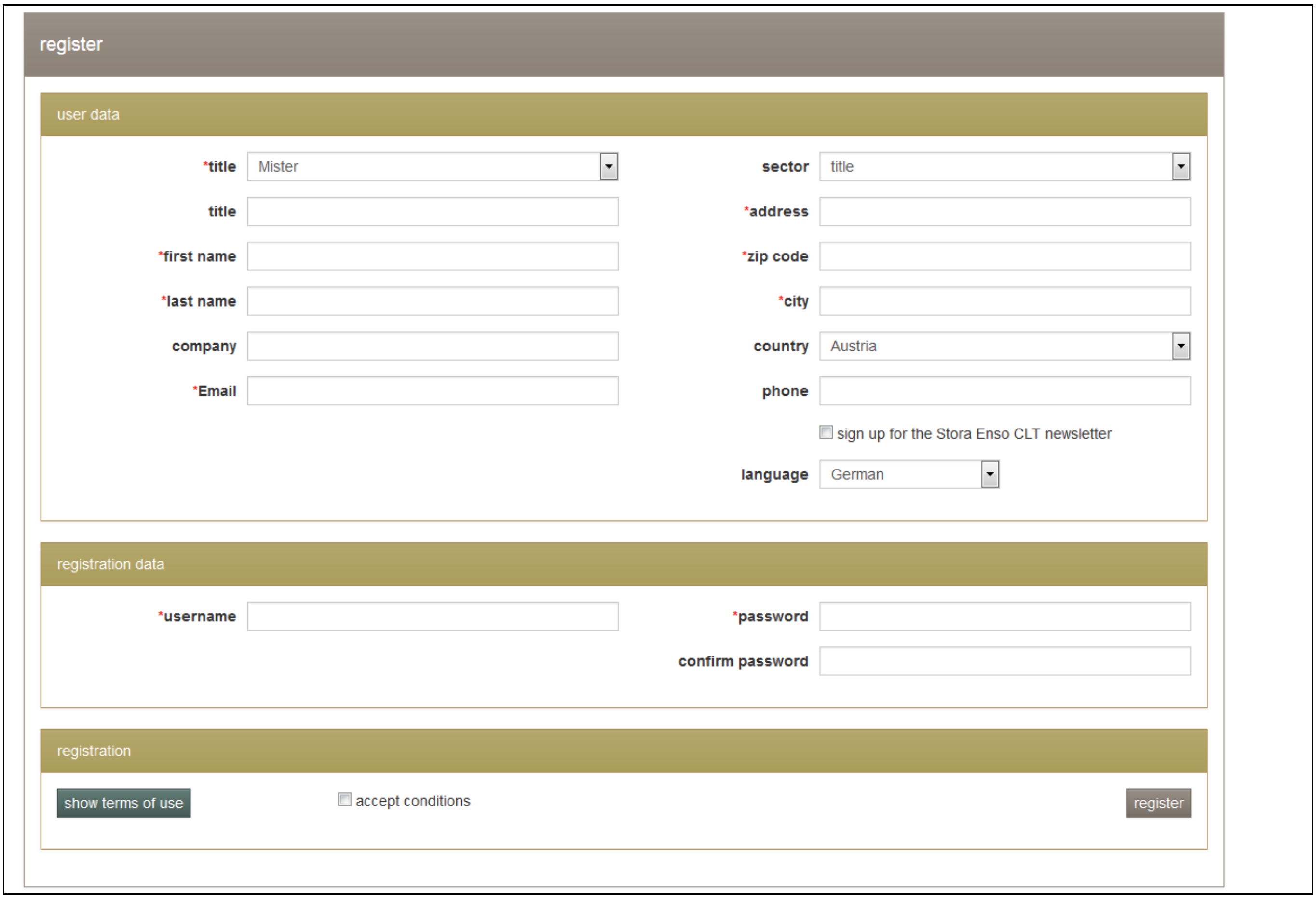
Please visit our website, where the software is located:

www.engineer.clt.info



You need to register and sign up in order to create an account.





Fill in the required fields, read the terms of use, accept these by putting a check mark in the box, next to “accept conditions” and click register.

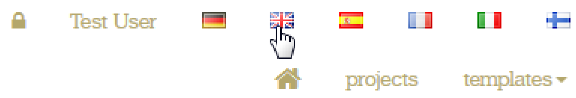
For future sessions you will be able to sign on with your username and password that you´ve created now.

Note: the list of countries in the pull-down menu “**country**” contains a list of all countries in this world. However, the software may only be used in the countries, mentioned in the disclaimer & terms of use.

A structural analysis or a building physics analysis needs to follow the local regulations (e.g.: national annex in European regulations, such as the Eurocode series). The software only contains the regulations from some countries, listed in chapter 5. The use of the software for an analysis of structures, to be built in other countries, bears the risk of a wrong interpretation or application of the applicable standards. For more information, please read the disclaimer & terms of use.

3. Language settings

Clicking one of the flags in the right upper corner of your screen will let you set the language for the software. This language setting can be changed at any time. Changing the language will change the language in the user interface on the screen. Results will be displayed in the same language as the current operating language. This applies to the PDF-print as well.



Note: when changing the language, it is assumed that the user is using a keyboard that is related to the chosen language. Therefore the decimal separator for the English setting is a point and not a comma. Entering numeric values with a comma in the English setting will lead to an error. In that case the corresponding error message will appear.

4. General information about the software

4.1. Accessing and using the software

The *CLTengineer* is an online software and can be accessed through the internet by means of a web browser. The software was designed for use with MS Internet Explorer 10 and Mozilla Firefox (version 39.0.3). It is absolutely possible that the software will perform just as well on any different browser (Google Chrome, Safari, etc.), but it cannot be guaranteed. This means that there is no local installation of the software on a computer required. Therefore this software is independent from any operating system and can be used on PC (Microsoft Windows platform) or MAC (i.OS). Probably on other operating systems too, but this cannot be guaranteed.

4.2. Availability of the software

The nature of an online software is that it relies on an internet connection. If there is no internet connection, the software cannot be used. The software is physically located on a web server and can be accessed by the use of a web browser. The internet connection is required for a communication between the user interface (browser) and the software on the server. This might sound quite limiting, but these days internet connections are widely available.

4.3. Working with the software

The fact that the software is sitting on a remote server might raise many questions, such as “how fast will it respond?”, “where is my data saved?” etc.

In all software tests, the software reacts quickly. This was tested from several locations and all kind of different connections to the internet (through mobile phone (3G and Edge), public WiFi, cable internet connection, etc.). In almost no case the work was slowed down, due to a slower internet connection. The amount of data being transferred for the analysis is not that large, so a fluent work is possible. Only modules with a higher amount of data might require a bit longer response time (e.g. the wall and deep beam analysis).

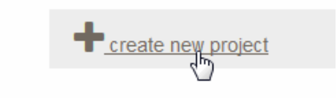
Whenever the input of data is being confirmed with a mouse click on the respective icon, the data is being saved on the server. In most cases, this comes along with an automatic analysis of the system. Therefore the loss of data as result of forgetting to save is excluded.

All data and projects are stored on the remote server. This can be compared with a webmail email account at any of the free mail providers, such as Google Mail, Hotmail, Yahoo, etc. When having such an email account, all mails, contact data, etc. is sitting on that server and can be retrieved by the user at any time. The same principle applies to our software. Excluded are times of server maintenance. Usually this maintenance is being done during weekends in night time (Central European Time) and is of short duration.

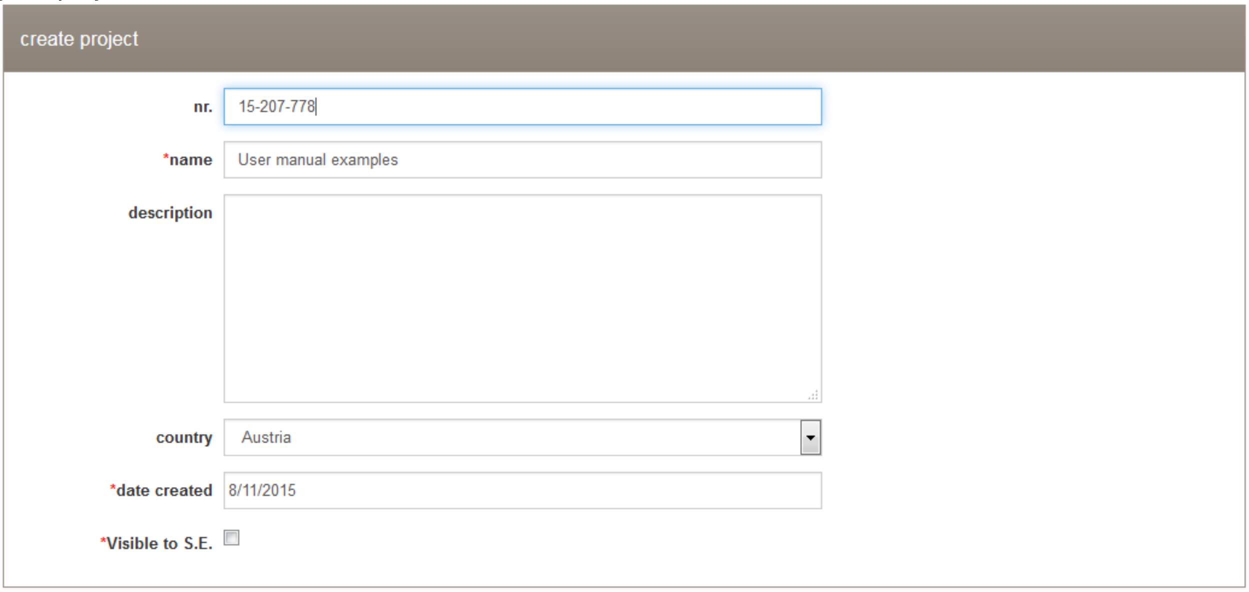
However, data loss can never be excluded. For more details, please read the disclaimer & terms of use.

5. Creating a project

Once signed on to the software, you are in your home screen, where your projects are listed. If you did not create a project yet, the list will be empty. In order to create a project, click "+ create new project"



Give your project a name. You can insert a project description, if desired. This will help you in future to identify your projects.



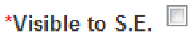
In the pulldown menu for country, you have to pick a country for your project. This setting will apply to your entire project. You will be able to select the following countries:

- Austria
- Finland
- France
- Germany
- Italy
- Spain
- United Kingdom
- Australia
- *Future development: Switzerland*

IMPORTANT: According to your selection, the applicable national regulations (national annexes of the Eurocode standards) will be applied to your design.

The list of design relevant documents will be listed in the output of the software.

If you want to allow Stora Enso employees to access and view your projects (e.g. for an easier technical support), please check the box “visible to S.E.”



Click the checkmark in order to save/confirm your input:

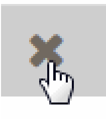
Now your first project will appear in your project list:


projects

	nr.	name	country	description	date created
	15-207-778	User manual examples	Austria		8/11/2015

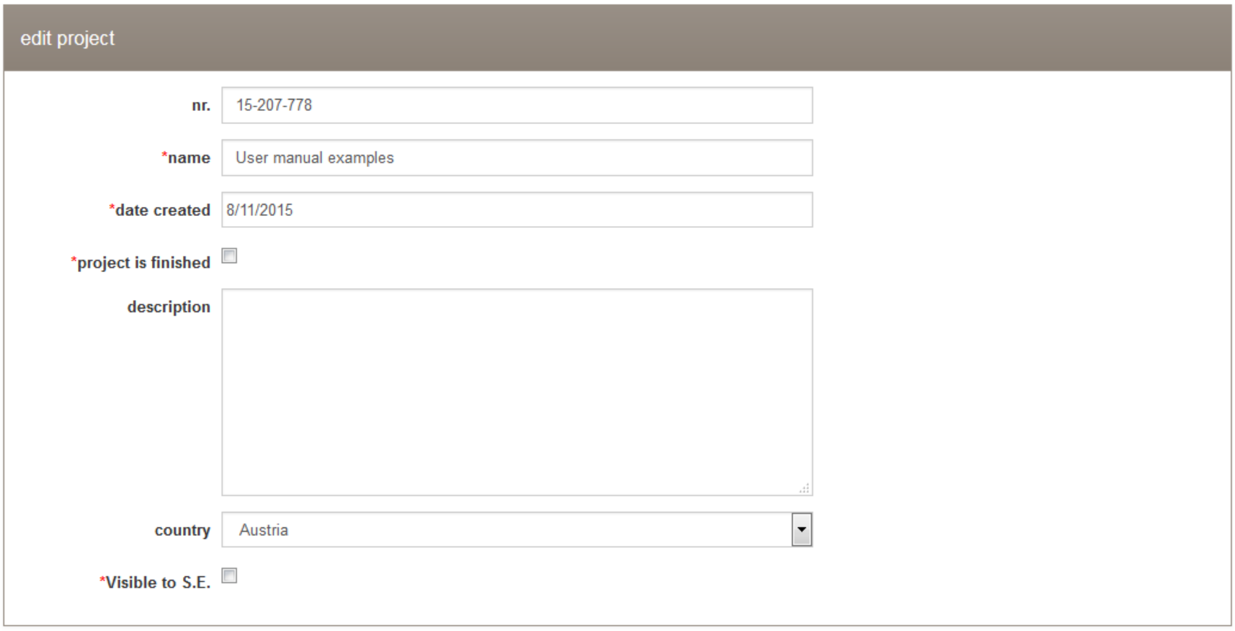
Clicking the line of your project will open your project.

Clicking the “x” icon will delete the project:

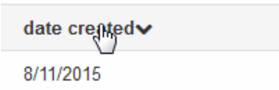


Clicking the edit icon gives you the possibility to edit the main project data (name, description and assigned country).

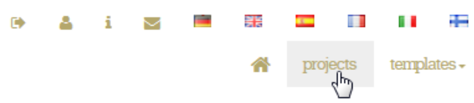
In the edit project pane, you can choose if a project is finished or not and change and given data.



To make the project navigation a bit easier, it is possible to sort the projects by each column ascending or descending, just by clicking any column title (in the image below we want to sort by creation date):



All projects (finished and ongoing) of a user can be found in the list, when clicking the “projects” icon:

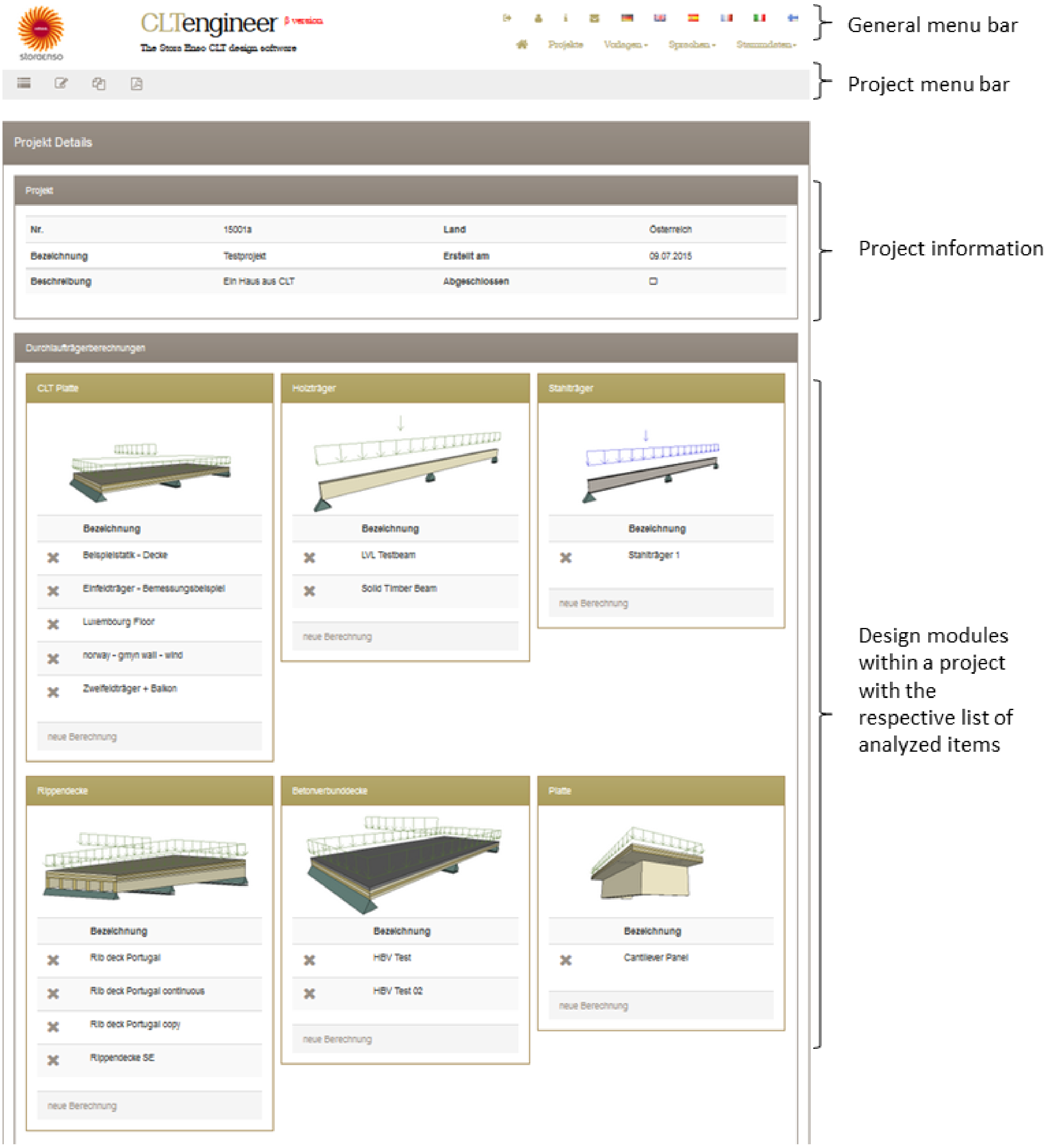


When clicking the “home” icon, you will be taken to a list of all projects that are not declared as finished yet:

This feature can help users who own many projects, to easier find their way around.
The home screen is the first thing a user will see, once logged-in.

6. Navigating within a project

A typical project screen will look as shown in the figure below:



6.1. Project menu bar

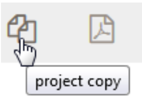
Use the list icon to get from a project again back to the home screen with the list of your projects:

…or use the home icon: 

Use the edit icon to edit the project information:

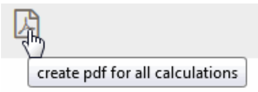
That´s the information that was entered, when starting a new project. See chapter 5.

Click the copy project icon, in order to create a copy of your project.



This can be helpful, if you want to create a structural analysis template of a typical project.

Click the PDF icon to create a detailed summary report of the entire project.

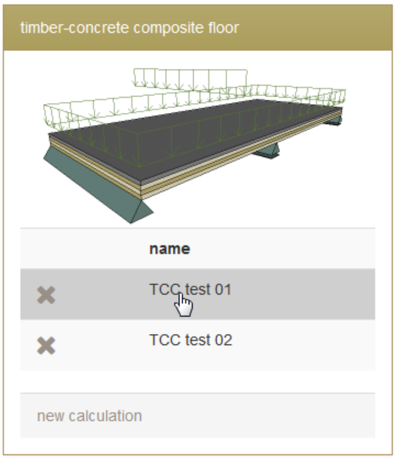


Note: if you click the PDF icon within an analysis, this will create only a PDF report of the respective analysis.

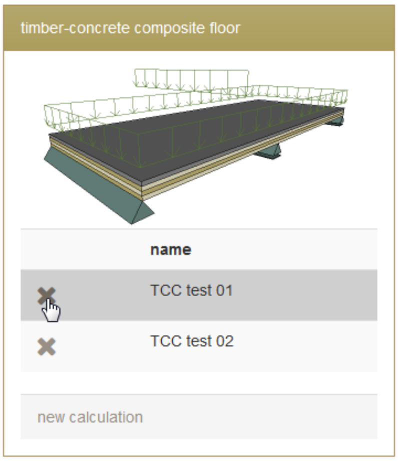
6.2. Starting an analysis or adding an analysis

In order to add a new element to your file, click “new calculation” in the respective box (e.g.: in the box for CLT panel):

All analysis items can be accessed by a simple click on the respective item:



An analysis item can be deleted by clicking the X icon at the respective item:



7. Structural analysis modules

7.1. Continuous beam – CLT panel

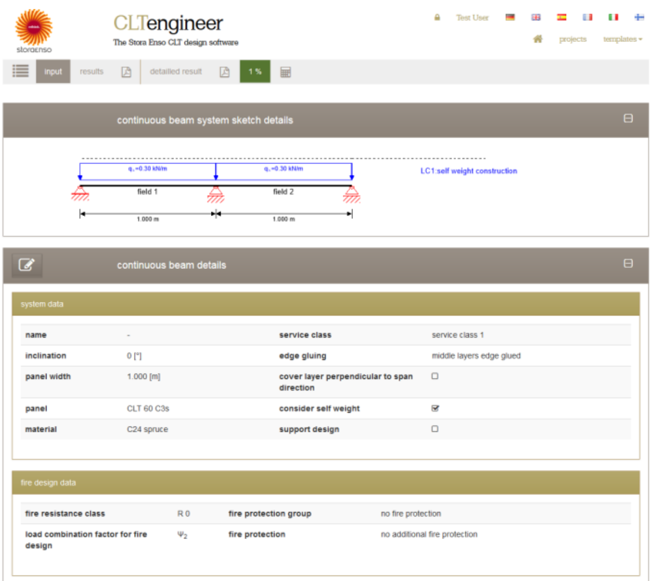
The module CLT panel is made for CLT with loading, perpendicular to the plane of the CLT (floor, roof, etc.). This chapter contains lot of procedures and methods that are applicable to other design modules as well. Therefore it is recommended to read at least this chapter in depth.

7.1.1. Design basics

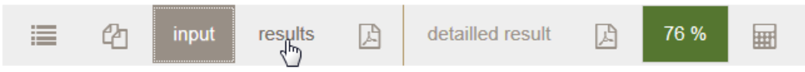
CLT is created by laminating timber lamination battens crosswise (orthogonal) in layers. Therefore a panel has longitudinal layers and cross layers. If a panel is subject to loading out of plane, the crosswise layering will influence the distribution of internal forces and the mechanical properties of a CLT section.
The fact that the cross layers are quite weak in comparison to the longitudinal layers, one cannot ignore these weak layers. Their effect needs to be included in the structural analysis. There are many analysis methods that are applicable to CLT design, such as the Modified Gamma Theory, the Shear Analogy, Timoshenko Theory and Finite Element Analysis [1].
This software module is based on the Timoshenko Theory.
For the Service Limit State (SLS) design, deformations originating from flexural moments and from shear need to be taken into account. The Timoshenko Theory is for CLT panels a solid and good analysis method, which provides reasonable design results, compared to all other methods, within the range of practical construction [2].

7.1.1. Creating an analysis

When clicking “new calculation”, a new analysis page will open, showing a default beam:



This is the input page of the analysis. A switch to the result or detailed result page is possible, by clicking the respective item in the grey menu bar:

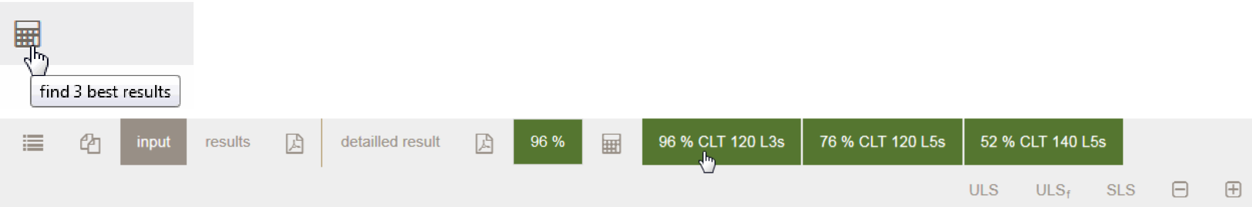


7.1.2. Menu bar

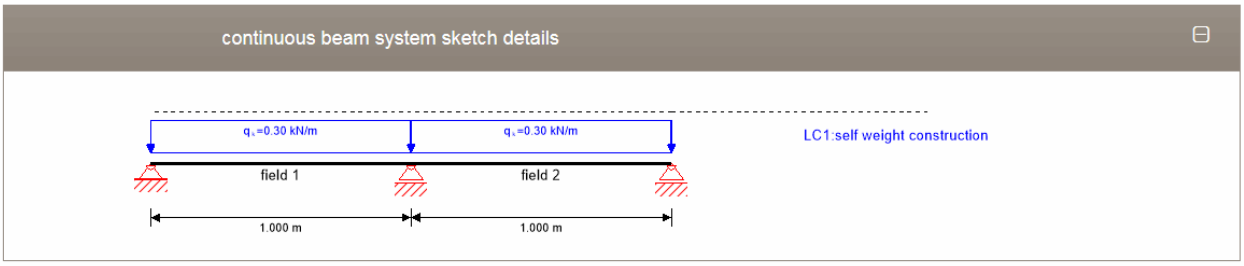
On top of your design pages (either input or results), you will have a grey menu bar.
Clicking here the list icon, gets you back to your list of elements that you have designed for the given project.
Clicking “input” puts you to the input page.
Clicking “results” will give you a short summary of the relevant analysis results.
Clicking “detailed results” will give you a all design results.
Clicking the PDF icon next to “results” will create a pdf-file of the short result summary.
Clicking the PDF icon next to “detailed results” will create a pdf-file of the detailed analysis result.

At any given time in the analysis progress you will find the total design ratio for the given system. If the ratio is below 100%, the system is not overloaded – beyond 100% some adjustments need to be done, in order to make the provide a system that suits the applicable loading and geometry.

Clicking the calculator icon will analyze the 3 best results (CLT panels) for the given system.

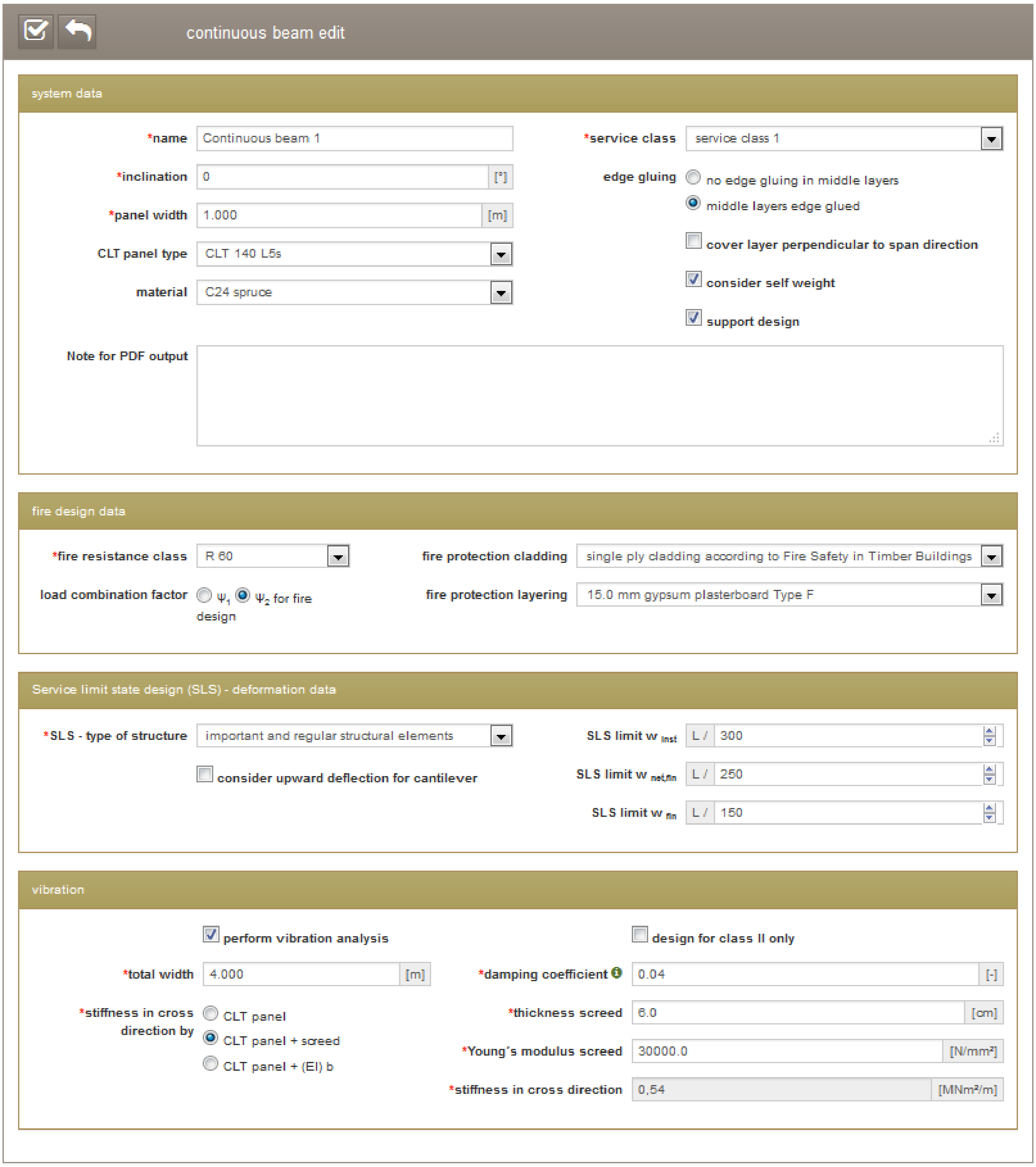


Click the result that you want to adopt for your design.
Once new analysis data in fed into the system and once the data is confirmed, the design ratio will adjust automatically and the system sketch on top of the page will adjust to display the currently given system:



7.1.3. Continuous beam details

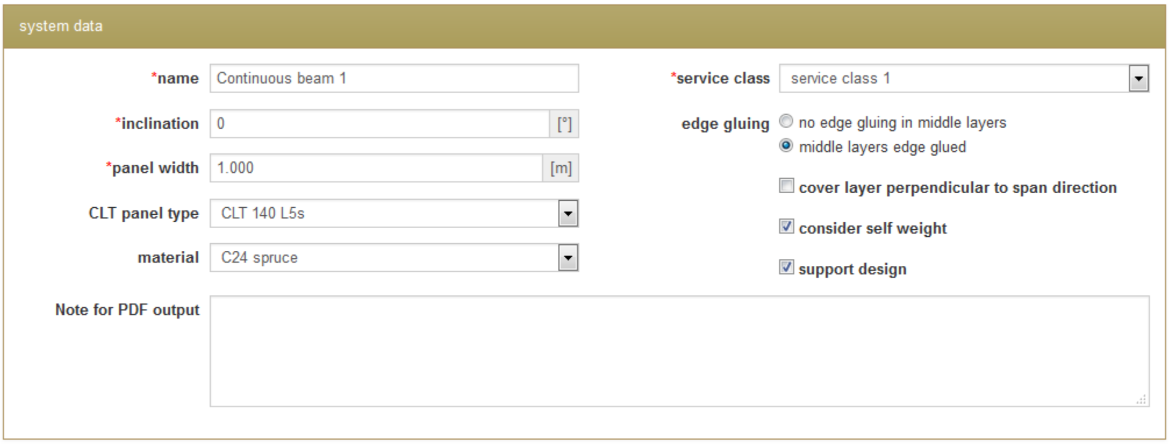
Click the edit button in the “continuous beams details” box in order to edit the data:



Once the data input is finished, click the check mark icon in order to save/confirm your input:

Pressing the enter key will have the same effect. The system is being automatically re-analyzed and the design ratio will be displayed. All results can be viewed at any time in the "results" or "detailed results" page.
Clicking the backwards arrow will cancel the recent input and you will return to the input summary:

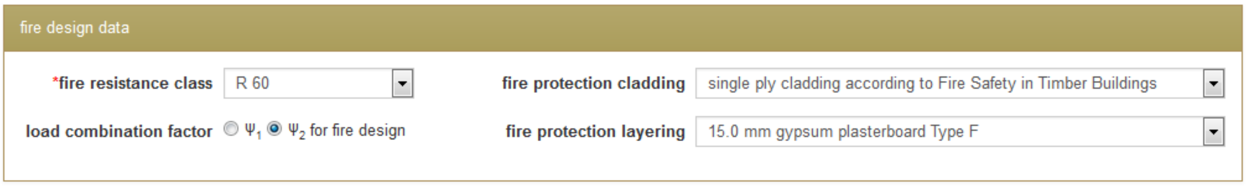
7.1.3.1. System Data:



Name: give your system a name, so you can identify the element in the list of at the project level.
Inclination: for a floor the inclination will be typically 0°. For roofs give the inclination, measured between the CLT plane and the horizontal plane.
Panel width: Usually this will be 1,00 m (by default). If you analyze a CLT panel that is only 0,80 m wide, edit the value accordingly. All loading that will be applied to the system will be entered in kN per linear meter.
CLT panel type: choose a CLT panel type.
Material: pick from the pulldown menu the material of the lamination of the CLT (typically C24 spruce).
Service class: pick the service class (1 or 2 – class 3 is for Stora Enso CLT not permitted).
Edge gluing: choose if the middle layers receive edge gluing, or not. Usually Store Enso CLT has edge gluing in all layers. Cover layers will always be edge-glued. This setting effects the rolling shear strength.
Cover layer perpendicular to span: choose if your cover layers (principal direction of the CLT) are oriented in span direction, or not.
Consider self weight: if the check mark is placed, the self weight of the CLT panel is being taken into account automatically (can be verified in the system sketch on top of the page).
Support design: choose if the support pressure in at the supports shall be verified or not.

7.1.3.2. Fire design data:

Edit the fire design data:



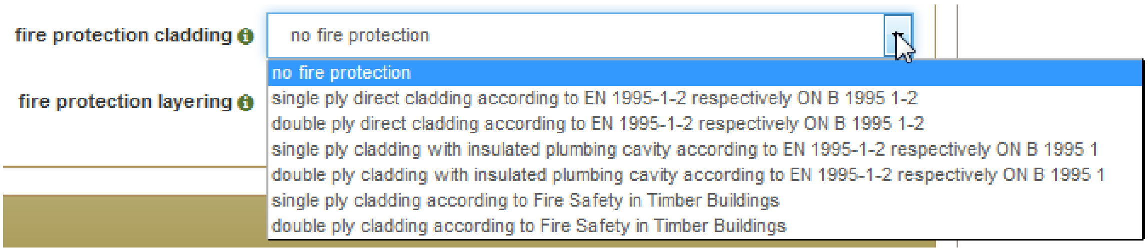
The fire design is being executed according to EN1995-1-2 [3] and it´s national annexes.

It is always assumed that fire is acting on the CLT form the bottom.

As alternative, the user can choose to do the fire design (determination of the residual timber section) according to the guideline Fire Safety In Timber Buildings [4].

First the fire resistance class will be chosen. If R0 is chosen, no fire design will be executed. Generally Eurocode 5 leaves it up to the engineer, if the load combination for fire design is applying a load combination factor of $\psi 2$ or $\psi 1$. The user can choose this here in the input for fire design.

If protective cladding is being attached to the timber structure, this shall be selected in the pull down menu at “fire protection cladding”. The following items can be chosen:

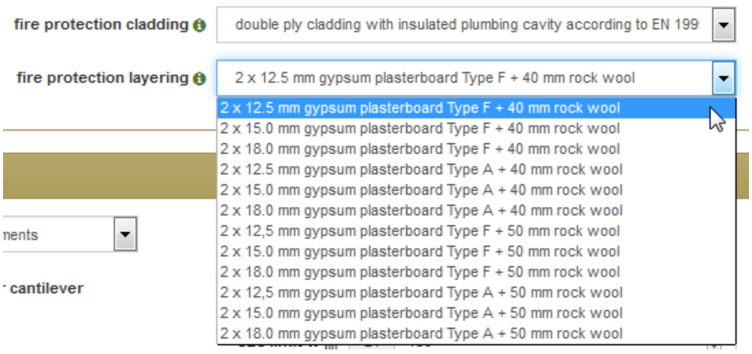


This results in a variation of the following parameters:

- Single or double ply
- Attached directly to the CLT or with an insulated plumbing cavity in between
- Design according to EN1995-1-2 [3] and ON B 1995-1-2 [5] or design according to Fire Safety In Timber Buildings [4]

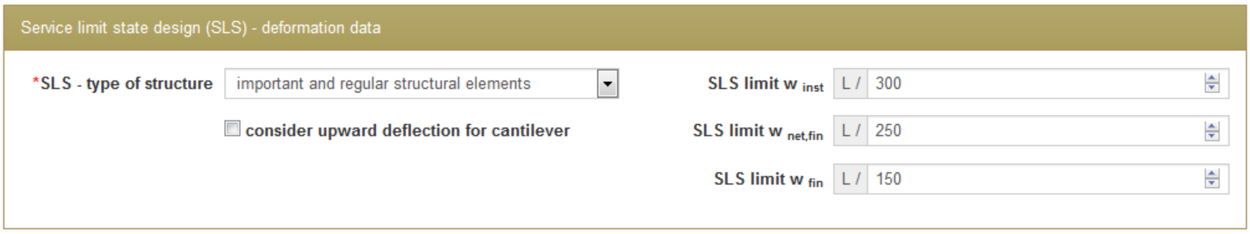
Except for the analysis according to Fire Safety In Timber Buildings, the Austrian national annex is always included in the fire design, because it is more detailed than the national annex of other countries.

The precise layup of the fire protection cladding can be selected in the pull-down menu “fire protection layering”:



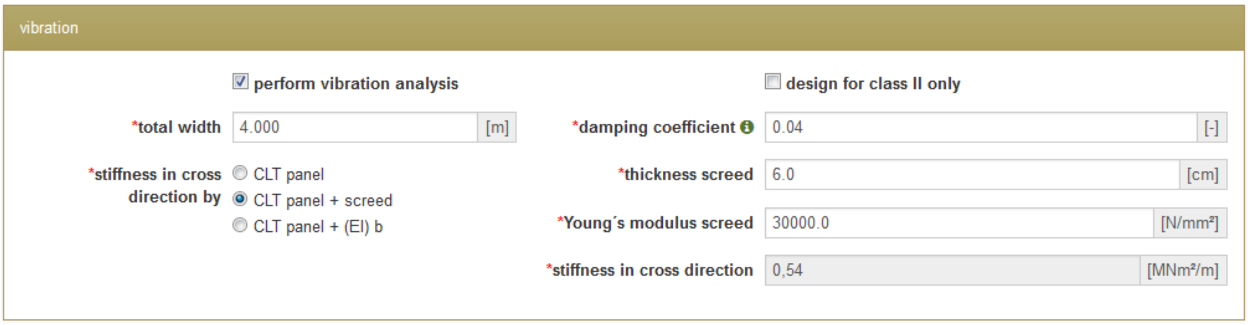
More information about fire design can be found in the document “CLT cross laminated timber – fire protection” by Stora Enso (Andreas Golger) [6]

7.1.3.3. SLS deformation data:



Set the system type. The proposed deflection limits for the SLS design will be displayed. The limits can be edited by the user.

7.1.3.4. Vibration analysis:



If a vibration analysis is required, set the check mark accordingly (perform vibration analysis). This is usually not required for roofs.

Total width: this is the total width of the floor system (usually equal to the width of the room that is hosting the floor. This width is only being used for the vibration analysis and can be different from the system width, entered in “system data” above.

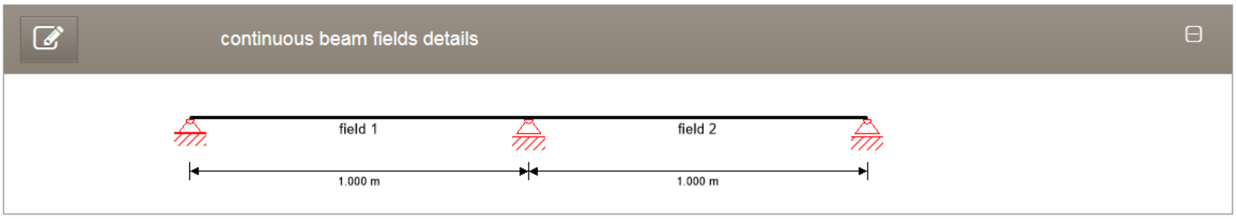
Stiffness in cross direction: pick if the stiffness in cross direction (perpendicular to principal direction) is being contributed by:

- CLT panel (only by the CLT panel´s cross layers)
- CLT panel + screed (by the CLT panel´s cross layers and additionally by the screed on top of the panel) For that you need to insert the Young´s modulus for the screed and the thickness of the screed.
- CLT panel + (EI)b: here the user can define an arbitrary value for the additional stiffness in cross direction. Additional stiffness means the stiffness that is provided by any other element (layer) on top of the CLT or below the CLT.

The stiffness of the CLT is considered in all cases.

Damping coefficient: this value is usually in a range between 1% (0,01) and 5% (0,05). For a CLT floor with a wet screed on top (separated by an insulation layer), 4% (0,04) will be the applicable damping coefficient.

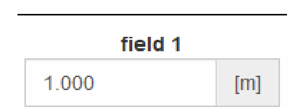
7.1.4. Continuous beam fields details



Click edit in order to edit the geometry of the beam. The default system is a beam with 3 supports (2 fields).

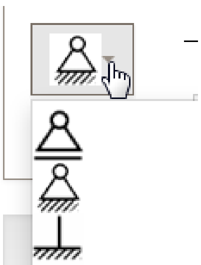
Revise the number of central fields by clicking the “+” or “-“ icon:

Insert the length of the respective spans.



If applicable, insert the length of a cantilever part on the left and/or right end of the beam.

Pick the support type for each support:



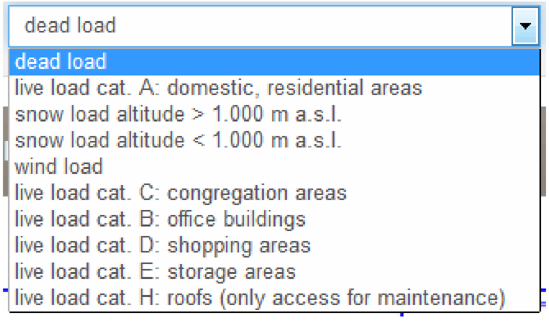
- Pin support, fixed in horizontal direction
- Pin support, free in horizontal direction
- Fixed support (no translatory/rotatory movement possible)

Confirm/save your input by clicking the check mark icon:

7.1.5. Loading

Enter a load case group:

Pick a load case group from the pulldown menu:

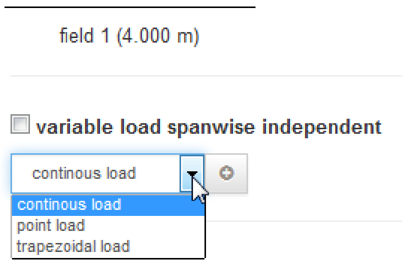


Click the “+” icon in order to create the load case group.

Inserting loads to a load case group

If you would like to add a load to a load case group, click the edit icon at the respective load case group:

Select for each span the load type that shall be applied:



Click the “+” icon in order to add the load to the respective span:

Now the magnitude and geometry data can be edited (for point load and trapezoidal load).

Clicking the check box “apply to all fields” can be activated, if a load shall be applied in the given magnitude to all fields. This makes the input procedure more efficient.

Clicking the field “variable load spanwise independent” is usually applied with variable loads. Variable loads on a continuous beam can or may not be present along the entire system. They might occur only in one span and not in the others. If this effect shall be reflected in the analysis and if the software shall do all possible load combinations, put a check mark in the box and the software will include all the required possible combinations automatically.

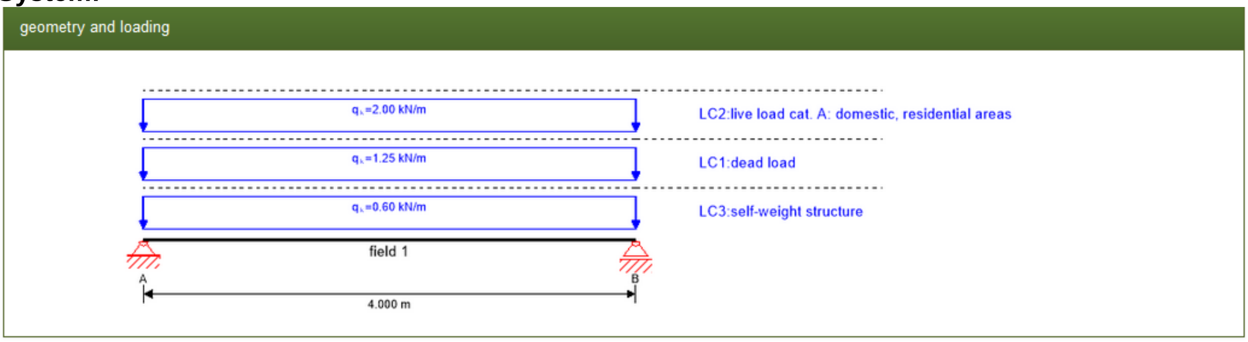
Confirm/save the input by clicking the check mark icon:

By clicking the check mark icon (save/confirm), the software is analyzing the system and results are being generated. These results can be viewed by clicking "results" or "detailed results".

7.1.6. Results

The user has the choice to either see only the design relevant results by clicking "results" or the entire list of results can be displayed by clicking "detailed result".

System:



The geometry with all the loading will be displayed.

Utilization rates:

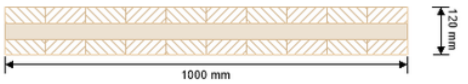
utilisation ratios

global utilization ratio									**96 %**
ULS	28 %	ULS fire	18 %	SLS	63 %	vibration	96 %	support	4 %

All design relevant utilization rates are being displayed. Those higher than 100% are highlighted in red.

Section:

section CLT 120 L3s



layer	thickness	type	material
1	40.0 mm	L	C24 spruce
2	40.0 mm	C	C24 spruce
3	40.0 mm	L	C24 spruce

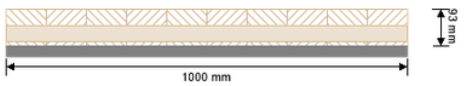
	area	moment of inertia	section modulus
	[mm²]	[mm⁴]	[mm³]
net	80,000	138,666,700	2,311,111
total	120,000	144,000,000	2,400,000

Z	static moment
-60	0
-20	1,600,000
0	1,600,000
20	1,600,000
60	0

The section with all its relevant properties is being displayed.

Section fire design:

section fire CLT 120 L3s



layer	thickness	type	material	$\beta_{0,h}$	$\beta_{1,h}$
1	40.0 mm	L	C24 spruce	0.65	1.3
2	40.0 mm	C	C24 spruce	0.65	1.3
3	13.0 mm	L	C24 spruce	0.65	1.3

fire protection layering: no additional fire protection

k_0	d_0	$d_{char,0,h}$	$d_{ef,h}$
[-]	[mm]	[mm]	[mm]
1	7	20	27

	area	moment of inertia	section modulus
	[mm²]	[mm⁴]	[mm³]
net	53,000	48,904,520	1,051,710
total	93,000	67,029,740	1,441,500

Z	static moment
-36	0
0	659,256
4	652,453
44	652,453
57	0

The section for the fire design is being displayed.

Material values:

material values

material	$f_{m,k}$	$f_{t,0,k}$	$f_{t,90,k}$	$f_{c,0,k}$	$f_{c,90,k}$	$f_{v,k}$	$f_{r,k\ min}$	$E_{0,mean}$	G_{mean}	$G_{r,mean}$
	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]
C24 spruce	24.00	14.00	0.12	21.00	2.50	4.00	1.25	12,500.00	690.00	50.00

Material values used for the analysis are being displayed.

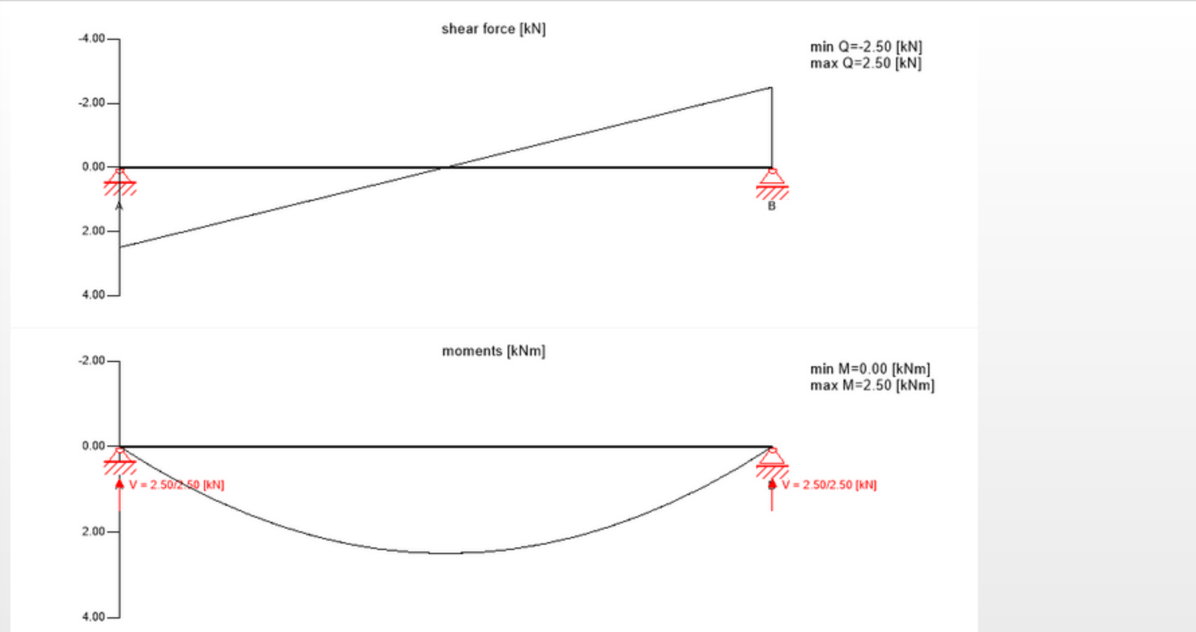
Diagrams of all load groups and all load combinations for the respective design (ULS, SLS, fire) are being displayed:

results of all load groups

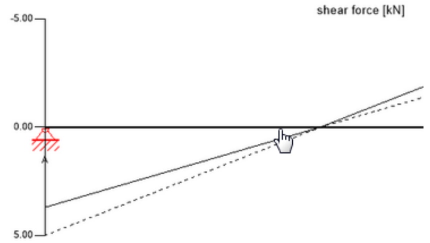
load case category: dead load

continuous load

field	direction	q_k	all members
1	local	1.25	☐



The maximum and minimum values are given in the diagrams. Other values from intermediate points along the beam can be retrieved in a table by clicking the respective curve or diagram:



value for 1.35/1.00 * LC1:dead load + 1.35/1.00 * LC3:self-weight structure

Distanz	min W	max W	min φ	max φ	min Qz	max Qz	min My	max My
0.0	0.0	0.0	-0.003842	-0.002846	3.700	4.995	0.000	0.000
0.2	0.000654	0.000883	-0.003787	-0.002805	3.330	4.496	0.703	0.949
0.4	0.001284	0.001733	-0.003627	-0.002687	2.960	3.996	1.332	1.798
0.6	0.001875	0.002531	-0.003375	-0.0025	2.590	3.497	1.887	2.547
0.8	0.002414	0.003258	-0.003043	-0.002254	2.220	2.997	2.368	3.197
1.0	0.00289	0.003901	-0.002642	-0.001957	1.850	2.498	2.775	3.746
1.2	0.003294	0.004446	-0.002182	-0.001617	1.480	1.998	3.108	4.196
1.4	0.003618	0.004884	-0.001677	-0.001242	1.110	1.499	3.367	4.545
1.6	0.003855	0.005205	-0.001137	-0.000842	0.740	0.999	3.552	4.795
1.8	0.004003	0.005404	-0.000574	-0.000425	0.370	0.499	3.663	4.945
2.0	0.004058	0.005479	0.0	0.0	0.000	0.000	3.700	4.995
2.2	0.00402	0.005427	0.000426	0.000574	-0.500	-0.370	3.663	4.945
2.4	0.003888	0.005249	0.000842	0.001137	-0.999	-0.740	3.552	4.795
2.6	0.003667	0.00495	0.001242	0.001677	-1.499	-1.110	3.367	4.545
2.8	0.003359	0.004535	0.001617	0.002182	-1.998	-1.480	3.108	4.196
3.0	0.002972	0.004012	0.001957	0.002642	-2.498	-1.850	2.775	3.746
3.2	0.002512	0.003392	0.002254	0.003043	-2.997	-2.220	2.368	3.197
3.4	0.00199	0.002686	0.0025	0.003375	-3.497	-2.590	1.887	2.547
3.6	0.001415	0.001911	0.002687	0.003627	-3.996	-2.960	1.332	1.798
3.8	0.000802	0.001083	0.002805	0.003787	-4.496	-3.330	0.703	0.949
4.0	0.0	0.0	0.002846	0.003842	-4.995	-3.700	0.000	0.000

close

7.1.6.1. Results ULS design and ULS fire design:

The design results and all relevant data are being summarized in tables for Ultimate Limit State design and fire design. Shear stress and flexural stress diagrams are given too.

Ultimate limit state (ULS) - design results (34 %)

flexural design

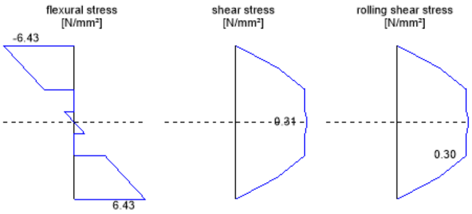
field	$f_{m,k}$	γ_m	k_{mod}	k_{sys}	$f_{m,d}$	M_d	$\sigma_{m,d}$	utilisation
	[N/mm²]	[-]	[-]	[-]	[N/mm²]	[kNm]	[N/mm²]	
1	24.00	1.25	0.80	1.10	16.90	-9.86	3.27	19 %
2	24.00	1.25	0.80	1.10	16.90	-16.57	5.49	32 %
3	24.00	1.25	0.90	1.10	19.01	19.42	6.43	34 %

shear analysis

field	$f_{v,k}$	γ_m	k_{mod}	$f_{v,d}$	V_d	$\tau_{v,d}$	utilisation
	[N/mm²]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]	
1	4.00	1.25	0.80	2.56	17.69	0.17	7 %
2	4.00	1.25	0.80	2.56	18.01	0.17	7 %
3	4.00	1.25	0.90	2.88	31.70	0.31	11 %

rolling shear

field	$f_{r,k}$	γ_m	k_{mod}	$f_{r,d}$	V_d	$\tau_{r,d}$	utilisation
	[N/mm²]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]	
1	1.25	1.25	0.80	0.80	17.69	0.17	21 %
2	1.25	1.25	0.80	0.80	18.01	0.17	21 %
3	1.25	1.25	0.90	0.90	31.70	0.30	33 %



Ultimate limit state (ULS) fire design - results (17 %)

flexural design

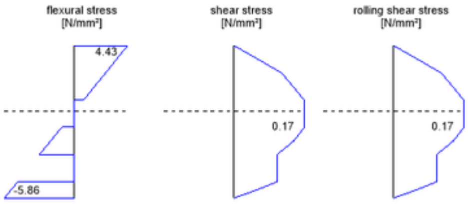
field	$f_{m,k}$	γ_m	k_{mod}	k_{sys}	k_{fi}	$f_{m,d}$	M_d	$\sigma_{m,d}$	utilisation
	[N/mm²]	[-]	[-]	[-]	[-]	[N/mm²]	[kNm]	[N/mm²]	
1	24.00	1.00	1.00	1.10	1.15	30.36	-5.28	3.37	11 %
2	24.00	1.00	1.00	1.10	1.15	30.36	-8.04	5.14	17 %
3	24.00	1.00	1.00	1.10	1.15	30.36	-8.04	5.14	17 %

shear analysis

field	$f_{v,k}$	γ_m	k_{mod}	$f_{v,d}$	V_d	$\tau_{v,d}$	utilisation
	[N/mm²]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]	
1	4.00	1.00	1.00	4.60	9.78	0.13	3 %
2	4.00	1.00	1.00	4.60	9.39	0.12	3 %
3	4.00	1.00	1.00	4.60	13.01	0.17	4 %

rolling shear

field	$f_{r,k}$	γ_m	k_{mod}	$f_{r,d}$	V_d	$\tau_{r,d}$	utilisation
	[N/mm²]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]	
1	1.25	1.00	1.00	1.44	9.78	0.13	9 %
2	1.25	1.00	1.00	1.44	9.39	0.12	8 %
3	1.25	1.00	1.00	1.44	13.01	0.17	12 %



7.1.6.2. Results support bearing pressure

supportdesign (6 %)

support	support type	support width	net area	k_{mod}	γ_m	$k_{c,90}$	$f_{c,90,k}$	$f_{c,90,d}$	V_{max}	V_{min}	$\sigma_{c,90,d}$	combination	utilisation
		[mm]	[cm²]	[-]	[-]	[-]	[N/mm²]	[N/mm²]	[kN]	[kN]	[N/mm²]		
A	rigid plate	200	2300.00	0.80	1.25	1.40	2.50	2.24	12.73	0.00	0.06	LCO2	2 %
B	CLT 120 C5s	120	1800.00	0.80	1.25	1.90	2.50	3.04	32.77	0.00	0.18	LCO2	6 %
C	rigid plate	240	3000.00	0.80	1.25	1.90	2.50	3.04	45.76	0.00	0.15	LCO2	5 %
D	CLT 120 C5s	120	1500.00	0.90	1.25	1.40	2.50	2.52	22.97	0.00	0.15	LCO3	6 %

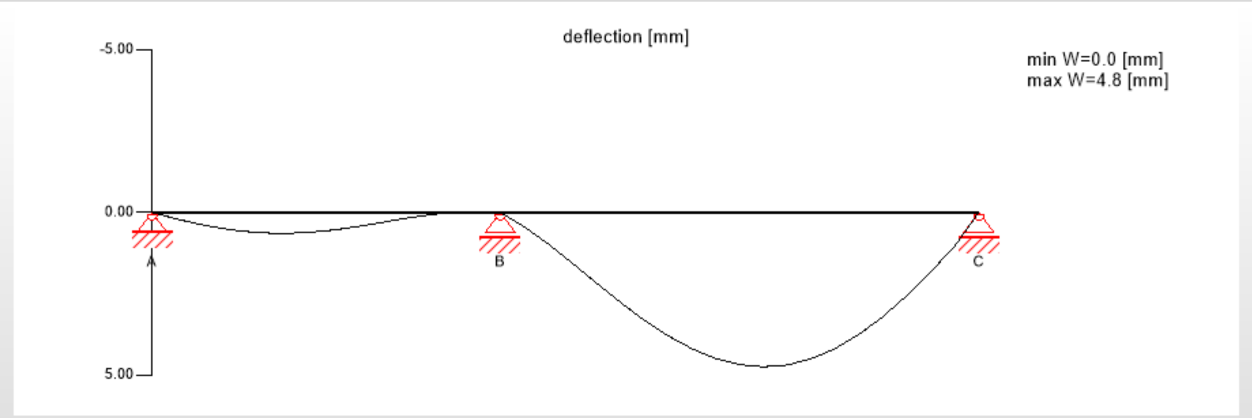
The bearing pressure analysis is being performed for each support (if chosen on the input screen).

7.1.6.3. Results SLS design - deformation

All deflection curves for the different load combinations are being displayed:

characteristic combinations

combination: 1.00/1.00 * LC1:dead load + 1.00/1.00 * LC2:self-weight structure



Maximum and minimum values are given next to the curve. Intermediate values are displayed in a table, when clicking the curve.

The design results of the Service Limit State (SLS) design are displayed in a table, in a similar way, as for the ULS design:

Service limit state design (SLS) - design results (70 %)

initial deflection [w_{char}]

field	K_{def}	L_{ref}	limit	$w_{calc.}$	utilisation
		[m]	[mm]	[mm]	
1	0.8	3.3	L/300 = 11.2	3.5	31 %
2	0.8	3.4	L/300 = 11.4	1.5	13 %
3	0.8	4.0	L/300 = 13.3	9.4	70 %

final deflection [$w_{char}+w_{q.p.}*K_{def}$]

field	K_{def}	L_{ref}	limit	$w_{calc.}$	utilisation
		[m]	[mm]	[mm]	
1	0.8	3.3	L/150 = 22.3	5.5	24 %
2	0.8	3.4	L/150 = 22.8	2.1	9 %
3	0.8	4.0	L/150 = 26.7	13.5	51 %

net final deflection [$w_{q.p.}*(1+K_{def})$]

field	K_{def}	L_{ref}	limit	$w_{calc.}$	utilisation
		[m]	[mm]	[mm]	
1	0.8	3.3	L/250 = 13.4	4.4	33 %
2	0.8	3.4	L/250 = 13.7	1.4	10 %
3	0.8	4.0	L/250 = 16.0	9.3	58 %

Note: for each span a reference length is given. This length is the base for the deflection limits (e.g.: L/150). In a deflection limit L/150, the reference length L_{ref} is being divided by 150. In all applied design standards, the deflection limits of cantilevers are double of those for spans, with supports on both ends. Therefore the reference length of cantilevers is the double of the system length of the respective cantilever.

Depending on the national annex of Eurocode 5, different design verifications might be required. Usually the initial deflection, the net final deflection and the final deflection need to be checked.

Using the Austrian national annex, the deflection parameters shall be explained:

W_{inst}

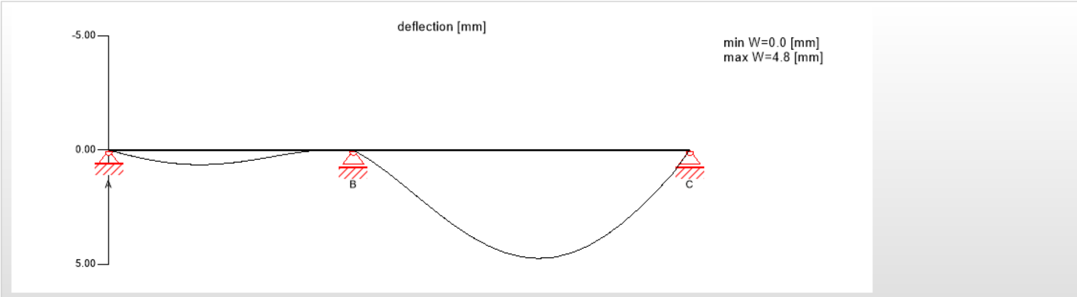
$$w_{inst} = \underbrace{\sum_{j\geq 1} w_{inst,G,j} + w_{inst,Q1} + \sum_{i>1} \psi_{0,i} \cdot w_{inst,Q,i}}_{characteristic\ load\ combination}$$

See equation NA.7.2-E2 in the Austrian national annex to EN1995-1-1 [7].

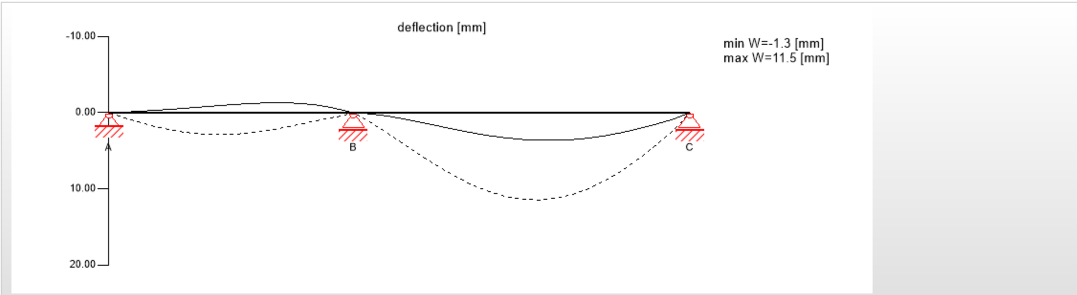
Note: the equation on the left is the applicable for Austria. In other countries this could be different (e.g.: France does not include $W_{inst,G}$ in the instant deflecton.)

characteristic combinations

combination: 1.00/1.00 * LC1:dead load + 1.00/1.00 * LC2:self-weight structure



combination: 1.00/1.00 * LC1:dead load + 1.00/1.00 * LC2:self-weight structure + 1.00/0.00 * LC3:live load cat. A: domestic, residential areas



initial deflection [w_{char}]

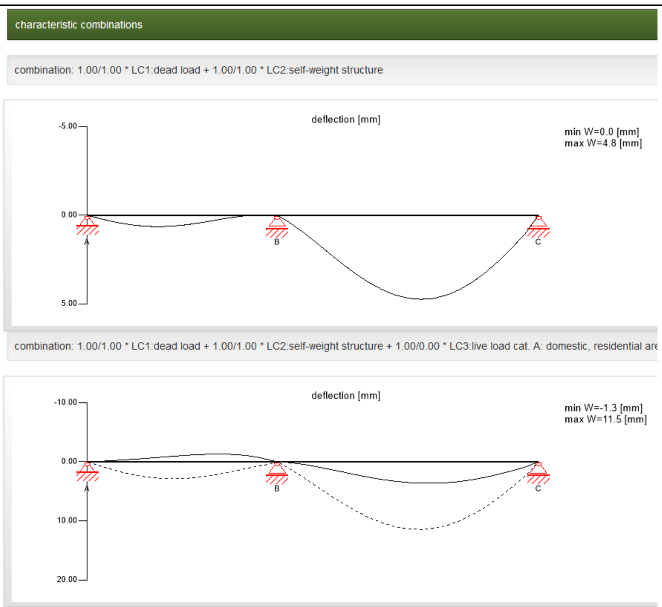
field	k_{def}	L_{ref}	limit	$w_{calc.}$	utilisation
		[m]	[mm]	[mm]	
1	0.8	4.0	L/300 = 13.3	2.9	22 %
2	0.8	5.5	L/300 = 18.3	11.5	63 %

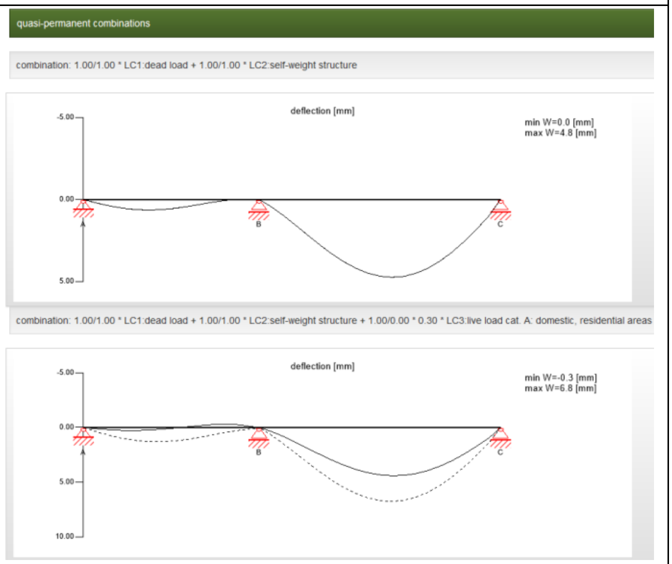
$$w_{inst} = \underbrace{\sum_{j\geq 1} w_{inst,G,j} + w_{inst,Q1} + \sum_{i>1} \psi_{0,i} \cdot w_{inst,Q,i}}_{characteristic\ load\ combination} = \underbrace{11{,}5}_{characteristic\ load\ combination} = 11{,}5\ mm$$

$\mathbf{W_{fin}}$

$$w_{fin} = \underbrace{w_{inst}}_{characteristic\ load\ combination} + \underbrace{w_{creep}}_{quasi\ permanent\ load\ combination}$$

See equation NA.7.2-E1 in the Austrian national annex to EN1995-1-1 [7].





final deflection [$w_{char}+w_{q.p.}\cdot k_{def}$]

field	K_{def}	L_{ref}	limit	$w_{calc.}$	utilisation
		[m]	[mm]	[mm]	
1	0.8	4.0	L/150 = 26.7	3.9	15 %
2	0.8	5.5	L/150 = 36.7	16.9	46 %

$$w_{fin} = w_{inst} + w_{creep} = \underbrace{11{,}5}_{characteristic\ load\ combination} + \underbrace{6{,}8 \cdot \overbrace{0{,}8}^{k_{def}}}_{quasi\ permanent\ load\ combination} = 16{,}94\ mm$$

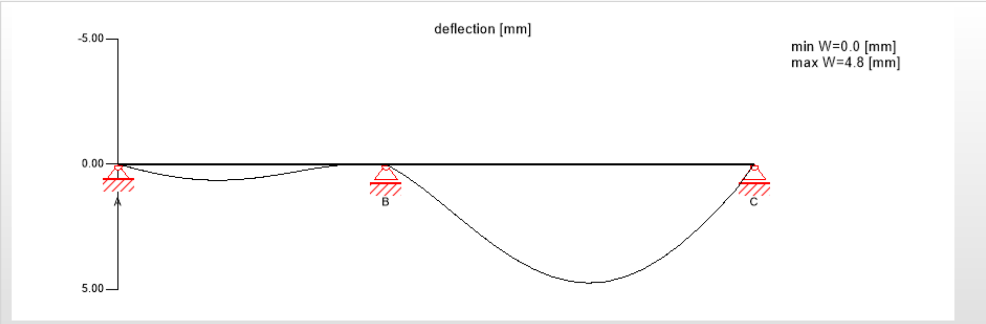
$w_{net,fin}$

$$w_{net,fin} = \underbrace{w_{inst,2} + w_{creep}}_{quasi\ permanent\ load\ combination} - \underbrace{w_c}_{camber} = \left[\sum_{j\geq 1} w_{inst,G,j} + \sum_{i\geq 1} \psi_{2,i} \cdot w_{inst,Q,i}\right] \cdot (1 + k_{def}) - w_c$$

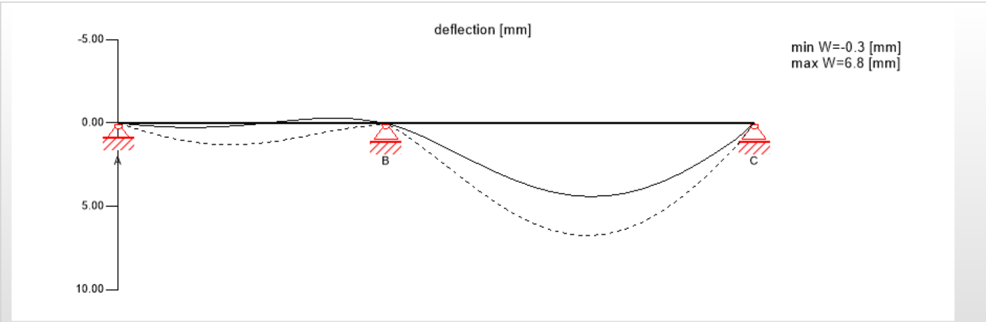
See equation NA.7.2 in the Austrian national annex to EN1995-1-1 [7].

quasi-permanent combinations

combination: 1.00/1.00 * LC1:dead load + 1.00/1.00 * LC2:self-weight structure



combination: 1.00/1.00 * LC1:dead load + 1.00/1.00 * LC2:self-weight structure + 1.00/0.00 * 0.30 * LC3:live load cat. A: domestic, residential areas



net final deflection [$w_{q.p.}$*(1+k_{def})]

field	K_{def}	L_{ref}	limit	$w_{calc.}$	utilisation
		[m]	[mm]	[mm]	
1	0.8	4.0	L/250 = 16.0	2.3	15 %
2	0.8	5.5	L/250 = 22.0	12.2	55 %

$$w_{net,fin} = \underbrace{w_{inst,2} + w_{creep}}_{quasi\ permanent\ load\ combination} - \underbrace{w_c}_{camber} = \underbrace{\left[\sum_{j\geq 1} w_{inst,G,j} + \sum_{i\geq 1} \psi_{2,i} \cdot w_{inst,Q,i}\right]}_{6{,}8\ mm} \cdot \left(1 + \underbrace{k_{def}}_{0{,}8}\right) - \underbrace{w_c}_{0} = 12{,}24\ mm$$

SLS design and the national specifications

	SLS – deformation – deflection of beams	Note
Austria	$w_{inst} = \underbrace{\sum_{j\geq1} w_{inst,G,j} + w_{inst,Q1} + \sum_{i>1} \psi_{0,i} \cdot w_{inst,Q,i}}_{characteristic\ load\ combination}$	
	$w_{fin} = \underbrace{\sum_{j\geq1} w_{inst,G,j} + w_{inst,Q1} + \sum_{i>1} \psi_{0,i} \cdot w_{inst,Q,i}}_{w_{inst}\ characteristic\ load\ combination} + \underbrace{\left[\sum_{j\geq1} w_{inst,G,j} + \sum_{i\geq1} \psi_{2,i} \cdot w_{inst,Q,i}\right] \cdot k_{def}}_{w_{creep}\ quasi\ permanent\ load\ combination}$	
	$w_{net,fin} = \underbrace{w_{inst,2} + w_{creep}}_{quasi\ permanent\ load\ combination} - \underbrace{w_c}_{camber} = \left[\sum_{j\geq1} w_{inst,G,j} + \sum_{i\geq1} \psi_{2,i} \cdot w_{inst,Q,i}\right] \cdot (1 + k_{def}) - w_c$	
Finland	$w_{inst} = \underbrace{\sum_{j\geq1} w_{inst,G,j} + w_{inst,Q1} + \sum_{i>1} \psi_{0,i} \cdot w_{inst,Q,i}}_{characteristic\ load\ combination}$	
	$w_{fin} = \underbrace{\sum_{j\geq1} w_{inst,G,j} + w_{inst,Q1} + \sum_{i>1} \psi_{0,i} \cdot w_{inst,Q,i}}_{w_{inst}\ characteristic\ load\ combination} + \underbrace{\left[\sum_{j\geq1} w_{inst,G,j} + \sum_{i\geq1} \psi_{2,i} \cdot w_{inst,Q,i}\right] \cdot k_{def}}_{w_{creep}\ quasi\ permanent\ load\ combination}$	
	$w_{net,fin} = \underbrace{w_{inst,2} + w_{creep}}_{quasi\ permanent\ load\ combination} - \underbrace{w_c}_{camber} = \left[\sum_{j\geq1} w_{inst,G,j} + \sum_{i\geq1} \psi_{2,i} \cdot w_{inst,Q,i}\right] \cdot (1 + k_{def}) - w_c$	
France	$w_{inst} = \underbrace{w_{inst,Q1} + \sum_{i>1} \psi_{0,i} \cdot w_{inst,Q,i}}_{characteristic\ load\ combination}$	
	$w_{fin} = \underbrace{w_{inst,Q1} + \sum_{i>1} \psi_{0,i} \cdot w_{inst,Q,i}}_{w_{inst}\ characteristic\ load\ combination} + \underbrace{\left[\sum_{j\geq1} w_{inst,G,j} + \sum_{i\geq1} \psi_{2,i} \cdot w_{inst,Q,i}\right] \cdot k_{def}}_{w_{creep}\ quasi\ permanent\ load\ combination}$	
	$w_{net,fin} = \underbrace{w_{inst,2} + w_{creep}}_{quasi\ permanent\ load\ combination} - \underbrace{w_c}_{camber} = \left[\sum_{j\geq1} w_{inst,G,j} + \sum_{i\geq1} \psi_{2,i} \cdot w_{inst,Q,i}\right] \cdot (1 + k_{def}) - w_c$	
Germany	$w_{inst} = \underbrace{\sum_{j\geq1} w_{inst,G,j} + w_{inst,Q1} + \sum_{i>1} \psi_{0,i} \cdot w_{inst,Q,i}}_{characteristic\ load\ combination}$	
	$w_{fin} = \underbrace{\sum_{j\geq1} w_{inst,G,j} + w_{inst,Q1} + \sum_{i>1} \psi_{0,i} \cdot w_{inst,Q,i}}_{w_{inst}\ characteristic\ load\ combination} + \underbrace{\left[\sum_{j\geq1} w_{inst,G,j} + \sum_{i\geq1} \psi_{2,i} \cdot w_{inst,Q,i}\right] \cdot k_{def}}_{w_{creep}\ quasi\ permanent\ load\ combination}$	
	$w_{net,fin} = \underbrace{w_{inst,2} + w_{creep}}_{quasi\ permanent\ load\ combination} - \underbrace{w_c}_{camber} = \left[\sum_{j\geq1} w_{inst,G,j} + \sum_{i\geq1} \psi_{2,i} \cdot w_{inst,Q,i}\right] \cdot (1 + k_{def}) - w_c$	

	SLS – deformation – deflection of beams	Note
Italy	$w_{inst} = \underbrace{\sum_{j\ge1} w_{inst,G,j} + w_{inst,Q1} + \sum_{i>1} \psi_{0,i}\cdot w_{inst,Q,i}}_{characteristic\ load\ combination}$	
	$w_{fin} = \underbrace{\sum_{j\ge1} w_{inst,G,j} + w_{inst,Q1} + \sum_{i>1}\psi_{0,i}\cdot w_{inst,Q,i}}_{w_{inst}\ characteristic\ load\ combination} + \underbrace{\left[\sum_{j\ge1} w_{inst,G,j} + \sum_{i\ge1}\psi_{2,i}\cdot w_{inst,Q,i}\right]\cdot k_{def}}_{w_{creep}\ quasi\ permanent\ load\ combination}$	
	$w_{net,fin} = \underbrace{w_{inst,2} + w_{creep}}_{quasi\ permanent\ load\ combination} - \underbrace{w_c}_{camber} = \left[\sum_{j\ge1} w_{inst,G,j} + \sum_{i\ge1}\psi_{2,i}\cdot w_{inst,Q,i}\right]\cdot(1+k_{def}) - w_c$	
Spain	$w_{inst} = \underbrace{w_{inst,Q1} + \sum_{i>1} \psi_{0,i}\cdot w_{inst,Q,i}}_{characteristic\ load\ combination}$	
	$w_{fin} = w_{act} = \underbrace{w_{inst,Q1} + \sum_{i>1}\psi_{0,i}\cdot w_{inst,Q,i}}_{w_{inst}\ characteristic\ load\ combination} + \underbrace{\left[\sum_{j\ge1} w_{inst,G,j} + \sum_{i\ge1}\psi_{2,i}\cdot w_{inst,Q,i}\right]\cdot k_{def}}_{w_{creep}\ quasi\ permanent\ load\ combination}$	1
	$w_{net,fin} = \underbrace{w_{inst,2} + w_{creep}}_{quasi\ permanent\ load\ combination} - \underbrace{w_c}_{camber} = \left[\sum_{j\ge1} w_{inst,G,j} + \sum_{i\ge1}\psi_{2,i}\cdot w_{inst,Q,i}\right]\cdot(1+k_{def}) - w_c$	
United Kingdom	$w_{inst} = \underbrace{\sum_{j\ge1} w_{inst,G,j} + w_{inst,Q1} + \sum_{i>1} \psi_{0,i}\cdot w_{inst,Q,i}}_{characteristic\ load\ combination}$	
	$w_{fin} = \underbrace{\sum_{j\ge1} w_{inst,G,j} + w_{inst,Q1} + \sum_{i>1}\psi_{0,i}\cdot w_{inst,Q,i}}_{w_{inst}\ characteristic\ load\ combination} + \underbrace{\left[\sum_{j\ge1} w_{inst,G,j} + \sum_{i\ge1}\psi_{2,i}\cdot w_{inst,Q,i}\right]\cdot k_{def}}_{w_{creep}\ quasi\ permanent\ load\ combination}$	
	$w_{net,fin} = \underbrace{w_{inst,2} + w_{creep}}_{quasi\ permanent\ load\ combination} - \underbrace{w_c}_{camber} = \left[\sum_{j\ge1} w_{inst,G,j} + \sum_{i\ge1}\psi_{2,i}\cdot w_{inst,Q,i}\right]\cdot(1+k_{def}) - w_c$	

<table>
<tr><th></th><th colspan="2">SLS – deformation – deflection of beams</th><th>Note</th></tr>
<tr><td rowspan="3">Australia</td><td>$w_{inst} = \underbrace{w_{inst}}_{characteristic\ load\ combination}$</td><td rowspan="3">Char. Load combination
$\sum G + \sum W$
$\sum G + \psi_2 \cdot \sum Q$
$\sum G + \psi_1 \cdot \sum Q + \sum W$
$\sum G + \psi_1 \cdot \sum Q + \sum E$
$\sum G + \psi_1 \cdot \sum Q + \sum S$
Quasi permanent load combination
$\sum G + \psi_1 \cdot \sum Q$
$\sum G + \psi_1 \cdot \sum Q + \sum S$</td><td></td></tr>
<tr><td>$w_{fin} = \underbrace{w_{inst}}_{characteristic\ load\ combination} + \underbrace{w_{creep}}_{quasi\ permanent\ load\ combination}$</td><td></td></tr>
<tr><td>$w_{net,fin} = \underbrace{w_{inst,2} + w_{creep}}_{quasi\ permanent\ load\ combination} - \underbrace{w_c}_{camber}$</td><td></td></tr>
<tr><td rowspan="3">Switzerland</td><td colspan="2"></td><td></td></tr>
<tr><td colspan="2"></td><td></td></tr>
<tr><td colspan="2"></td><td></td></tr>
<tr><td colspan="4">Notes:
1.) The w_{fin} in the software is actually referring to the w_{act} in UNE EN 1995-1-1 NA [8]</td></tr>
</table>

7.1.6.4. Results SLS design - vibration

vibration analysis (76 %)

analysis					
criterion	**calc.**	**class I**	**class II**	**class I**	**class II**
frequency criterion	17.524 [Hz]	8.000 [Hz]	6.000 [Hz]	46 %	34 %
acceleration criterion	0.000 [m/s²]	0.050 [m/s²]	0.100 [m/s²]	1 %	0 %
stiffness criterion	0.190 [mm]	0.250 [mm]	0.500 [mm]	76 %	38 %

general	
total mass	17.691 [t]
tributary width	2.660 [m]
stiffness longitudinal direction	2641.666 [kNm²]
stiffness cross direction	756.667 [kNm²]
k_q	1.171 [-]
modal damping	4.00 %
α	0.001
man weight	700 [N]
modal mass	8845.736 [kg]

The vibration analysis results are given in a table as shown in the figure above. This software was created for many countries and their applicable standards. Unfortunately the vibration design is still very poorly described in Eurocode 5 (EN 1995-1-1) [8]. The Austrian national annex [9] was just recently (Nov. 2014) issued and includes at this point the most extensive rules related to the vibration analysis. Therefore, for each country the applicable national annex was implemented in the software for the vibration design. For all items that were not addressed in the respective national annex, the Austrian national annex was applied.

In the Austrian national annex, 2 vibration classes are being introduced: class I and class II. This is a similar approach as by Hamm & Richter [5]. In that document Hamm & Richter refer to floors that extend across more than just one unit (room) or floors that only serve one unit (room). Obviously for floors that serve more units at the time, stricter requirements apply. The same idea was adopted in the national annex of Eurocode 5. Here Eurocode 5 refers to a class I (more strict requirements) and class II.

This idea was now also implemented in the software for countries that do not have this differentiation. It is finally up to the engineer and software user to decide, if class I or class II shall be design relevant.

7.1.6.5. Results characteristic support reactions

support reaction

load case category	k_{mod}	**A**	**B**	**C**	**D**
		[kN]	[kN]	[kN]	[kN]
self-weight structure	0.6	0.95	2.50	2.94	1.14
dead load	0.6	4.91	12.84	15.12	5.88
live load cat. A: domestic, residential areas	0.8	3.21	8.04	14.25	6.99
snow load altitude < 1.000 m a.s.l.	0.9	0.16	0.00	6.15	4.02

The table above shows the characteristic maximum support reactions that can be used as input for the structural design of other elements, receiving load form the here analyzed system.

At the end of each design result a list is listing all reference documents that the given analysis is based on.

reference documents for this analysis

valid for Austria

English title
EN 338
EN 1995-1-1
ETA-14/0349
Expertise Rolling shear, J. Blass
EN 1995-1-2
Technical expertise 122/2011/02: analysis of load bearing capacity and separation performance of CLT elements
Technical expertise 2434/2012 - BB: failure time tf of gypsum fire boards (GKF) according to ON B 3410
EN 1990
ÖNorm B 1995-1-1 NA
ÖNorm B 1995-1-2 NA
Fire safety in timber buildings - technical guildeline for Europe
National specifications concerning ÖNORM EN 1995-1-2, national comments and national supplements, chapter 12

7.2. Continuous beam – solid timber / glulam / LVL

This module will design a wood beam with a **rectangular section**. Wood can be solid timber, glulaminated timber or LVL. The module is set-up in a similar way as the continuous beam – CLT panel module (see chapter 7.1).

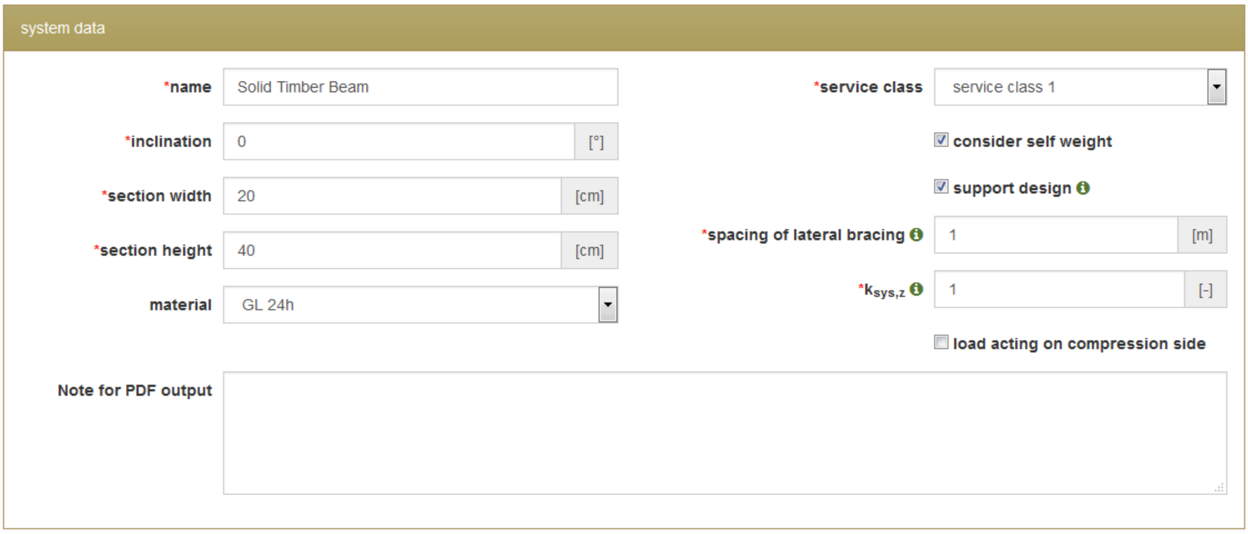
7.2.1. Design basics

The analysis in this design module is based on Eurocode 5 [8] and it´s national annexes.

7.2.2. Continuous beam details

Click the edit button in the “continuous beams details” box in order to edit the data:

7.2.2.1. System Data:



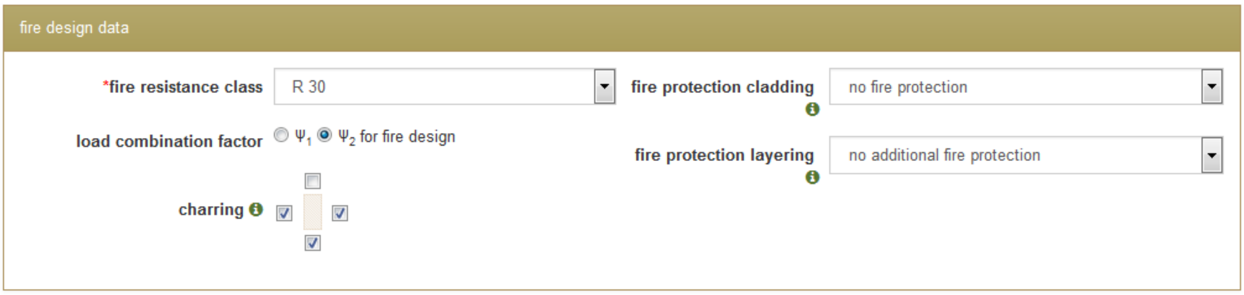
Spacing of lateral bracing: insert the spacing at which the beam is held in lateral direction. This value is entering the lateral torsional buckling design. The spacing could be for example the spacing of purlins or rafters that are supported by the beam. If a panels or sheathing is being fastened at the top flange of the beam, then put 0 as spacing, meaning the beam is continuously held.

$k_{sys,z}$: is the system factor for the given beam section in z-direction (see EN1995-1-1_6.6) [8]. Assuming a glulam beam is being picked, then the lamination is usually layered in vertical direction. Therefore no system factor can apply for bending about the Y-axis. For bending about the Z-axis, the tension face of the beam (lateral surface) is divided in all the lamination layers and therefore a system factor can be applied for bending about the Z-axis.

The feature **“load action on the compression side”** relates to the effective length of the beam for the lateral torsional buckling analysis, according to EN1995-1-1_6.3.3(3).

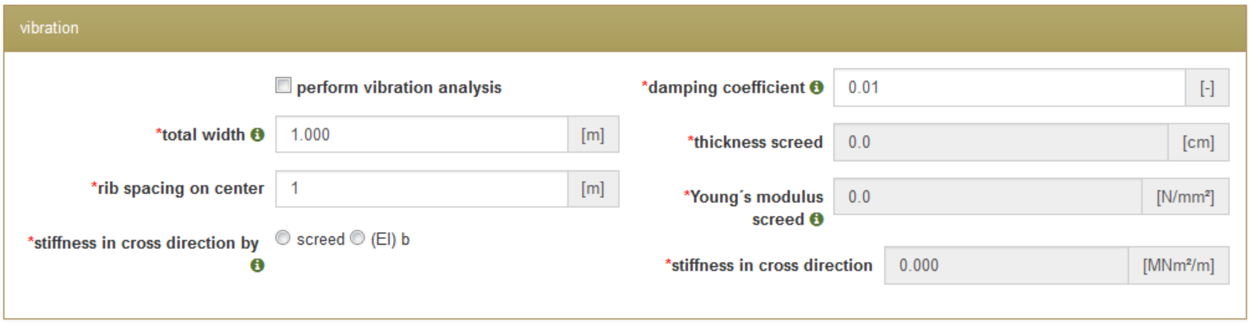
7.2.2.2. Fire design data:

Edit the fire design data:



Choose which faces of the beam are exposed to fire at the “charring” selection, by putting check marks next to the relevant face.

7.2.2.3. Vibration analysis:



If a vibration analysis is required, set the check mark accordingly (perform vibration analysis). This is usually not required for roofs.

Total width: this is the total width of the floor system (usually equal to the width of the room that is hosting the floor. This width is only being used for the vibration analysis and can be different from the system width, entered in “system data” above.

Stiffness in cross direction: pick if the stiffness in cross direction (perpendicular to principal direction) is being contributed by:

- screed (by the screed on top of the panel)
  For that you need to insert the Young´s modulus for the screed and the thickness of the screed.
- (EI)b: here the user can define an arbitrary value for the stiffness in cross direction. Stiffness means the stiffness that is provided by any other element (layer) on top of the beam.

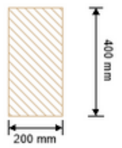
Damping coefficient: this value is usually in a range between 1% (0,01) and 5% (0,05). For a floor with joists and a wet screed on top of a sheathing (separated by an insulation layer), 3% (0,03) will be an appropriate damping coefficient. For lighter versions, the damping will be less (about 2%). [10]

7.2.3. Results

The user has the choice to either see only the design relevant results by clicking “results” or the entire list of results can be displayed by clicking “detailed result”.

Section:

section wooden beam 20/40

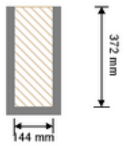


section width	section height	area	Iy	Iz
[cm]	[cm]	[mm²]	[mm⁴]	[mm⁴]
20	40	80,000	1,066,667,000	266,666,700

The section with all its relevant properties is being displayed.

Section fire design:

section fire wooden beam 20/40



fire protection layering: no additional fire protection

section width	section height	area	Iy	Iz
[cm]	[cm]	[mm²]	[mm⁴]	[mm⁴]
14.4	37.2	53,568	617,746,200	92,565,500

k_0	d_0	β_n	$d_{ef,v}$	$d_{ef,h}$	section width	section height
[-]	[mm]	[mm/min]	[mm]	[mm]	[cm]	[cm]
1	7	0.7	6	3	14.4	37.2

The section for the fire design is being displayed.

Material values:

material values

material	$f_{m,k}$	$f_{t,0,k}$	$f_{t,90,k}$	$f_{c,0,k}$	$f_{c,90,k}$	$f_{v,k}$	$f_{r,k\ min}$	$E_{0,mean}$	G_{mean}	$E_{0,5}$
	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]
GL 24h	24.00	19.20	0.50	24.00	2.50	2.50	1.20	11,500.00	650.00	9,600.00

Material values used for the analysis are being displayed.

7.2.3.1. ULS design results

The design results and all relevant data are being summarized in tables for Ultimate Limit State design

Ultimate limit state (ULS) - design results (32 %)

flexural design

field	dist.	$f_{m,k}$	$f_{c,k}$	$f_{t,k}$	γ_m	k_{mod}	$k_{sys,y}$	$f_{m,y,d}$	$f_{c,d}$	$f_{t,d}$	$M_{y,d}$	$M_{z,d}$	$N_{c,d}$	$N_{t,d}$	$\sigma_{m,y,d}$	$\sigma_{m,z,d}$	$\sigma_{c,d}$	$\sigma_{t,d}$	utilisation
	[m]	[N/mm²]	[N/mm²]	[N/mm²]	[-]	[-]	[-]	[N/mm²]	[N/mm²]	[N/mm²]	[kNm]	[kNm]	[kN]	[kN]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	
1	3.0	24.00	24.00	19.20	1.25	0.60	1.00	12.00	11.52	10.14	-15.80	0.00	0.00	0.00	2.96	0.00	0.00	0.00	25 %
2	0.0	24.00	24.00	19.20	1.25	0.60	1.00	12.00	11.52	10.14	-15.80	0.00	0.00	0.00	2.96	0.00	0.00	0.00	25 %

shear analysis

field	dist.	$f_{v,k}$	γ_m	k_{mod}	$f_{v,d}$	V_d	$\tau_{v,d}$	utilisation
	[m]	[N/mm²]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]	
1	2.6	2.50	1.25	0.60	1.20	20.71	0.39	32 %
2	0.4	2.50	1.25	0.60	1.20	20.71	0.39	32 %

buckling design

field	dist.	$f_{m,k}$	$f_{c,k}$	γ_m	k_{mod}	$k_{sys,y}$	$k_{sys,z}$	$l_{k,y}$	$l_{k,z}$	λ_y	λ_z	$\lambda_{rel,y}$	$\lambda_{rel,z}$	β_c
	[m]	[N/mm²]	[N/mm²]	[-]	[-]	[-]	[-]	[m]	[m]	[-]	[-]	[-]	[-]	[-]
1	3.0	24.00	24.00	1.25	0.60	1.00	1.00	3.000	1.000	26	17	0.41	0.28	0.1
2	0.0	24.00	24.00	1.25	0.60	1.00	1.00	3.000	1.000	26	17	0.41	0.28	0.1

field	dist.	k_y	k_z	$k_{c,y}$	$k_{c,z}$	$f_{m,y,d}$	$f_{c,d}$	$M_{y,d}$	$M_{z,d}$	$N_{c,d}$	$\sigma_{c,d}$	$\sigma_{m,y,d}$	$\sigma_{m,z,d}$	utilisation
	[m]	[-]	[-]	[-]	[-]	[N/mm²]	[N/mm²]	[kNm]	[kNm]	[kN]	[N/mm²]	[N/mm²]	[N/mm²]	
1	3.0	0.59	0.54	0.99	1.00	12.00	11.52	-15.80	0.00	0.00	0.00	2.96	0.00	25 %
2	0.0	0.59	0.54	0.99	1.00	12.00	11.52	-15.80	0.00	0.00	0.00	2.96	0.00	25 %

lateral torsional buckling design

field	dist.	$f_{m,k}$	$f_{c,k}$	γ_m	k_{mod}	$k_{sys,y}$	l_{ef}	l_k	λ_y	$\lambda_{rel,y}$	$\lambda_{rel,m}$	β_c	k_y	$k_{c,y}$	$\sigma_{m,crit}$	k_{crit}	$f_{m,y,d}$	$f_{c,d}$	$M_{z,d}$	$N_{c,d}$	$\sigma_{c,d}$	$\sigma_{m,z,d}$	ratio
	[m]	[N/mm²]	[N/mm²]	[-]	[-]	[-]	[m]	[m]	[-]	[-]	[-]	[-]	[-]	[-]	[N/mm²]	[-]	[N/mm²]	[N/mm²]	[kNm]	[kN]	[N/mm²]	[N/mm²]	
1	3.0	24.00	24.00	1.25	0.60	1.00	1.000	1.000	9	0.14	0.20	0.1	0.50	1.00	592.71	1.00	12.00	11.52	0.00	0.00	0.00	0.00	25 %
2	0.0	24.00	24.00	1.25	0.60	1.00	1.000	1.000	9	0.14	0.20	0.1	0.50	1.00	592.71	1.00	12.00	11.52	0.00	0.00	0.00	0.00	25 %

Flexural design:

Flexural design is being performed according to EN1995-1-1, sections 6.1.6 and 6.2.3 and 6.2.4

Shear design:

Shear design is being performed according to EN1995-1-1, section 6.1.7.

Stability analysis:

Stability analysis (buckling and lateral torsional buckling) are being performed according to EN1995-1-1, section 6.3.

7.2.3.2. Fire design results

Ultimate limit state (ULS) fire design - results (15 %)

flexural design

field	dist.	$f_{m,k}$	$f_{c,k}$	$f_{t,k}$	γ_m	k_{mod}	k_{fi}	$k_{sys,y}$	$f_{m,y,d}$	$f_{c,d}$	$f_{t,d}$	$M_{y,d}$	$M_{z,d}$	$N_{c,d}$	$N_{t,d}$	$\sigma_{m,y,d}$	$\sigma_{m,z,d}$	$\sigma_{c,d}$	$\sigma_{t,d}$	utilisation
	[m]	[N/mm²]	[N/mm²]	[N/mm²]	[-]	[-]	[-]	[-]	[N/mm²]	[N/mm²]	[N/mm²]	[kNm]	[kNm]	[kN]	[kN]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	
1	3.0	24.00	24.00	19.20	1.00	1.00	1.15	1.00	28.95	27.60	24.29	-11.70	0.00	0.00	0.00	3.52	0.00	0.00	0.00	12 %
2	0.0	24.00	24.00	19.20	1.00	1.00	1.15	1.00	28.95	27.60	24.29	-11.70	0.00	0.00	0.00	3.52	0.00	0.00	0.00	12 %

shear analysis

field	dist.	$f_{v,k}$	γ_m	k_{mod}	k_{fi}	$f_{v,d}$	V_d	$\tau_{v,d}$	utilisation
	[m]	[N/mm²]	[-]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]	
1	2.63	2.50	1.00	1.00	1.15	2.88	15.63	0.44	15 %
2	0.37	2.50	1.00	1.00	1.15	2.88	15.63	0.44	15 %

buckling design

field	dist.	$f_{m,k}$	$f_{c,k}$	γ_m	k_{mod}	$k_{sys,y}$	$k_{sys,z}$	$l_{k,y}$	$l_{k,z}$	λ_y	λ_z	$\lambda_{rel,y}$	$\lambda_{rel,z}$	β_c
	[m]	[N/mm²]	[N/mm²]	[-]	[-]	[-]	[-]	[m]	[m]	[-]	[-]	[-]	[-]	[-]
1	3.0	24.00	24.00	1.00	1.00	1.00	1.00	3.000	1.000	28	24	0.44	0.38	0.1
2	0.0	24.00	24.00	1.00	1.00	1.00	1.00	3.000	1.000	28	24	0.44	0.38	0.1

field	dist.	k_y	k_z	$k_{c,y}$	$k_{c,z}$	$f_{m,y,d}$	$f_{c,d}$	$M_{y,d}$	$M_{z,d}$	$N_{c,d}$	$\sigma_{c,d}$	$\sigma_{m,y,d}$	$\sigma_{m,z,d}$	utilisation
	[m]	[-]	[-]	[-]	[-]	[N/mm²]	[N/mm²]	[kNm]	[kNm]	[kN]	[N/mm²]	[N/mm²]	[N/mm²]	
1	3.0	0.61	0.58	0.98	0.99	28.95	27.60	-11.70	0.00	0.00	0.00	3.52	0.00	12 %
2	0.0	0.61	0.58	0.98	0.99	28.95	27.60	-11.70	0.00	0.00	0.00	3.52	0.00	12 %

lateral torsional buckling design

field	dist.	$f_{m,k}$	$f_{c,k}$	γ_m	k_{mod}	$k_{sys,y}$	l_{ef}	l_k	λ_y	$\lambda_{rel,y}$	$\lambda_{rel,m}$	β_c	k_y	$k_{c,y}$	$\sigma_{m,crit}$	k_{crit}	$f_{m,y,d}$	$f_{c,d}$	$M_{z,d}$	$N_{c,d}$	$\sigma_{c,d}$	$\sigma_{m,z,d}$	ratio
	[m]	[N/mm²]	[N/mm²]	[-]	[-]	[-]	[m]	[m]	[-]	[-]	[-]	[-]	[-]	[-]	[N/mm²]	[-]	[N/mm²]	[N/mm²]	[kNm]	[kN]	[N/mm²]	[N/mm²]	
1	3.0	24.00	24.00	1.00	1.00	1.00	1.000	1.000	9	0.15	0.26	0.1	0.50	1.00	346.81	1.00	28.95	27.60	0.00	0.00	0.00	0.00	12 %
2	0.0	24.00	24.00	1.00	1.00	1.00	1.000	1.000	9	0.15	0.26	0.1	0.50	1.00	346.81	1.00	28.95	27.60	0.00	0.00	0.00	0.00	12 %

The ULS fire design is being performed according to EN1995-1-1 (analogous to the section above) and EN1995-1-2 [3]

7.3. Continuous beam – steel

This module will design a steel beam with a typical rolled or welded steel section. The module is set-up in a similar way as the continuous beam – CLT panel module (see chapter 7.1) and the module continuous beam – solid timber / glulam (see chapter 7.2).

7.3.1. Design basics

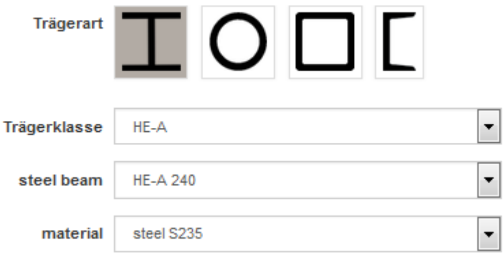
The analysis in this design module is based on Eurocode 3 [12] and it´s national annexes.

7.3.2. Continuous beam details

Click the edit button in the “continuous beams details” box in order to edit the data:

7.3.2.1. System Data:

Pick a profile by clicking the profile type icon and then choose in the pull-down menu below the section class, the beam size and finally the material:



7.3.3. Results

The user has the choice to either see only the design relevant results by clicking “results” or the entire list of results can be displayed by clicking “detailed result”.
Utilization rates, material parameters and results of the different load case categories and combinations are shown in a similar way as for the modules, described in the previous sections.

7.3.3.1. ULS design results

Ultimate limit state (ULS) - design results (71 %)

flexural design

Feld	Qkl	$M_{y,c,Rd}$	$M_{y,Ed}$	utilisation
	[-]	[kNm]	[kNm]	
1	1.00	159.07	101.09	64 %
2	1.00	159.07	101.09	64 %

shear analysis

Feld	Qkl	A_v	$V_{c,Rd}$	V_{Ed}	utilisation
	[-]	[kN]	[kN]	[kN]	
1	1.00	0.00	310.58	113.90	37 %
2	1.00	0.00	310.58	122.17	39 %

flexural design + shear analysis

Feld	Qkl	$V_{pl,Rd}$	V_{Ed}	$M_{y,c,Rd}$	$M_{y,c,Ed}$	utilisation
	[-]	[kN]	[kN]	[kNm]	[kNm]	
1	1.00	310.58	113.90	159.07	101.09	64 %
2	1.00	310.58	122.17	159.07	101.09	64 %

lateral torsional buckling design

Feld	Qkl	$M_{z,Rd}$	$M_{y,Rd}$	K_{yy}	K_{zz}	K_{yz}	K_{zy}	N_{Ed}	V_{Ed}	$M_{y,Ed}$	$M_{z,Ed}$	utilisation
	[-]	[kNm]	[kNm]	[-]	[-]	[-]	[-]	[kN]	[kN]	[kNm]	[kNm]	
1	1.00	0.00	142.74	0.00	0.00	0.00	0.00	0.00	113.90	101.09	0.00	71 %
2	1.00	0.00	142.74	0.00	0.00	0.00	0.00	0.00	122.17	101.09	0.00	71 %

SLS design results are similar to the SLS results of the previously described modules.

7.4. Continuous beam – rib deck

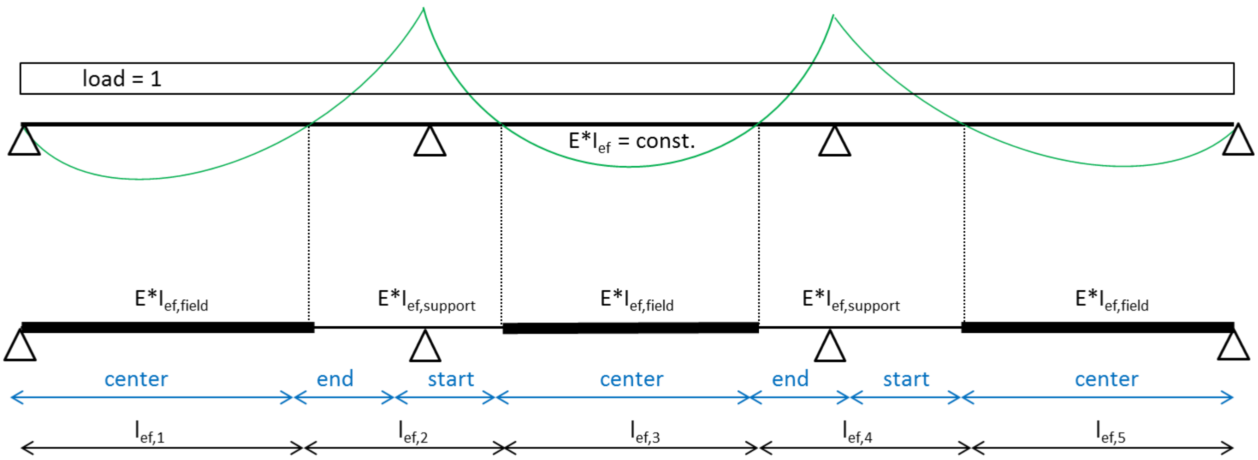
The rib deck module is for rib decks with the following layout:

- CLT deck on top of ribs (glulam, solid timber or LVL)
- ribs (glulam, solid timber or LVL) on top of a CLT deck
- ribs (glulam, solid timber or LVL) with a CLT deck above and below (box girder)

The CLT can be attached to the ribs in a rigid way (glued) or flexible (mechanical connectors).
The rib deck can be a simply supported beam with one span, a continuous beam with several spans with or without cantilevers at either end.

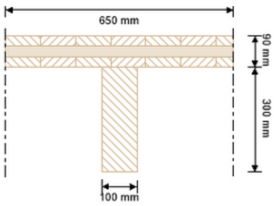
7.4.1. Design basics

For the analysis of rib decks and for the analysis of concrete composite elements (see chapter 7.5), it was chosen to apply the gamma method. The reason for that was, that an analysis with the Timoshenko theory would not be able to analyze the flexural stress in a rib deck section, with a flexible joint and reflect the influence of this flexibility in the joint between rib and deck. The shear analogy method reaches its limits, due to the large asymmetry in the section and the Steiner components in the moment of inertia (CLT section with rather small spacing between the lamination in principal direction and then the large distance to the C.O.G. of the rib) [12]. This lead to the decision, to use the gamma method.
The effective length of a beam portion is being determined by the location of zero points in a moment curve for a continuous constant load (load = 1) over the entire beam (incl. cantilevers). For a single span beam, the moment curve has its zero points exactly in the support points. Therefore the effective length is equal to the span. In case of a continuous beam, the beam is being divided in 3 zones: start, center and end. For these 3 zones the respective effective length will be taken into account, when calculating the γ-values.



These different γ-values in different parts of a beam are reflected in the design and are indicated in the result:

section rib deck: CLT 90 L3s - 10/30



layer	thickness	type	material
1	30.0 mm	L	C24 spruce
2	30.0 mm	C	C24 spruce
3	30.0 mm	L	C24 spruce
4	300.0 mm	L	C24 spruce

ULS

field	range	width	moment of inertia	area	$\gamma_{ref,length}$	γ values
		[cm]	[mm⁴]	[mm²]	[m]	
1	Start	12.80	0	0	0	0.000|0.000|0.000|
1	center	20.70	316,330,100	42,420	4.5	0.434|0.179|0.335|
1	end	12.80	257,615,800	37,680	3	0.324|0.109|0.238|
2	Start	12.80	257,615,800	37,680	3	0.324|0.109|0.238|
2	center	20.70	316,330,100	42,420	4.5	0.434|0.179|0.335|
2	end	12.80	0	0	0	0.000|0.000|0.000|

SLS

field	range	width	moment of inertia	area	$\gamma_{ref,length}$	γ values
		[cm]	[mm⁴]	[mm²]	[m]	
1	Start	12.80	0	0	0	0.000|0.000|0.000|
1	center	20.70	345,878,900	42,420	4.5	0.506|0.305|0.428|
1	end	12.80	274,856,100	37,680	3	0.382|0.216|0.315|
2	Start	12.80	274,856,100	37,680	3	0.382|0.216|0.315|
2	center	20.70	345,878,900	42,420	4.5	0.506|0.305|0.428|
2	end	12.80	0	0	0	0.000|0.000|0.000|

Since the Rigidity (red) is part of the γ-equation

$$\gamma_i = \frac{1}{\left(1 + \frac{\pi^2 \cdot E_i \cdot A_i}{{l_{ref}}^2} \cdot \frac{d_{ij}}{b_{ij} \cdot G_{R,ij}}\right)} = \frac{1}{\left(1 + \frac{\pi^2 \cdot E_i \cdot A_i}{{l_{ref}}^2} \cdot \frac{s_i}{K_i}\right)}$$

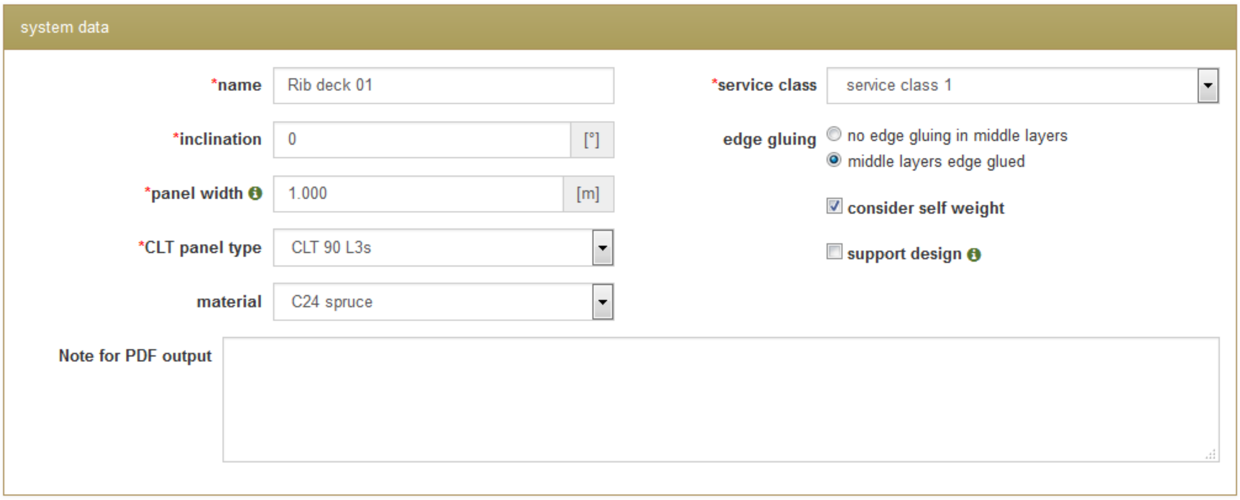
the γ-values will be different, in ULS and SLS design, because in SLS design K_{ser} is being used and in ULS design K_u.

Note: this module does the structural analysis for a rib deck in span direction. Not included in the design is the analysis of the deck itself, spanning between the ribs, perpendicular to the span direction. This design can easily be done, using the “continuous beam – CLT panel” module (see chapter 7.1).

7.4.2. Continuous beam details

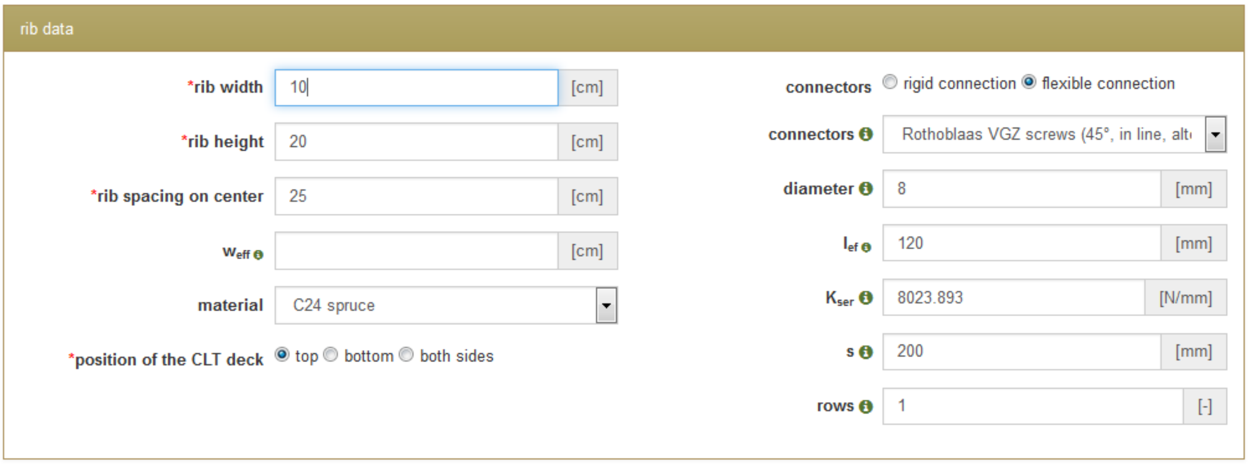
The input in this module follows the same logic as for the regular CLT deck (see chapter 7.1). The significant differences and important items will be displayed below.

7.4.2.1. System Data:



As in other modules it is recommended, to use a panel width of 1,00m. The panel width is independent from the rib spacing.
For the selection of the CLT panel type it shall be mentioned that it does not make any difference, whether the user specifies a C or a L panel. In this module the principal direction of the CLT deck is always oriented in span direction. Therefore the grain in the cover layers of the CLT will always be parallel to the grain of the rib.
For the support design: it is assumed that the rib deck is only being supported off the ribs. This is a conservative approach.

7.4.2.2. Rib Data:



Rib width and **height** are the dimensions of the rib.
Rib spacing is the spacing, measured from center line of a rib to the center line of the adjacent rib (not the clear spacing).

$\mathbf{W_{eff}}$ ist the effective width of inside the CLT deck that is contributing to the load bearing action of the composite section (rib + CLT). It is recommended to leave this input box empty. In that case the software will determine the effective width itself. This analysis is based on the report “Darstellung und praxistaugliche Aufbereitung für die Ermittlung mitwirkender Plattenbreiten von BSP-Elementen“ [13].
By choosing the **position of the CLT deck**, it can be chosen, whether the deck is located above, below or above and below the ribs. In case the CLT deck is located below the ribs, lateral torsional buckling of the ribs was not considered, because it is assumed that the compression side of the ribs is always braced laterally by either sheathing of a support.
The selection whether the **connection is rigid or flexible** is an important definition for the design. Rigid connections usually lead to a better efficiency, although the selection has to be based on the intentions of the engineer/carpenter and the capabilities in the rib deck production and on site. When choosing a flexible connection, more input will be required:

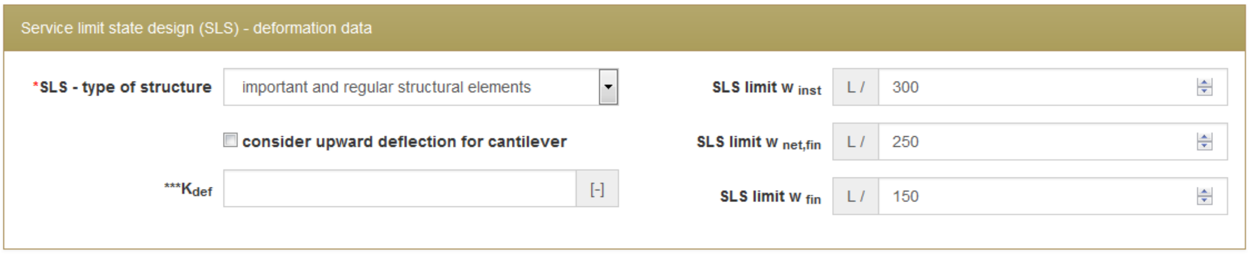
Connectors:
This pull-down menu gives a hand full of practical and typical connector types for rib decks. This incudes shear connectors (nails and partially threaded screws) and inclined screws (fully threaded).
The selection of the connectors is at this point solely for the determination of the rigidity k_{ser}!
A screw design that analyzes the load bearing capacity and any clearance and spacing is not part of the software development at this stage, but could be part of a future development.
Diameter (is the nominal diameter of the screws or the diameter of the nail).
$\mathbf{l_{ef}}$ is the effective length of the screw. This dimension is important for fully threaded screws. Ideally the embedment length in both (CLT and the rib) are equal, however the chosen screw length and CLT thickness will determine the effective embedment length. This effective length needs to be entered by the user.
Based on diameter and effective length a $\mathbf{k_{ser}}$ [N/mm] will be calculated of **one** connector. The additional input of the spacing and rows of connectors lead to a final rigidity of the CLT-rib joint.
If the desired connector cannot be found in the pull-down menu, the user can define an **arbitrary** $\mathbf{k_{ser}}$ by entering (overwriting) a value in the box. This gives the user a good amount of flexibility in the design.
s is the connector spacing in span direction from C.O.G. of a connection (e.g. crossed screws) or a connector (one screw or nail) to the C.O.G. of the next connection/connector.
The number or **rows** is counting the rows of connectors/connections perpendicular to the span (principal) direction.

7.4.2.3. Fire design Data:

For rib decks it is assumed that fire acts from the bottom. The fire design data can be chosen in a similar manner as in the module for CLT panels (see chapter 7.1). It is assumed that the fire protection cladding is attached directly to the bottom of the rib deck and runs straight from rib to rib, creating a non-insulated cavity between the ribs. The fire protection is calculated as if the CLT was attached directly to the CLT and ribs. This is a conservative approach. In this module the feature of insulated cavities is not available. Only analysis according to EN1995-1-2, incl. Önorm B 1995-1-2 is possible.

7.4.2.4. SLS design Data:

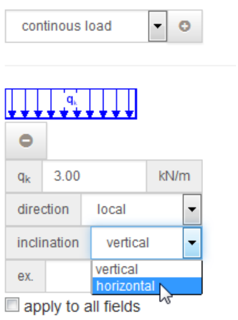
The SLS design data can be chosen in a similar manner as in the module for CLT panels.



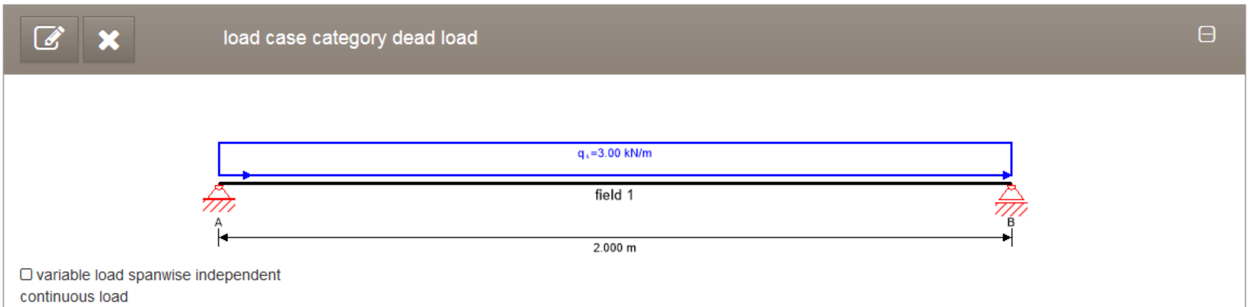
For rib decks a common k_{def} is being applied. Since most of the flexural rigidity originates from the ribs, the k_{mod} value is the one, applicable for the rib, in the given country and utilization class. However, if a user would like to apply a different value, a user defined k_{mod} can be entered in the input field for the SLS data.

7.4.3. Loading:

Generally the input of loads follows the same logic as in the other modules – see chapter 7.1.5.
The rib deck module shall provide the **possibility**, to design a rib deck **as wall element**.



For the input of a load in the plane of the rib deck, the direction needs to be set to a **local** coordinate system and the inclination of the load needs to be set to **horizontal**. Thinking of a wall element, these loads will then in reality be vertical, but the analysis model is not being tilted-up 90°, therefore the loading has to be inserted as just described.
Additionally the option "consider selfweight" in the system data needs to be unchecked (deactivated), otherwise the selfweight will be applied out of the plane of the system, which would not be typical for a wall. The selfweight needs to be inserted manually as a continuous load.
Attention needs to be paid to the orientation of a load in the plane of a rib deck. The arrows in the load diagram indicate the direction of a positive load. If the load needs to be applied in the opposite direction, the value needs to be entered negative. In the field "**ex.**", an **eccentricity** can be applied to the loading in plane (horizontal inclination). The eccentricity is being measured from the center of gravity of the entire rib deck section.



field	direction	q_k	inclination	ex.	all members
1	local	3.00	horizontal		☐

7.4.4. Results

The results in this module follows the same logic as for the regular CLT deck (see chapter 7.1). The significant differences and important items will be displayed below.

ULS design results:

Ultimate limit state (ULS) - design results (90 %)

flexural design

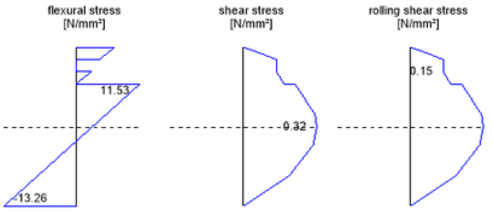
field	$f_{m,k}$	γ_m	k_{mod}	k_{sys}	$f_{m,d}$	M_d	$\sigma_{m,d}$	utilisation
	[N/mm²]	[-]	[-]	[-]	[N/mm²]	[kNm]	[N/mm²]	
1	24.00	1.25	0.80	1.00	14.77	-24.20	-13.26	90 %
2	24.00	1.25	0.80	1.00	14.77	-24.20	-13.26	90 %

shear analysis

field	$f_{v,k}$	γ_m	k_{mod}	$f_{v,d}$	V_d	$\tau_{v,d}$	utilisation
	[N/mm²]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]	
1	2.30	1.25	0.80	1.42	-21.26	0.32	23 %
2	2.30	1.25	0.80	1.42	21.26	0.32	23 %

rolling shear

field	$f_{r,k}$	γ_m	k_{mod}	$f_{r,d}$	V_d	$\tau_{r,d}$	utilisation
	[N/mm²]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]	
1	1.15	1.25	0.80	0.74	-21.26	0.15	20 %
2	1.15	1.25	0.80	0.74	21.26	0.15	20 %

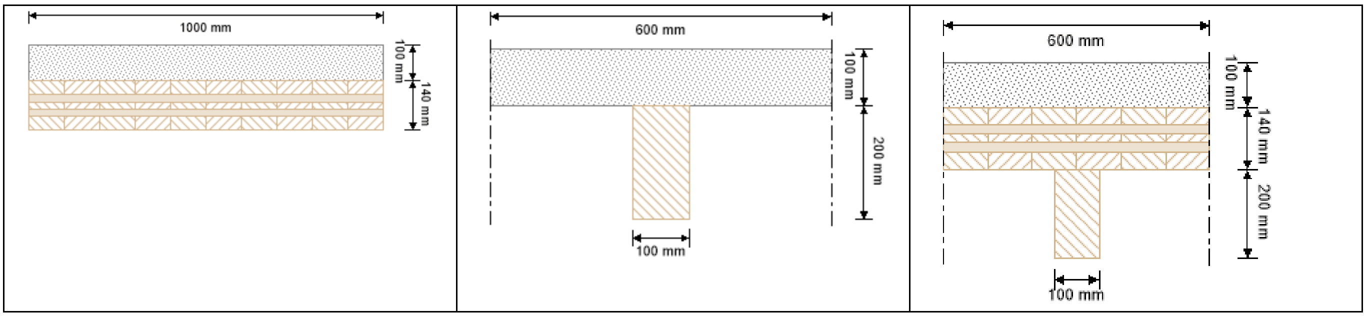


The ULS design results are displayed in a similar way as for the CLT panel design module(see chapter 7.1). The stress diagrams are drawn for the locations within the beam that cause the governing internal forces.
If loads in the plane of the rib deck element are entered (see chapter 7.4.3), buckling design will be conducted as well.
Note: the stress diagrams in the figure above have been generated for a continuous beam (2 spans) with a flexible bond between the deck and the rib. Therefore the offset in the flexural stress diagram can be noticed at the joint between deck and rib.

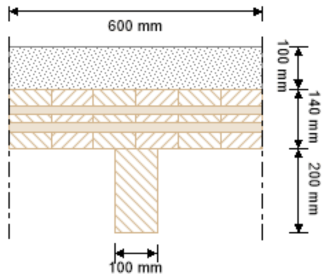
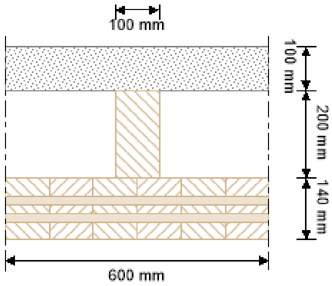
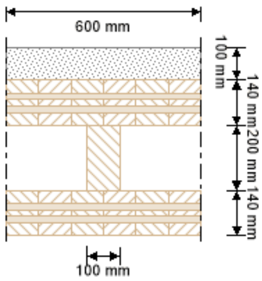
7.5. Continuous beam – concrete composite

The concrete composite module is for structures with the following layout:

- CLT deck with concrete topping
- Solid timber/glulam/LVL rib with concrete topping (no CLT)
- CLT deck with concrete topping above the CLT and ribs below the CLT



For the case CLT deck with concrete topping above the CLT and ribs below the CLT there are 3 different sub categories, depending on the position of the CLT-deck in relation to the rib:

		
Position of CLT deck: top	Position of CLT deck: bottom	Position of CLT deck: top & bottom

The connection between CLT and the concrete can be assumed rigid (glued, interlocking system, etc.) or flexible (use of mechanical shear connectors).
The CLT can be attached to the ribs in a rigid way (glued) or flexible (mechanical connectors).
The rib deck can be a simply supported beam with one span, a continuous beam with several spans with or without cantilevers at either end.

7.5.1. Design basics

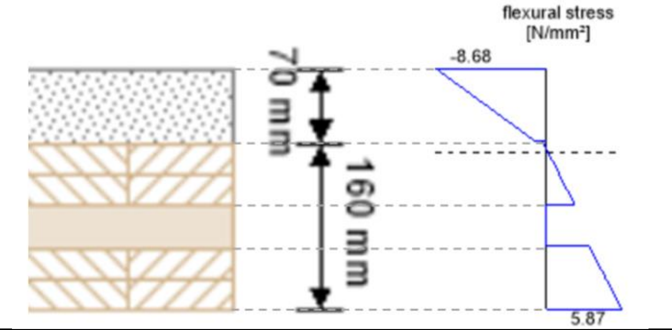
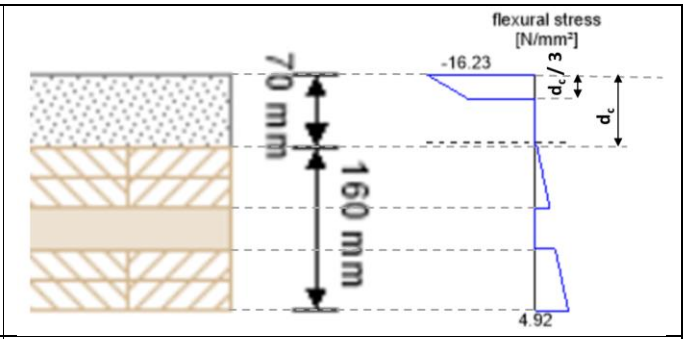
For the analysis of rib decks (see chapter 0) and for the analysis of concrete composite elements, it was chosen to apply the gamma method. Therefore, the principles, mentioned in chapter 0 above are valid for this module just as well.

7.5.1.1. Concrete composite specific items:

When dealing with concrete composite structures, the material behavior of both materials, the concrete and the timber, need to be considered. For this software it is assumed that concrete is being attached to the timber elements in fresh/liquid state. This means that the shrinkage stress will have to be taken by the timber. Another stress, induced by the concrete is the stress due to creep. These effects are time dependent and need to be taken into account. Therefore the ULS and SLS design needs to be done for the time T=28 days (for the hardened concrete, this can be seen as T=0) , that is the time after which the concrete should have its design strength and rigidity and for the time T=∞, when all shrinkage and creep processes are finished. For that reason, the rigidities of the connections CLT to concrete and/or CLT to rib and/or concrete to rib need to be analyzed.

7.5.1.2. Design assumptions for the concrete

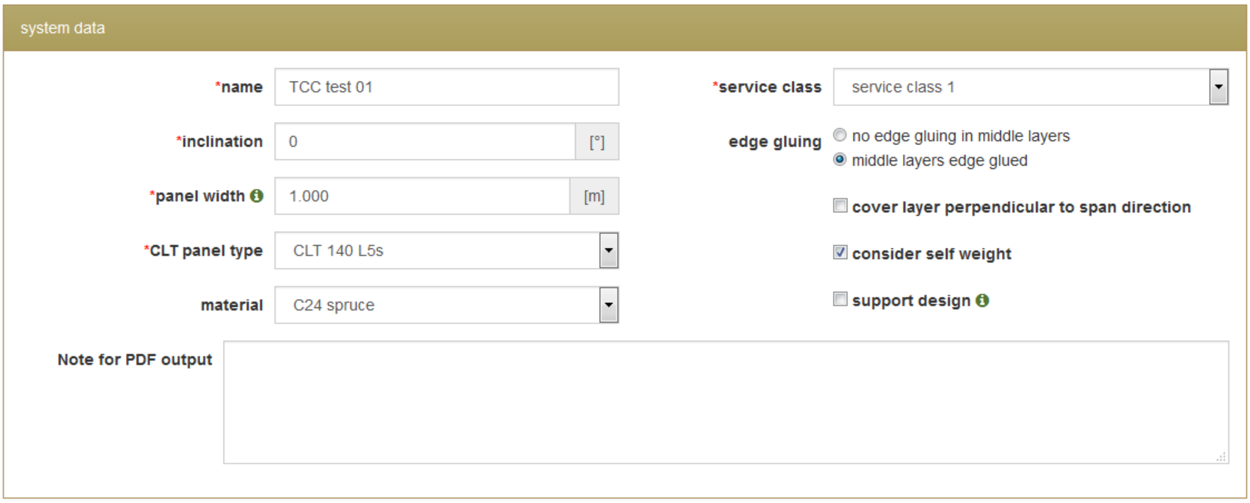
- Concrete is not reinforced for structural purposes. Generally the placement of reinforcement is recommended for crack control. This can be obtained by steel fiber concrete too.
- Having no structural reinforcement leads to the design assumptions that in case there is only compressive stress in the concrete, the entire concrete section shall be effective. This is comparable to "state I" in concrete design – concrete is not cracked.
- As soon as tensile stress is reaching the concrete in zones with positive flexural moments (tensile stress at the bottom of the section), it is assumed that concrete is cracked, similar to "state II" in concrete design. In that case the compression zone in concrete is assumed to have a depth of 1/3 of the depth of the concrete section.
- In areas with negative moments (tensile stress on top of the section, e.g.: at central supports on continuous beams) it is assumed that the entire concrete section is cracked and no force can be transferred in the concrete section. In these areas the effective section is reduced to the timber section only.

	
Only compressive stress in concrete	Tensile stress reaches bottom face of concrete - concrete cracks – compression zone height in concrete is a third of the thickness of the concrete topping d_c / 3

7.5.2.Continuous beam details

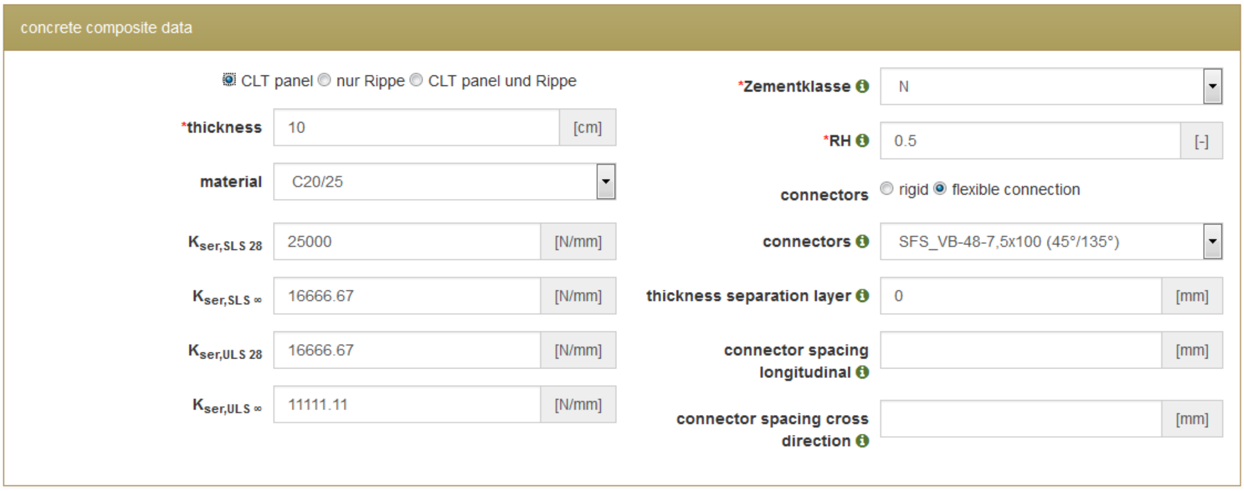
The input in this module follows the same logic as for the CLT rib decks (see chapter 0). The significant differences and important items will be displayed below.

7.5.2.1. System Data:



As in other modules it is recommended, to use a panel width of 1,00m. The panel width is independent from the rib spacing. In systems without CLT panels, the panel width can be seen as system width.
For the selection of the CLT panel type it shall be mentioned that it does not make any difference, whether the user specifies a C or a L panel. In this module the principal direction of the CLT deck is always oriented in span direction. If the principal direction of CLT shall be turned for 90°, the box at “cover layer perpendicular to span direction” shall be checked.
For the support design: it is assumed that the rib deck is only being supported off the ribs. This is a conservative approach.

7.5.2.2. Concrete composite Data:

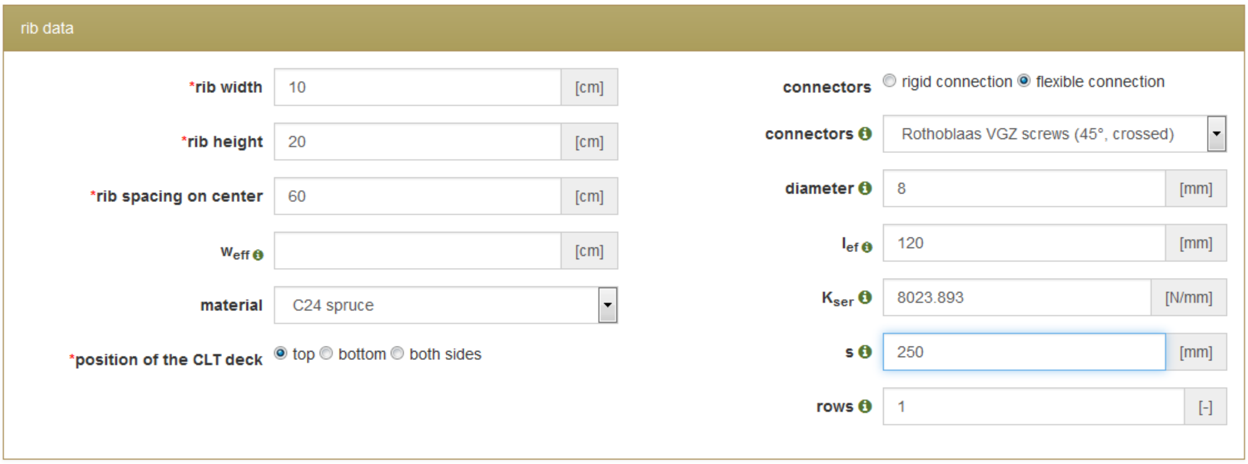


Thickness is the thickness of the concrete topping.
Material is the concrete grade according to EN1992-1-1 [15].
K_{ser} values are relevant for a flexible connection between the concrete and the timber. These values are calculated for the case t=28d and t=∞ and for ULS and SLS. The rigidity k_{ser} depends on the type of connectors and the material parameters of the concrete and the timber.
Cement class for concrete is related to the reactivity of the cement, whether it is bonding rapidly, normally or slow. Therefore the 3 classes R (rapid), N (normal) and S (slow).
RH is the relative humidity in the environment of the concrete in % (0,5 is 50%).
At this point the software is featuring concrete composite connectors from:

- SFS (also distributed by Rothoblaas), according to ETA-13/0699 [15]
- TiComTec, according to DIBt approval Z-9.1-557 [16]

Thickness separation layer: a separation layer thickness can be specified, in case there is an insulation or a sheathing (e.g.: lost formwork for concrete deck with timber ribs) between the timber and the concrete layer.
Connector spacing longitudinal is the connector spacing in span direction. (Note: leave blank for TiComTec connectors).
Connector spacing cross direction is the connector spacing in direction, perpendicular to the span.

7.5.2.3. Rib Data



This box only needs to be filled, if the system contains ribs.

Rib width and **height** are the dimensions of the rib.
Rib spacing is the spacing, measured from center line of a rib to the center line of the adjacent rib (not the clear spacing).
W_{eff} ist the effective width of inside the CLT deck that is contributing to the load bearing action of the composite section (rib + CLT). It is recommended to leave this input box empty. In that case the software will determine the effective width itself. This analysis is based on the report “Darstellung und praxistaugliche Aufbereitung für die Ermittlung mitwirkender Plattenbreiten von BSP-Elementen“ [13].
By choosing the **position of the CLT deck**, it can be chosen, whether the deck is located above, below or above and below the ribs.
The selection whether the **connection is rigid or flexible** is an important definition for the design. Rigid connections usually lead to a better efficiency, although the selection has to be based on the intentions of the engineer/carpenter and the capabilities in the rib deck production and on site. When choosing a flexible connection, more input will be required – see chapter 7.4.2.2.

7.5.2.4. Fire design Data

The fire design data can be chosen in a similar manner as in the module for CLT panels (see chapter 7.1) or similar to the fire design of rib decks, if the concrete composite floor involves a rib (see chapter 7.4.2.3).

7.5.3. Results

The results in this module follows the same logic as for the regular CLT deck (see chapter 7.1). The significant differences and important items will be displayed below.

7.5.3.1. ULS design results

Ultimate limit state (ULS) - design results (31 %)

flexural design T=28

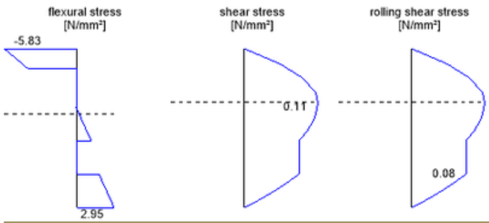
field	dist.	$f_{m,k}$	γ_m	k_{mod}	k_{sys}	$f_{m,d}$	M_d	$\sigma_{m,d}$	utilization
	[m]	[N/mm²]	[-]	[-]	[-]	[N/mm²]	[kNm]	[N/mm²]	
1	2.0	38.00	2.00	0.80	1.00	15.20	14.86	-4.76	31 %

shear analysis T=28

field	dist.	$f_{v,k}$	γ_m	k_{mod}	$f_{v,d}$	V_d	$\tau_{v,d}$	utilization
	[m]	[N/mm²]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]	
1	0.0	4.00	2.00	0.80	2.56	14.86	0.11	4 %

rolling shear T=28

field	dist.	$f_{r,k}$	γ_m	k_{mod}	$f_{r,d}$	V_d	$\tau_{r,d}$	utilization
	[m]	[N/mm²]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]	
1	0.0	1.05	2.00	0.80	0.67	14.86	0.08	12 %



flexural design T=∞

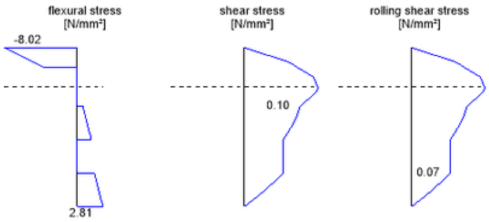
field	dist.	$f_{m,k}$	γ_m	k_{mod}	k_{sys}	$f_{m,d}$	M_d	$\sigma_{m,d}$	utilization
	[m]	[N/mm²]	[-]	[-]	[-]	[N/mm²]	[kNm]	[N/mm²]	
1	2.0	38.00	2.00	0.80	1.00	15.20	14.86	-4.54	30 %

shear analysis T=∞

field	dist.	$f_{v,k}$	γ_m	k_{mod}	$f_{v,d}$	V_d	$\tau_{v,d}$	utilization
	[m]	[N/mm²]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]	
1	0.0	4.00	2.00	0.80	2.56	14.86	0.10	4 %

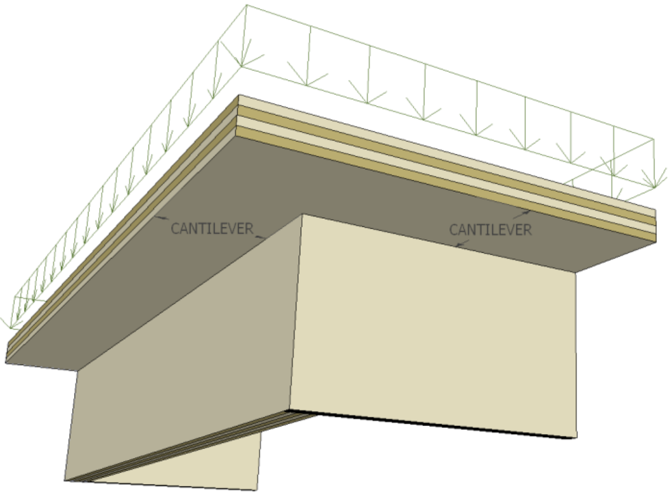
rolling shear T=∞

field	dist.	$f_{r,k}$	γ_m	k_{mod}	$f_{r,d}$	V_d	$\tau_{r,d}$	utilization
	[m]	[N/mm²]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]	
1	0.0	1.05	2.00	0.80	0.67	14.86	0.07	10 %



The ULS design results are displayed in a similar way as for the CLT panel design module(see chapter 7.1). The stress diagrams are drawn for the locations within the beam that cause the governing internal forces.

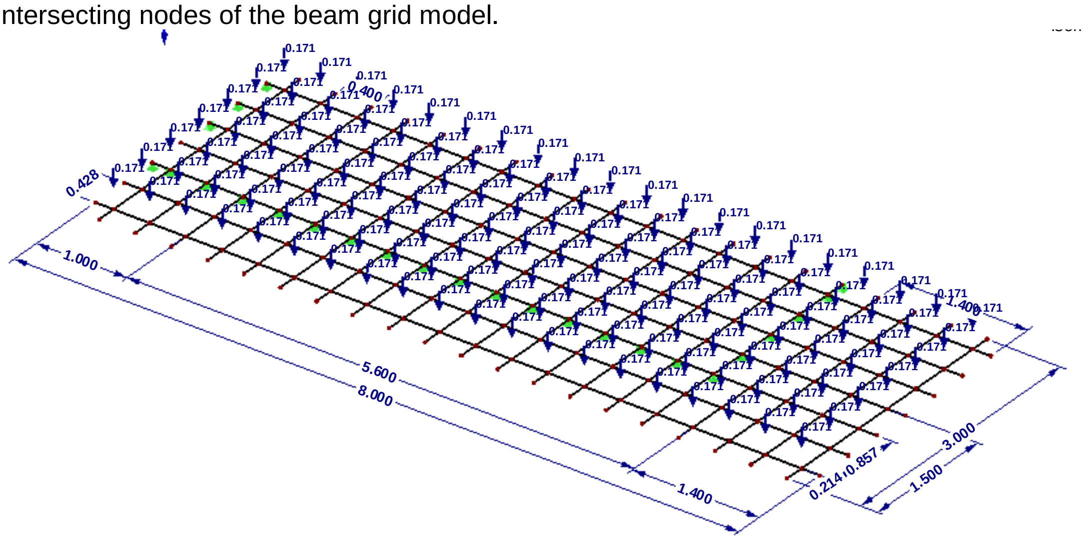
7.6. 2-way cantilever CLT panel at corner



This module will design a CLT panel that is located at the corner of a building and is cantilevering out in 2 directions (in principal direction and in cross direction). In design practice, engineers used so far good judgement and some simplified engineering approaches, by trying to interpret a beam with a cantilever into the system. Probably the best approach to such a problem would be a FE analysis. This module shall help the user to save time and help these, who don´t have access to FE software. The here presented method is an engineering approach as well, but a closer approach to the real solution than to interpret a beam (spanning in one direction only) with a cantilever into the system. Since this is only a solid engineering method, the results of this module **deviate from a FE model**, but the deviations are on the **conservative side**.

7.6.1. Design basics

The design approach at this module is, to describe the CLT panel as a beam grid model. There are beams that run in principal direction of the panels and beams that run in cross direction. The beams in principal direction have the rigidity and moment of inertia of the CLT panel in principal direction and the beams in cross direction have the properties of the CLT in cross direction. This engineering approach was published in "Cross-Laminated Timber Structural Design" [10].
In this design module, the CLT panel is being modeled by a beam grid with a square mesh width of about 40 cm. The exact width will be a multiple of the panel dimension. All loading is being applied as point load in the intersecting nodes of the beam grid model.

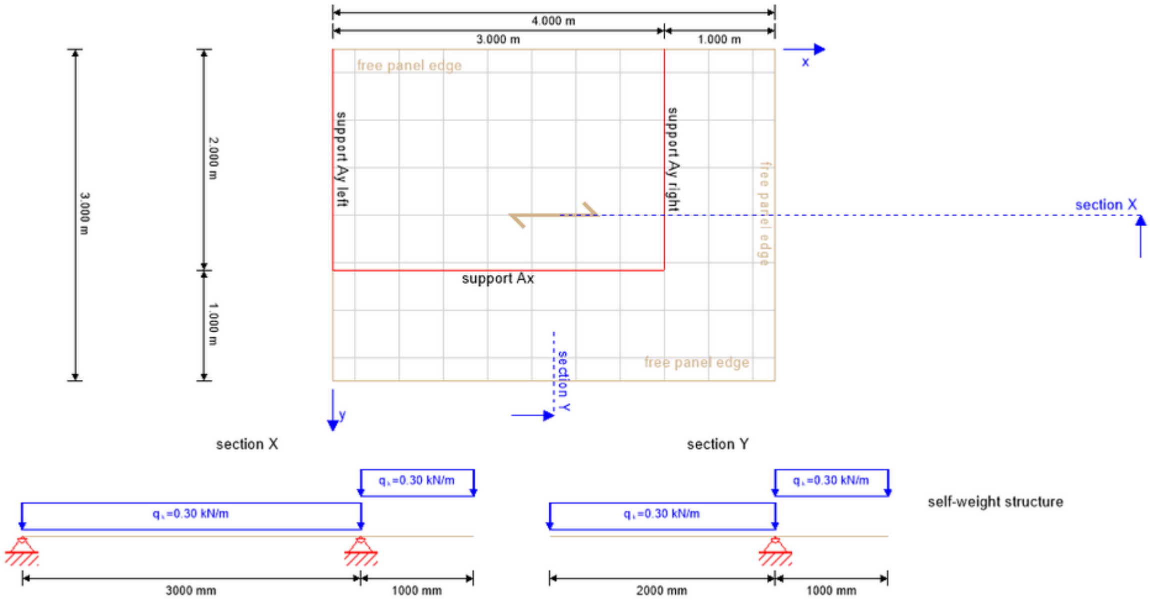


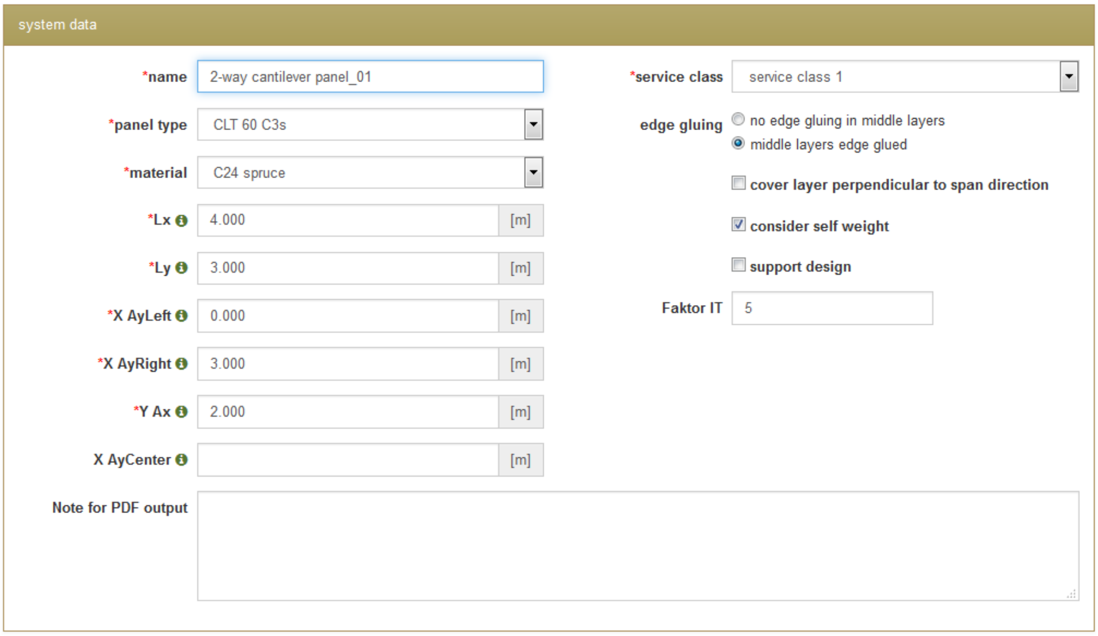
The deformation of the system is being analyzed according to the Timoshenko beam theory, taking all deformation due to flexural moments and shear into account.

$$w_{total} = w_M + w_V = \frac{1}{E \cdot I_{eff}} \cdot \int (M \cdot \bar{M})\, dx + \frac{1}{G \cdot A_{eff,G}} \cdot \int (V \cdot \bar{V})\, dx$$

7.6.2. Panel details

7.6.2.1. System Data:



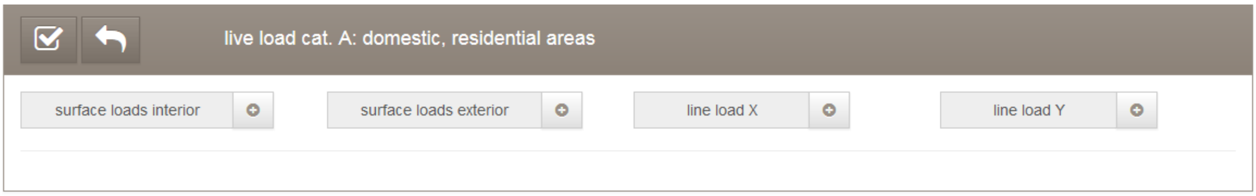


Lx is the total length in X direction and **Ly** is the total length on Y direction. When starting the design and the input at this module, there is already some existing data and a corresponding system sketch above. Comparing the values in the list with those in the sketch might help to understand the logic of the input.
X AyLeft is the X coordinate of the left support line (red line) in Y direction.
X AyRight is the X coordinate of the rihgt support line (red line) in Y direction.
X AyMiddle is the X coordinate of the central support line (red line) in Y direction. If there is no support line in the middle, then leave this box blank.
Y Ax is the Y coordinate of the support line in x direction.
The principal direction of the CLT is indicated in the system sketch and is usually oriented in X direction (main span direction).

Check the box "**cover layer perpendicular to span direction**", if the principal direction shall be in Y direction. The system sketch includes a section in X and in Y direction for a better understanding of the system.

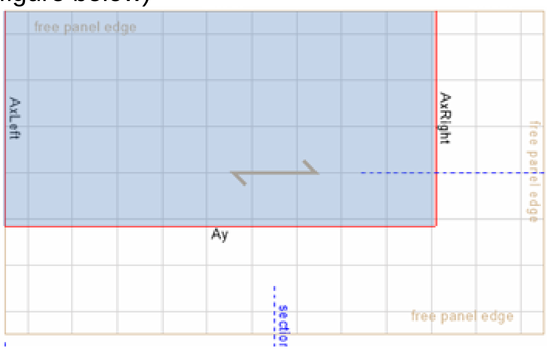
The input of data for fire design SLS design and vibration design follow the same logic as described in chapter 7.1.

7.6.2.2. Loading:



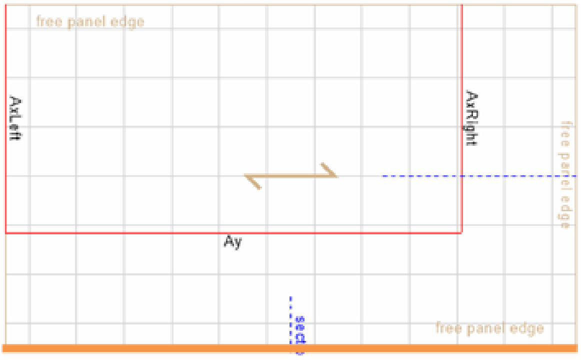
Adding load case groups works the same was as described in chapter 7.1.5.
This module allows the user to add:

- Surface loads on the interior part of the panel (area that is enclosed by the supports – colored blue in the figure below)



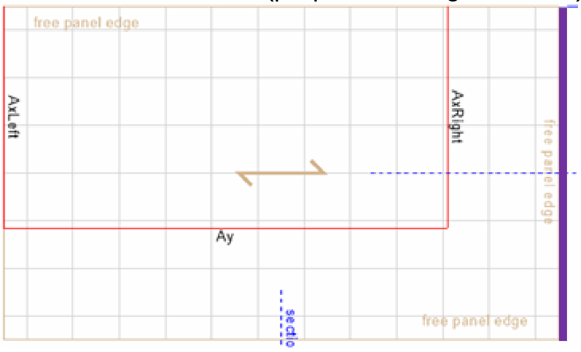
- Surface loads on the exterior part of the panel (area that is on the other side of the supports – colored green in the figure below)

- Line load in X direction puts a line load along the panel edge in the cantilever portion on the edge that is oriented in X direction (orange line in figure below):



Such a line load could be for example a dead load of a parapet wall around the edge of a roof.

- Line load in Y direction puts a line load along the panel edge in the cantilever portion on the edge that is oriented in Y direction (purple line in figure below):

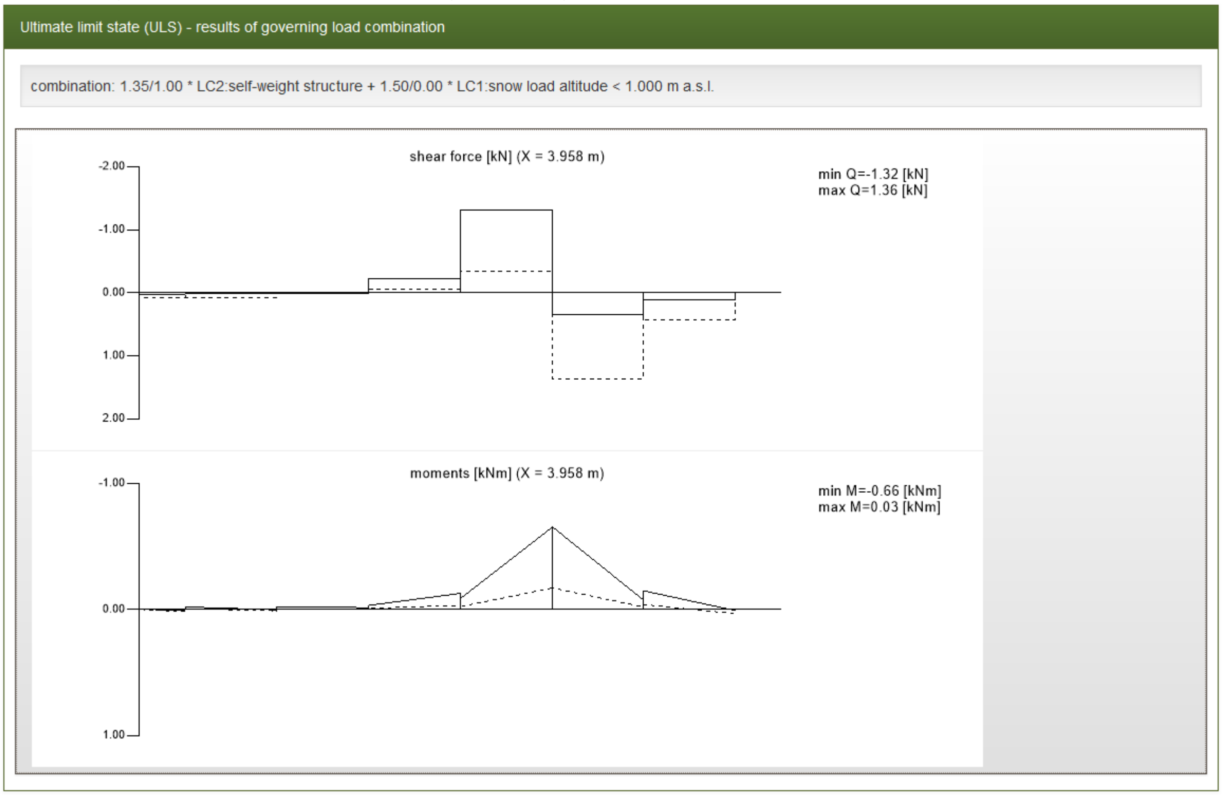


7.6.3. Results

The results in this module follows the same logic as for the regular CLT deck (see chapter 7.1). The significant differences and important items will be displayed below.

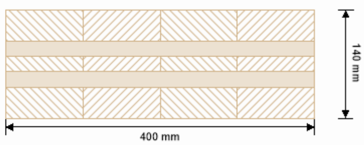
7.6.3.1. ULS design results

ULS design – internal forces of the governing load combination:



The design governing shear force and moments are displayed in the diagrams. All internal forces are being calculated at the intersection points of the beam grid model. That is the reason, why the curves are not smooth, but polygonal. The values are given for a beam grid element with a given width (= mesh width of the beam grid model). The exact width of the beam elements is given in the section properties, in the result page:

section CLT 140 L5s



layer	thickness	type	material
1	40.0 mm	L	C24 spruce
2	20.0 mm	C	C24 spruce
3	20.0 mm	L	C24 spruce
4	20.0 mm	C	C24 spruce
5	40.0 mm	L	C24 spruce

As in other modules, only the extreme values are indicated. All intermediate values can be viewed by a click into the respective diagram and will be displayed in a table:

value for 1.35/1.00 * LC2:self-weight structure + 1.50/0.00 * LC1:snow load altitude < 1.000 m a.s.l.

X	Y	min M	max M	X	Y	min Q	max Q
[m]	[m]	[kNm]	[kNm]	[m]	[m]	[kN]	[kN]
3.958	0.000	0.000	0.000	3.958	0.000	0.022	0.083
3.958	0.214	0.005	0.018	3.958	0.214	0.022	0.083
3.958	0.214	-0.020	-0.005	3.958	0.214	0.019	0.072
3.958	0.643	0.003	0.011	3.958	0.643	0.019	0.072
3.958	0.643	-0.022	-0.006	3.958	0.643	0.004	0.017
3.958	1.071	-0.014	-0.004	3.958	1.071	0.004	0.017
3.958	1.071	-0.032	-0.008	3.958	1.071	-0.222	-0.058
3.958	1.500	-0.127	-0.033	3.958	1.500	-0.222	-0.058
3.958	1.500	-0.085	-0.022	3.958	1.500	-1.317	-0.342
3.958	1.929	-0.649	-0.169	3.958	1.929	-1.317	-0.342
3.958	1.929	-0.658	-0.171	3.958	1.929	0.354	1.363
3.958	2.357	-0.074	-0.019	3.958	2.357	0.354	1.363
3.958	2.357	-0.147	-0.038	3.958	2.357	0.110	0.423
3.958	2.786	0.009	0.034	3.958	2.786	0.110	0.423
3.958	2.786	0.000	0.000	3.958	2.786	0.000	0.000
3.958	3.000	0.000	0.000	3.958	3.000	0.000	0.000

close

The ULS design results are displayed in a similar way as for the CLT panel design module(see chapter 7.1). The stress diagrams are drawn for the locations within the beam that cause the governing internal forces.
Note: the stress diagrams in the figure above have been generated for a continuous beam (2 spans) with a flexible bond between the deck and the rib. Therefore the offset in the flexural stress diagram can be noticed at the joint between deck and rib.

The ULS design results are being displayed in a similar way as in the other modules:

Ultimate limit state (ULS) - design results (13 %)

flexural design

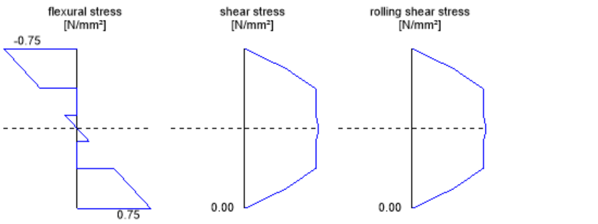
X	Y	Ri	$f_{m,k}$	γ_m	k_{mod}	k_{sys}	$f_{m,d}$	M_d	$\sigma_{m,d}$	utilisation
[m]	[m]	[-]	[N/mm²]	[-]	[-]	[-]	[N/mm²]	[kNm]	[N/mm²]	
3.96	2.36	Y	24.00	1.25	1.00	1.10	21.12	0.66	2.66	13 %

shear analysis

X	Y	Ri	$f_{v,k}$	γ_m	k_{mod}	$f_{v,d}$	V_d	$\tau_{v,d}$	utilisation
[m]	[m]	[-]	[N/mm²]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]	
3.96	2.36	Y	4.00	1.25	1.00	3.20	1.36	0.08	2 %

rolling shear

X	Y	Ri	$f_{r,k}$	γ_m	k_{mod}	$f_{r,d}$	V_d	$\tau_{r,d}$	utilisation
[m]	[m]	[-]	[N/mm²]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]	
3.96	2.36	Y	1.25	1.25	1.00	1.00	1.36	0.08	8 %

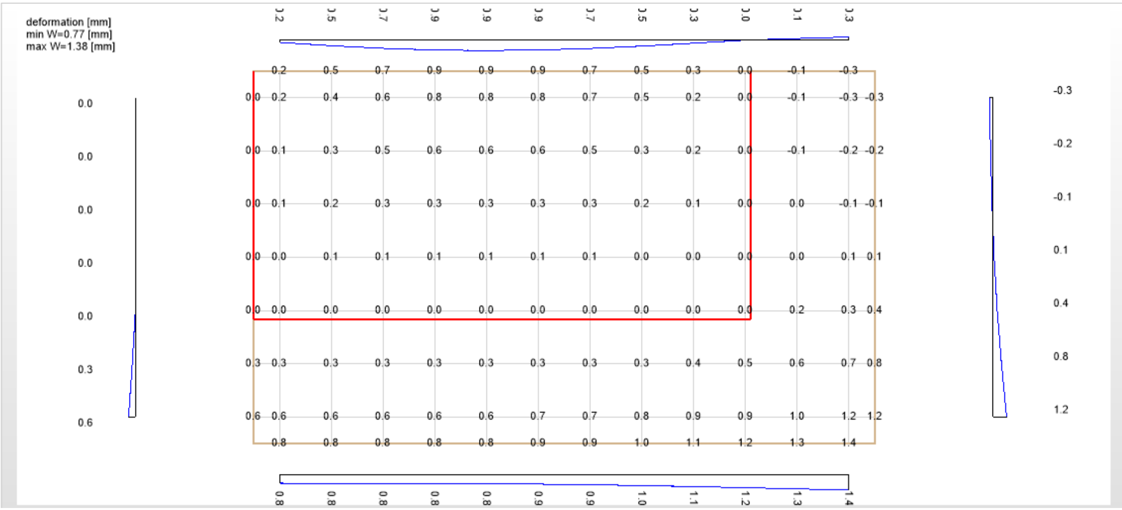


7.6.3.2. SLS design results

The results for the SLS design are being displayed in plan view, with deflection values for each intersecting node. Each load combination is being displayed in a separate figure:

quasi-permanent combinations

combination: 1.00/1.00 * LC2:self-weight structure



The blue curves to the outside of the panel are the deformation curves of the panel edges.

The comparison of the design governing deformation with the set limits is being done in similar way as in the other modules:

Service limit state design (SLS) - design results (31 %)

initial deflection [w_{char}]

X	Y	K_{def}	L_{ref}	limit	$w_{calc.}$	utilization
[m]	[m]		[m]	[mm]	[mm]	
4.79	3.0	0.8	2.0	L/300 = 6.7	1.4	21 %

final deflection [$w_{char}+w_{q.p.}*k_{def}$]

X	Y	K_{def}	L_{ref}	limit	$w_{calc.}$	utilization
[m]	[m]		[m]	[mm]	[mm]	
4.79	3.0	0.8	2.0	L/150 = 13.3	2.5	19 %

net final deflection [$w_{q.p.}*(1+k_{def})$]

X	Y	K_{def}	L_{ref}	limit	$w_{calc.}$	utilization
[m]	[m]		[m]	[mm]	[mm]	
4.79	3.0	0.8	2.0	L/250 = 8.0	2.5	31 %

The design governing point in the panel is being displayed with its X and Y coordinate, to clearly indicate the spot, where the given deformation occurs.

7.7. Columns - CLT

The module CLT columns is made for the structural analysis of CLT columns, with loading in plane and out of plane.

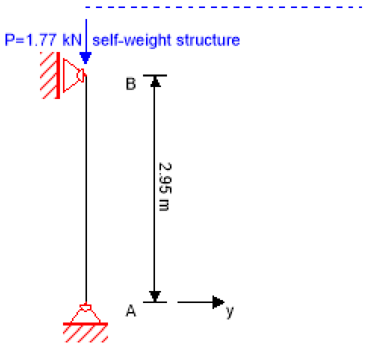
7.7.1. Design basics

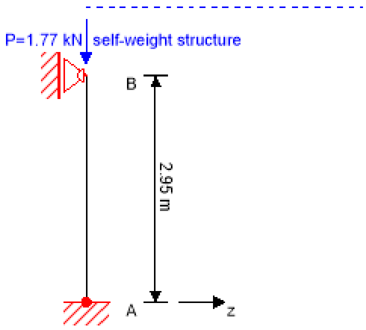
This design module performs the stability analysis according to EN 1995-1-1, chapter 6.3 [8]. The analysis of internal forces is done, using the net section of the CLT.

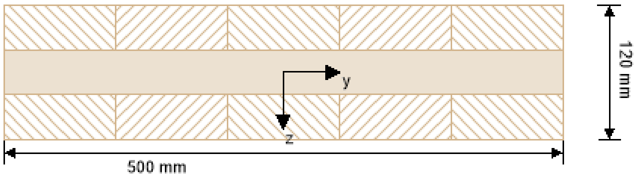
7.7.2. Column details

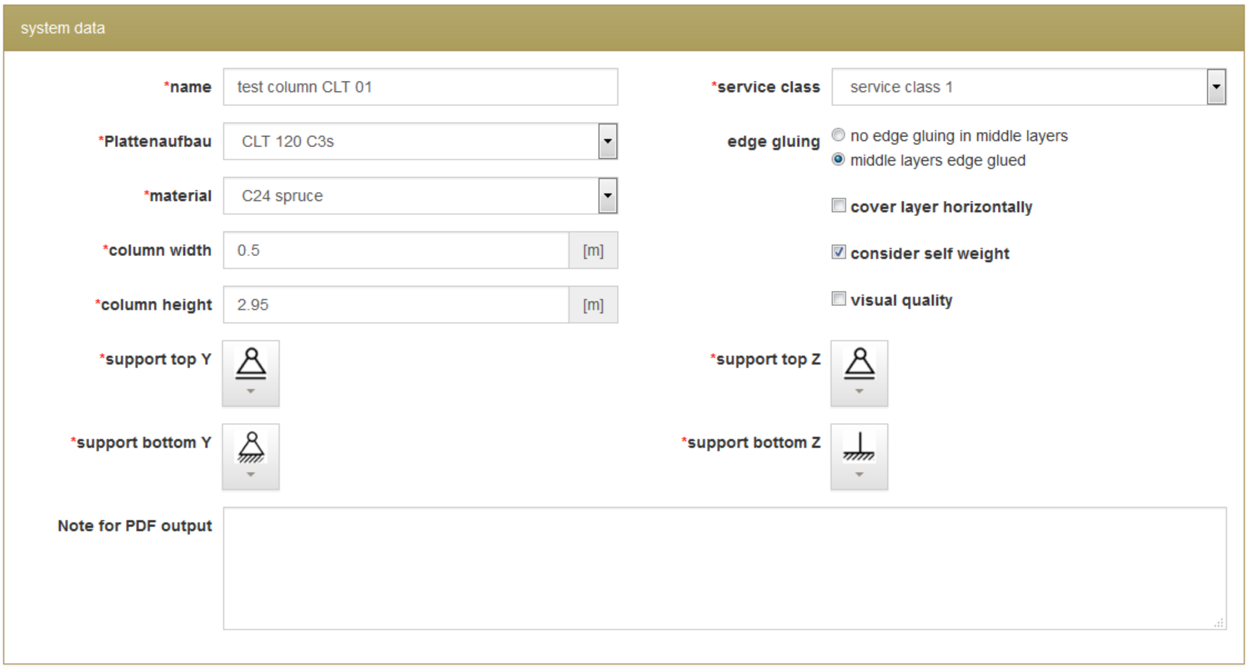
The input in this module follows the same logic as for the regular CLT deck (see chapter 7.1). The significant differences and important items will be displayed below.

7.7.2.1. System Data:

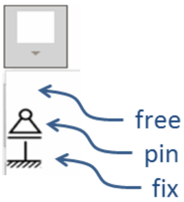








Column width and **column height** define the geometry of the column.
The **boundary conditions** of the supports need to be selected in the pull-down menu:

	 **Note:** free is displayed as white box on white background (not visible). For free, click above the pin icon.
Choice for bottom support: pin or fix	Choice for top support: free, pin or fix

Visual quality shall be checked, if the CLT shall be from visual grade. This is influencing the maximum lamination width and this parameter will enter the design for loading in the plane of CLT.
The selection "**cover layer horizontally**" shall be selected, if the cover layer shall be oriented horizontally. Choosing a "C" or a "L" panel when selecting the CLT section does not influence the orientation of the cover layer. The cover layer is in this module by default oriented vertically.

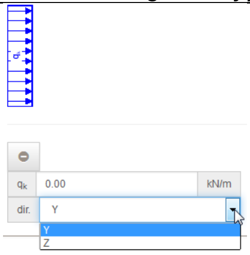
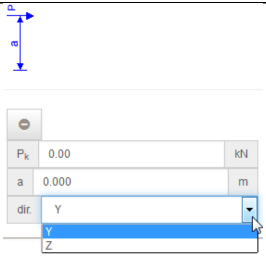
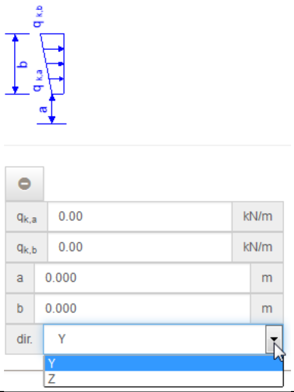
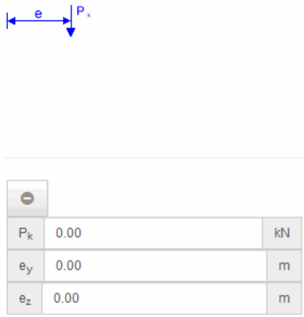
7.7.2.2. Fire design data

The input for fire design data is analogous to the input for wooden beams. See chapter 7.2.2.2.

7.7.3. Loading

The input in this module follows the same logic as for the regular CLT deck (see chapter 7.1). The significant differences and important items will be displayed below.

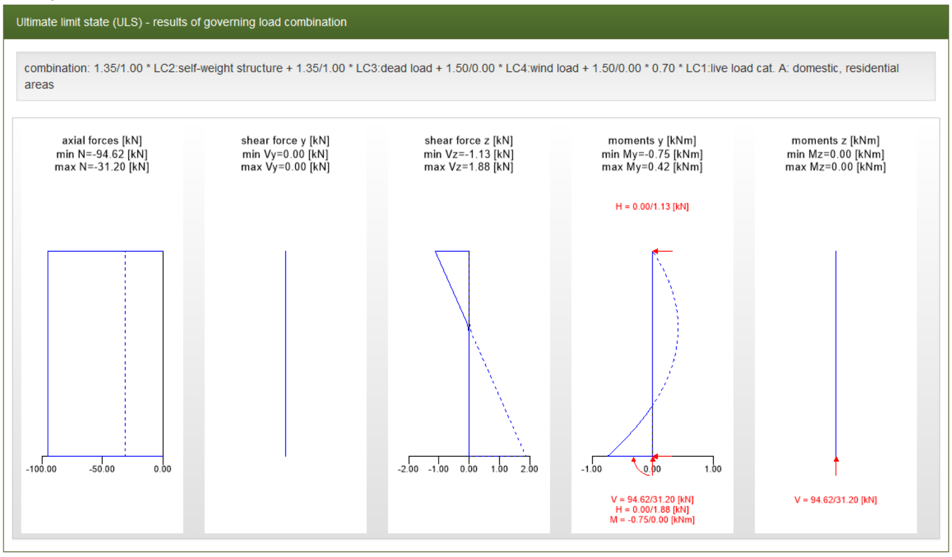
The following load types can be entered:

			
Lateral continuous load in or out of plane (in Y or Z direction)	Lateral point load in or out of plane (in Y or Z direction)	Lateral trapezoidal load in or out of plane (in Y or Z direction)	Vertical load (axial) with the possibility to add an eccentricity in Y and Z direction

7.7.4. Results

The results in this module follows the same logic as for the regular CLT deck (see chapter 7.1). The significant differences and important items will be displayed below.

The display of results is analogous to other modules. For the governing load combination in the short result compilation will look like that:



Maximum and minimum values are given in the graphical output. Intermediate values can be retrieved by clicking the graphics.

7.7.4.1. ULS design results

Ultimate limit state (ULS) - design results (12 %)

flexural design

dist.	$f_{m,k}$	$f_{o,k}$	$f_{t,k}$	γ_m	k_{mod}	$k_{sys,y}$	$f_{m,y,d}$	$f_{o,d}$	$f_{t,d}$	$M_{y,d}$	$M_{z,d}$	$N_{o,d}$	$N_{t,d}$	$\sigma_{m,y,d}$	$\sigma_{m,z,d}$	$\sigma_{o,d}$	$\sigma_{t,d}$	utilisation
[m]	[N/mm²]	[N/mm²]	[N/mm²]	[-]	[-]	[-]	[N/mm²]	[N/mm²]	[N/mm²]	[kNm]	[kNm]	[kN]	[kN]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	
0.0	24.00	21.00	14.00	1.25	0.90	1.10	19.01	15.12	10.08	-0.75	0.00	-94.62	0.00	0.32	0.00	1.18	0.00	2 %

shear analysis

dist.	$f_{v,k}$	γ_m	k_{mod}	$f_{v,d}$	V_d	$\tau_{v,d}$	utilisation
[m]	[N/mm²]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]	
0.0	4.00	1.25	0.90	2.88	1.88	0.02	1 %

rolling shear

dist.	$f_{r,k}$	γ_m	k_{mod}	$f_{r,d}$	V_d	$\tau_{r,d}$	utilisation
[m]	[N/mm²]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]	
0.0	1.25	1.25	0.90	0.90	1.88	0.02	2 %

shear design in plane of CLT - gross section

dist.	$f_{IP,Gross,k}$	γ_m	k_{mod}	$f_{IP,Gross,d}$	V_d	$\tau_{v,d}$	utilisation
[m]	[N/mm²]	[-]	[-]	[N/mm²]	[kNm]	[N/mm²]	
2.0	3.50	1.25	0.90	2.52	0.00	0.00	0 %

shear design in plane of CLT - net section

dist.	$f_{IP,Net,k}$	γ_m	k_{mod}	$f_{IP,Net,d}$	$V_{Net,d}$	$\tau_{v,Net,d}$	utilisation
[m]	[N/mm²]	[-]	[-]	[N/mm²]	[kNm]	[N/mm²]	
2.0	8.00	1.25	0.90	5.76	0.00	0.00	0 %

shear design in plane of CLT - gross section combined

dist.	γ_m	k_{mod}	$f_{v,d}$	$f_{IP,Gross,d}$	V_d	$\tau_{v,d}$	$V_{Gross,d}$	$\tau_{v,Gross,d}$	ratio
[m]	[-]	[-]	[N/mm²]	[N/mm²]	[kN]	[N/mm²]	[kNm]	[N/mm²]	
2.0	1.25	0.90	2.88	2.52	0.68	0.01	0.00	0.00	0 %

shear design in plane of CLT - net section combined

dist.	γ_m	k_{mod}	$f_{v,d}$	$f_{IP,Net,d}$	V_d	$\tau_{v,d}$	$V_{Net,d}$	$\tau_{v,Net,d}$	ratio
[m]	[-]	[-]	[N/mm²]	[N/mm²]	[kN]	[N/mm²]	[kNm]	[N/mm²]	
2.0	1.25	0.90	2.88	5.76	0.68	0.01	0.00	0.00	0 %

torsional shear design in plane of CLT - in face glued surfaces

$f_{T,Node,k}$	γ_m	k_{mod}	$f_{T,Node,d}$	$V_{delta,d}$	I_p	$\tau_{t,d}$	utilisation
[N/mm²]	[-]	[-]	[N/mm²]	[kNm]	[mm⁴]	[N/mm²]	
2.50	1.25	0.90	1.80	0.00	84375010.00	0.00	0 %

buckling design

dist.	$f_{m,k}$	$f_{o,k}$	γ_m	k_{mod}	$k_{sys,y}$	$k_{sys,z}$	$l_{k,y}$	$l_{k,z}$	λ_y	λ_z	$\lambda_{rel,y}$	$\lambda_{rel,z}$	β_o
[m]	[N/mm²]	[N/mm²]	[-]	[-]	[-]	[-]	[m]	[m]	[-]	[-]	[-]	[-]	[-]
0.0	24.00	21.00	1.25	0.80	1.10	1.00	2.000	1.400	48	5	0.77	0.08	0.1

dist.	k_y	k_z	$k_{o,y}$	$k_{o,z}$	$f_{m,y,d}$	$f_{o,d}$	$M_{y,d}$	$M_{z,d}$	$N_{o,d}$	$\sigma_{o,d}$	$\sigma_{m,y,d}$	$\sigma_{m,z,d}$	utilisation
[m]	[-]	[-]	[-]	[-]	[N/mm²]	[N/mm²]	[kNm]	[kNm]	[kN]	[N/mm²]	[N/mm²]	[N/mm²]	
0.0	0.82	0.49	0.91	1.00	16.90	13.44	0.00	0.00	-117.12	1.46	0.00	0.00	12 %

lateral torsional buckling design

dist.	$f_{m,k}$	$f_{o,k}$	γ_m	k_{mod}	$k_{sys,y}$	l_{ef}	l_k	λ_y	$\lambda_{rel,y}$	$\lambda_{rel,m}$	β_o	k_y	$k_{o,y}$	$\sigma_{m,orit}$	k_{orit}	$f_{m,y,d}$	$f_{o,d}$	$M_{z,d}$	$N_{o,d}$	$\sigma_{o,d}$	$\sigma_{m,z,d}$	ratio
[m]	[N/mm²]	[N/mm²]	[-]	[-]	[-]	[m]	[m]	[-]	[-]	[-]	[-]	[-]	[-]	[N/mm²]	[-]	[N/mm²]	[N/mm²]	[kNm]	[kN]	[N/mm²]	[N/mm²]	
0.0	24.00	21.00	1.25	0.80	1.10	2.000	2.000	48	0.77	1.06	0.1	0.82	0.91	21.53	0.77	16.90	13.44	0.00	-117.12	1.46	0.00	12 %

The ULS design results will be explained more detailed below.

Flexural design:

flexural design

dist.	$f_{m,k}$	$f_{c,k}$	$f_{t,k}$	γ_m	k_{mod}	$k_{sys,y}$	$f_{m,y,d}$	$f_{c,d}$	$f_{t,d}$	$M_{y,d}$	$M_{z,d}$	$N_{c,d}$	$N_{t,d}$	$\sigma_{m,y,d}$	$\sigma_{m,z,d}$	$\sigma_{c,d}$	$\sigma_{t,d}$	utilisation
[m]	[N/mm²]	[N/mm²]	[N/mm²]	[-]	[-]	[-]	[N/mm²]	[N/mm²]	[N/mm²]	[kNm]	[kNm]	[kN]	[kN]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	
1.2	24.00	21.00	14.00	1.25	0.90	1.10	19.01	15.12	10.08	12.60	72.00	-94.62	0.00	5.45	5.40	1.18	0.00	61 %

This includes the analysis according to EN1995-1-1, chapters 6.1.2, 6.1.4, 6.1.6 and 6.2 [8].

Shear and rolling shear design:

shear analysis

dist.	$f_{v,k}$	γ_m	k_{mod}	$f_{v,d}$	V_d	$\tau_{v,d}$	utilisation
[m]	[N/mm²]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]	
0.0	4.00	1.25	0.90	2.88	56.25	0.65	23 %

rolling shear

dist.	$f_{r,k}$	γ_m	k_{mod}	$f_{r,d}$	V_d	$\tau_{r,d}$	utilisation
[m]	[N/mm²]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]	
0.0	1.25	1.25	0.90	0.90	56.25	0.65	72 %

The design in the tables above covers the shear and rolling shear analysis for shear load perpendicular to the plane of CLT.

shear design in plane of CLT - gross section

dist.	$f_{IP,Gross,k}$	γ_m	k_{mod}	$f_{IP,Gross,d}$	V_d	$\tau_{v,d}$	utilisation
[m]	[N/mm²]	[-]	[-]	[N/mm²]	[kNm]	[N/mm²]	
0.0	3.50	1.25	0.90	2.52	150.00	1.88	74 %

shear design in plane of CLT - net section

dist.	$f_{IP,Net,k}$	γ_m	k_{mod}	$f_{IP,Net,d}$	$V_{Net,d}$	$\tau_{v,Net,d}$	utilisation
[m]	[N/mm²]	[-]	[-]	[N/mm²]	[kNm]	[N/mm²]	
0.0	8.00	1.25	0.90	5.76	150.00	5.63	98 %

The design in the tables above covers the shear analysis for shear load in the plane of CLT for the net and gross section. This shear design follows the Expertise by Prof Blass on shear in the plane of CLT [18].

Shear stress in timber elements for loading in 2 different directions is being combined and verified according to the Austrian national annex of EN 1995-1-1 [9], equation NA.6.15-E1. In this software, this combination was adapted for all countries.

Shear combination for shear on gross section

shear analysis

dist.	$f_{v,k}$	γ_m	k_{mod}	$f_{v,d}$	V_d	$\tau_{v,d}$	utilisation
[m]	[N/mm²]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]	
0.0	4.00	1.25	0.90	2.88	56.25	0.65	23 %

shear design in plane of CLT - gross section

dist.	$f_{IP,Gross,k}$	γ_m	k_{mod}	$f_{IP,Gross,d}$	V_d	$\tau_{v,d}$	utilisation
[m]	[N/mm²]	[-]	[-]	[N/mm²]	[kNm]	[N/mm²]	
0.0	3.50	1.25	0.90	2.52	150.00	1.88	74 %

shear design in plane of CLT - gross section combined

dist.	γ_m	k_{mod}	$f_{v,d}$	$f_{IP,Gross,d}$	V_d	$\tau_{v,d}$	$V_{Gross,d}$	$\tau_{v,Gross,d}$	ratio
[m]	[-]	[-]	[N/mm²]	[N/mm²]	[kN]	[N/mm²]	[kNm]	[N/mm²]	
0.0	1.25	0.90	2.88	2.52	56.25	0.65	150.00	1.88	60 %

EN 1995-1-1 [9], equation NA.6.15-E1

$$\left(\frac{\tau_{y,d}}{f_{v,d}}\right)^2 + \left(\frac{\tau_{z,d}}{f_{v,d}}\right)^2 \leq 1$$

Adapted to shear in and out of plane, this means:

$$\underbrace{\left(\frac{\tau_{v,d}}{f_{v,d}}\right)^2}_{perpendicular\ to\ plane} + \underbrace{\left(\frac{\tau_{v,Gross,d}}{f_{IP,Gross,d}}\right)^2}_{in\ plane} \leq 1$$

Expressed in numbers with values from the example on the left:

$$\underbrace{\left(\frac{0{,}65}{2{,}88}\right)^2}_{perpendicular\ to\ plane} + \underbrace{\left(\frac{1{,}88}{2{,}52}\right)^2}_{in\ plane} = 0{,}60 \leq 1$$

Shear combination for shear on net section

shear analysis

dist.	$f_{v,k}$	γ_m	k_{mod}	$f_{v,d}$	V_d	$\tau_{v,d}$	utilisation
[m]	[N/mm²]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]	
0.0	4.00	1.25	0.90	2.88	56.25	0.65	23 %

shear design in plane of CLT - net section

dist.	$f_{IP,Net,k}$	γ_m	k_{mod}	$f_{IP,Net,d}$	$V_{Net,d}$	$\tau_{v,Net,d}$	utilisation
[m]	[N/mm²]	[-]	[-]	[N/mm²]	[kNm]	[N/mm²]	
0.0	8.00	1.25	0.90	5.76	150.00	5.63	98 %

shear design in plane of CLT - net section combined

dist.	γ_m	k_{mod}	$f_{v,d}$	$f_{IP,Net,d}$	V_d	$\tau_{v,d}$	$V_{Net,d}$	$\tau_{v,Net,d}$	ratio
[m]	[-]	[-]	[N/mm²]	[N/mm²]	[kN]	[N/mm²]	[kNm]	[N/mm²]	
0.0	1.25	0.90	2.88	5.76	56.25	0.65	150.00	5.63	100 %

EN 1995-1-1 [9], equation NA.6.15-E1

$$\left(\frac{\tau_{y,d}}{f_{v,d}}\right)^2 + \left(\frac{\tau_{z,d}}{f_{v,d}}\right)^2 \leq 1$$

Adapted to shear in and out of plane, this means:

$$\underbrace{\left(\frac{\tau_{v,d}}{f_{v,d}}\right)^2}_{perpendicular\ to\ plane} + \underbrace{\left(\frac{\tau_{v,Net,d}}{f_{IP,Net,d}}\right)^2}_{in\ plane} \leq 1$$

Expressed in numbers with values from the example on the left:

$$\underbrace{\left(\frac{0{,}65}{2{,}88}\right)^2}_{perpendicular\ to\ plane} + \underbrace{\left(\frac{5{,}63}{5{,}76}\right)^2}_{in\ plane} = 1{,}006 < 1$$

Torsional shear in the plane of CLT in the face glued surfaces

torsional shear design in plane of CLT - in face glued surfaces

$f_{T,Node,k}$	γ_m	k_{mod}	$f_{T,Node,d}$	$V_{delta,d}$	I_p	$\tau_{t,d}$	utilisation
[N/mm²]	[-]	[-]	[N/mm²]	[kNm]	[mm⁴]	[N/mm²]	
2.50	1.25	0.90	1.80	150.00	84375010.00	1.67	93 %

For this analysis the torsional shear that occurs in each face glued surface (intersecting surface of 2 crossing lamination plates). For this, the lamination plate width needs to be known.
For Stora Enso CLT it is assumed, that the lamination width is as follows:

- Non-visual grade CLT (NVI): lamination plate width a_{lam} = 15 cm
- Visual grade CLT (VI & IVI): lamination plate width a_{lam} = 10 cm

$$\tau_{t,d} = \frac{M_{T,i,d}}{I_{p,i}} + \frac{a_{lam}}{2}$$

$M_{T,I,d}$ = design torsional moment per glued surface, derived from the design moment
$I_{p,i}$ = polar moment of inertia for the intersecting surface = a_{Lam}^4 / 6

CLT Engineer

Buckling and lateral torsional buckling analysis follow EN 1995-1-1 [8], chapter 6.3:

buckling design

dist.	$f_{m,k}$	$f_{c,k}$	γ_m	k_{mod}	$k_{sys,y}$	$k_{sys,z}$	$l_{k,y}$	$l_{k,z}$	λ_y	λ_z	$\lambda_{rel,y}$	$\lambda_{rel,z}$	β_c
[m]	[N/mm²]	[N/mm²]	[-]	[-]	[-]	[-]	[m]	[m]	[-]	[-]	[-]	[-]	[-]
1.2	24.00	21.00	1.25	0.90	1.10	1.00	2.000	1.400	48	5	0.77	0.08	0.1

dist.	k_y	k_z	$k_{c,y}$	$k_{c,z}$	$f_{m,y,d}$	$f_{c,d}$	$M_{y,d}$	$M_{z,d}$	$N_{c,d}$	$\sigma_{c,d}$	$\sigma_{m,y,d}$	$\sigma_{m,z,d}$	utilisation
[m]	[-]	[-]	[-]	[-]	[N/mm²]	[N/mm²]	[kNm]	[kNm]	[kN]	[N/mm²]	[N/mm²]	[N/mm²]	
1.2	0.82	0.49	0.91	1.00	19.01	15.12	12.60	72.00	-94.62	1.18	5.45	5.40	69 %

lateral torsional buckling design

dist.	$f_{m,k}$	$f_{c,k}$	γ_m	k_{mod}	$k_{sys,y}$	l_{ef}	l_k	λ_y	$\lambda_{rel,y}$	$\lambda_{rel,m}$	β_c	k_y	$k_{c,y}$	$\sigma_{m,crit}$	k_{crit}	$f_{m,y,d}$	$f_{c,d}$	$M_{z,d}$	$N_{c,d}$	$\sigma_{c,d}$	$\sigma_{m,z,d}$	ratio
[m]	[N/mm²]	[N/mm²]	[-]	[-]	[-]	[m]	[m]	[-]	[-]	[-]	[-]	[-]	[-]	[N/mm²]	[-]	[N/mm²]	[N/mm²]	[kNm]	[kN]	[N/mm²]	[N/mm²]	
1.0	24.00	21.00	1.25	0.90	1.10	2.000	2.000	48	0.77	1.06	0.1	0.82	0.91	21.53	0.77	19.01	15.12	75.00	-42.12	0.53	5.63	42 %

7.7.4.2. fire design results

The fire design of a CLT column is analogous to the ULS design – see chapter 7.7.4.1, just using the residual section, after the fire.

7.8. Columns – solid timber / glulam / LVL

The module CLT columns is made for the structural analysis of columns made from rectangular sections of either glulaminated timber, solid timber or LVL. Loading can be in plane and/or out of plane.
The input, results and analysis are mostly analogous to the module CLT columns – see chapter 7.7.

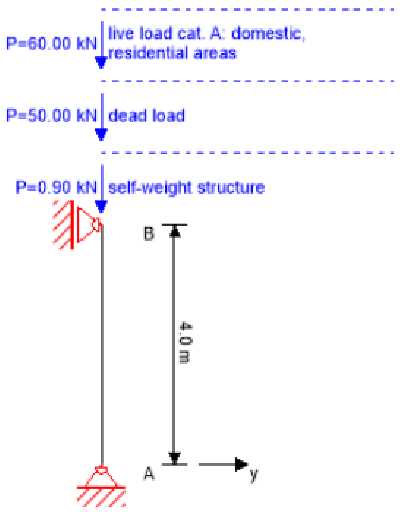
7.8.1. Design basics

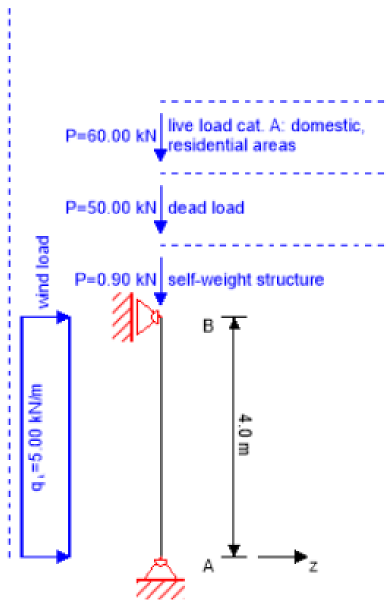
This design module performs the stability analysis according to EN 1995-1-1, chapter 6.3 [8].

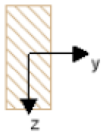
7.8.2. Column details

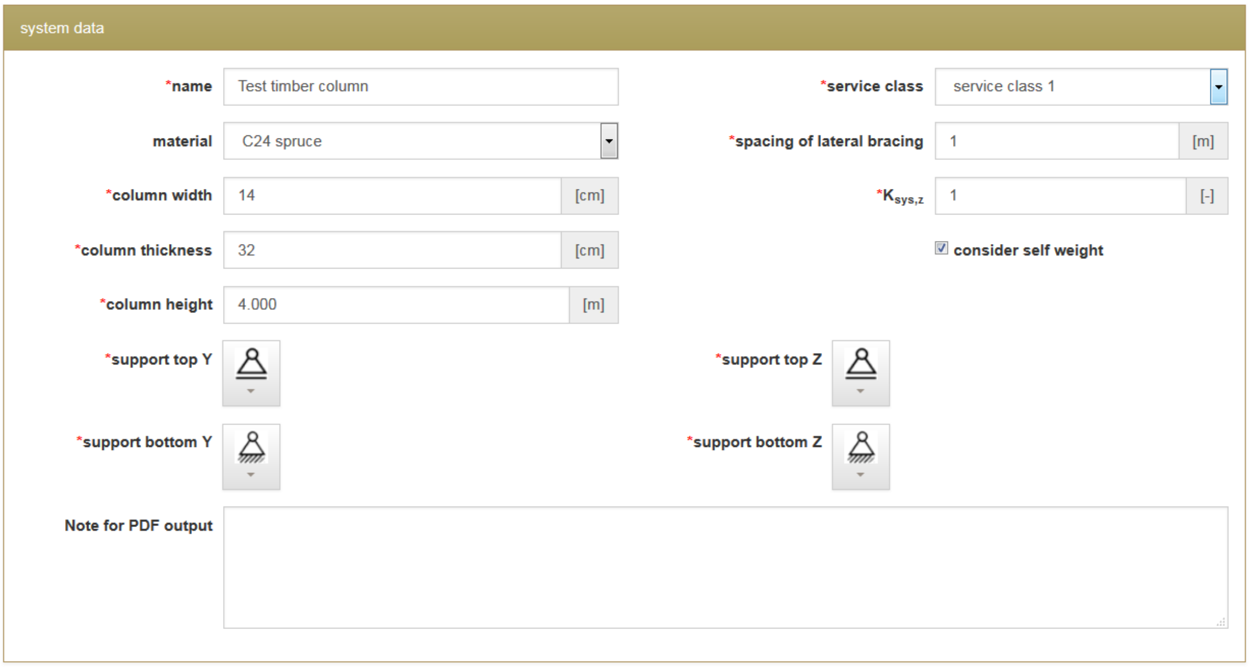
The input in this module follows the same logic as for the regular CLT deck (see chapter 7.1). The significant differences and important items will be displayed below.

7.8.2.1. System Data:



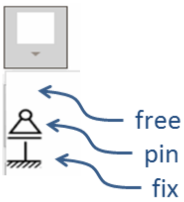






Column width and **column height** define the geometry of the column (rectangular section).
Spacing of lateral bracing: insert the spacing at which the beam is held in lateral direction. This value is entering the lateral torsional buckling design. The spacing could be for example the spacing of purlins or rafters that are supported by the beam. If a panels or sheathing is being fastened at the top flange of the beam, then put 0 as spacing, meaning the beam is continuously held.
$\mathbf{k_{sys,z}}$**:** is the system factor for the given beam section in z-direction (see EN1995-1-1_6.6) [8]. Assuming a glulam beam is being picked, then the lamination is usually layered in vertical direction. Therefore no system factor can apply for bending about the Y-axis. For bending about the Z-axis, the tension face of the beam (lateral surface) is divided in all the lamination layers and therefore a system factor can be applied for bending about the Z-axis.

The **boundary conditions** of the supports need to be selected in the pull-down menu:

	 **Note:** free is displayed as white box on white background (not visible). For free, click above the pin icon.
Choice for bottom support: pin or fix	Choice for top support: free, pin or fix

7.8.3. Results

The results in this module follows the same logic as for the CLT column (see chapter 7.7.47.1). The significant differences and important items will be displayed below.

7.8.3.1. ULS design results

Ultimate limit state (ULS) - design results (61 %)

flexural design

dist.	$f_{m,k}$	$f_{c,k}$	$f_{t,k}$	γ_m	k_{mod}	$k_{sys,y}$	$f_{m,y,d}$	$f_{c,d}$	$f_{t,d}$	$M_{y,d}$	$M_{z,d}$	$N_{c,d}$	$N_{t,d}$	$\sigma_{m,y,d}$	$\sigma_{m,z,d}$	$\sigma_{c,d}$	$\sigma_{t,d}$	utilisation
[m]	[N/mm²]	[N/mm²]	[N/mm²]	[-]	[-]	[-]	[N/mm²]	[N/mm²]	[N/mm²]	[kNm]	[kNm]	[kN]	[kN]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	
2.0	24.00	21.00	14.00	1.30	0.90	1.00	16.62	14.54	9.83	15.00	0.00	-131.71	0.00	6.28	0.00	2.94	0.00	42 %

shear analysis Y

dist.	$f_{v,k}$	γ_m	k_{mod}	$f_{v,d}$	V_d	$\tau_{v,d}$	utilisation
[m]	[N/mm²]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]	
3.68	2.30	1.30	0.90	1.59	0.00	0.00	0 %

shear analysis Z

dist.	$f_{v,k}$	γ_m	k_{mod}	$f_{v,d}$	V_d	$\tau_{v,d}$	utilisation
[m]	[N/mm²]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]	
0.32	2.30	1.30	0.90	1.59	12.60	0.42	26 %

shear analysis combined

dist.	$f_{v,k}$	γ_m	k_{mod}	$f_{v,d}$	$V_{y,d}$	$V_{z,d}$	$\tau_{v,y,d}$	$\tau_{v,z,d}$	ratio
[m]	[N/mm²]	[-]	[-]	[N/mm²]	[kN]	[kN]	[N/mm²]	[N/mm²]	
0.32	2.30	1.30	0.90	1.59	0.00	12.60	0.00	0.42	7 %

buckling design

dist.	$f_{m,k}$	$f_{c,k}$	γ_m	k_{mod}	$k_{sys,y}$	$k_{sys,z}$	$l_{k,y}$	$l_{k,z}$	λ_y	λ_z	$\lambda_{rel,y}$	$\lambda_{rel,z}$	β_c
[m]	[N/mm²]	[N/mm²]	[-]	[-]	[-]	[-]	[m]	[m]	[-]	[-]	[-]	[-]	[-]
2.0	24.00	21.00	1.30	0.90	1.00	1.00	4.000	1.000	43	25	0.73	0.42	0.2

dist.	k_y	k_z	$k_{c,y}$	$k_{c,z}$	$f_{m,y,d}$	$f_{c,d}$	$M_{y,d}$	$M_{z,d}$	$N_{c,d}$	$\sigma_{c,d}$	$\sigma_{m,y,d}$	$\sigma_{m,z,d}$	utilisation
[m]	[-]	[-]	[-]	[-]	[N/mm²]	[N/mm²]	[kNm]	[kNm]	[kN]	[N/mm²]	[N/mm²]	[N/mm²]	
2.0	0.81	0.60	0.86	0.97	16.62	14.54	15.00	0.00	-131.71	2.94	6.28	0.00	61 %

lateral torsional buckling design

dist.	$f_{m,k}$	$f_{c,k}$	γ_m	k_{mod}	$k_{sys,y}$	l_{ef}	l_k	λ_y	$\lambda_{rel,y}$	$\lambda_{rel,m}$	β_c	k_y	$k_{c,y}$	$\sigma_{m,crit}$	k_{crit}	$f_{m,y,d}$	$f_{c,d}$	$M_{z,d}$	$N_{c,d}$	$\sigma_{c,d}$	$\sigma_{m,z,d}$	ratio
[m]	[N/mm²]	[N/mm²]	[-]	[-]	[-]	[m]	[m]	[-]	[-]	[-]	[-]	[-]	[-]	[N/mm²]	[-]	[N/mm²]	[N/mm²]	[kNm]	[kN]	[N/mm²]	[N/mm²]	
2.0	24.00	21.00	1.30	0.90	1.00	4.000	1.000	11	0.18	0.56	0.2	0.51	1.00	75.58	1.00	16.62	14.54	0.00	-131.71	2.94	0.00	38 %

The ULS design results will be explained more detailed below.

Flexural design:

flexural design

dist.	$f_{m,k}$	$f_{c,k}$	$f_{t,k}$	γ_m	k_{mod}	$k_{sys,y}$	$f_{m,y,d}$	$f_{c,d}$	$f_{t,d}$	$M_{y,d}$	$M_{z,d}$	$N_{c,d}$	$N_{t,d}$	$\sigma_{m,y,d}$	$\sigma_{m,z,d}$	$\sigma_{c,d}$	$\sigma_{t,d}$	utilisation
[m]	[N/mm²]	[N/mm²]	[N/mm²]	[-]	[-]	[-]	[N/mm²]	[N/mm²]	[N/mm²]	[kNm]	[kNm]	[kN]	[kN]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	
2.0	24.00	21.00	14.00	1.30	0.90	1.00	16.62	14.54	9.83	15.00	0.00	-131.71	0.00	6.28	0.00	2.94	0.00	42 %

This includes the analysis according to EN1995-1-1, chapters 6.1.2, 6.1.4, 6.1.6 and 6.2 [8].

Shear design:

shear analysis Y

dist.	$f_{v,k}$	γ_m	k_{mod}	$f_{v,d}$	V_d	$\tau_{v,d}$	utilisation
[m]	[N/mm²]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]	
3.68	2.30	1.30	0.90	1.59	0.00	0.00	0 %

shear analysis Z

dist.	$f_{v,k}$	γ_m	k_{mod}	$f_{v,d}$	V_d	$\tau_{v,d}$	utilisation
[m]	[N/mm²]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]	
0.32	2.30	1.30	0.90	1.59	12.60	0.42	26 %

shear analysis combined

dist.	$f_{v,k}$	γ_m	k_{mod}	$f_{v,d}$	$V_{y,d}$	$V_{z,d}$	$\tau_{v,y,d}$	$\tau_{v,z,d}$	ratio
[m]	[N/mm²]	[-]	[-]	[N/mm²]	[kN]	[kN]	[N/mm²]	[N/mm²]	
0.32	2.30	1.30	0.90	1.59	0.00	12.60	0.00	0.42	7 %

Shear stress in timber elements for loading in 2 different directions is being combined and verified according to the Austrian national annex of EN 1995-1-1 [9], equation NA.6.15-E1. In this software, this combination was adapted for all countries.

$$\left(\frac{\tau_{y,d}}{f_{v,d}}\right)^2 + \left(\frac{\tau_{z,d}}{f_{v,d}}\right)^2 \leq 1$$

Buckling and lateral torsional buckling analysis follow EN 1995-1-1 [8], chapter 6.3:

buckling design

dist.	$f_{m,k}$	$f_{c,k}$	γ_m	k_{mod}	$k_{sys,y}$	$k_{sys,z}$	$l_{k,y}$	$l_{k,z}$	λ_y	λ_z	$\lambda_{rel,y}$	$\lambda_{rel,z}$	β_c
[m]	[N/mm²]	[N/mm²]	[-]	[-]	[-]	[-]	[m]	[m]	[-]	[-]	[-]	[-]	[-]
2.0	24.00	21.00	1.30	0.90	1.00	1.00	4.000	1.000	43	25	0.73	0.42	0.2

dist.	k_y	k_z	$k_{c,y}$	$k_{c,z}$	$f_{m,y,d}$	$f_{c,d}$	$M_{y,d}$	$M_{z,d}$	$N_{c,d}$	$\sigma_{c,d}$	$\sigma_{m,y,d}$	$\sigma_{m,z,d}$	utilisation
[m]	[-]	[-]	[-]	[-]	[N/mm²]	[N/mm²]	[kNm]	[kNm]	[kN]	[N/mm²]	[N/mm²]	[N/mm²]	
2.0	0.81	0.60	0.86	0.97	16.62	14.54	15.00	0.00	-131.71	2.94	6.28	0.00	61 %

lateral torsional buckling design

dist.	$f_{m,k}$	$f_{c,k}$	γ_m	k_{mod}	$k_{sys,y}$	l_{ef}	l_k	λ_y	$\lambda_{rel,y}$	$\lambda_{rel,m}$	β_c	k_y	$k_{c,y}$	$\sigma_{m,crit}$	k_{crit}	$f_{m,y,d}$	$f_{c,d}$	$M_{z,d}$	$N_{c,d}$	$\sigma_{c,d}$	$\sigma_{m,z,d}$	ratio
[m]	[N/mm²]	[N/mm²]	[-]	[-]	[-]	[m]	[m]	[-]	[-]	[-]	[-]	[-]	[-]	[N/mm²]	[-]	[N/mm²]	[N/mm²]	[kNm]	[kN]	[N/mm²]	[N/mm²]	
2.0	24.00	21.00	1.30	0.90	1.00	4.000	1.000	11	0.18	0.56	0.2	0.51	1.00	75.58	1.00	16.62	14.54	0.00	-131.71	2.94	0.00	38 %

7.8.3.2. fire design results

The fire design of a CLT column is analogous to the ULS design – see chapter 7.7.4.1, just using the residual section, after the fire.

7.9. Columns - steel

The module steel columns is made for the structural analysis of columns made from steel sections (wide flange or tubes).
The input is mostly analogous to the module CLT columns – see chapter 7.7.

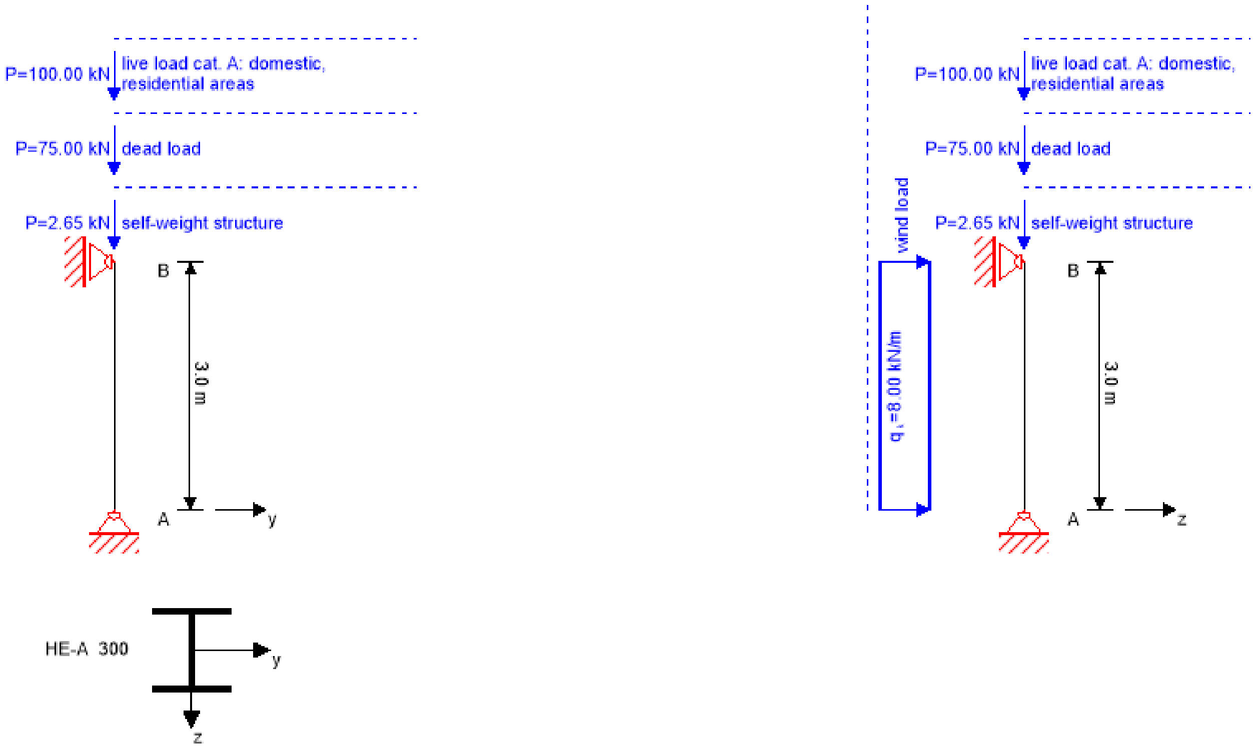
7.9.1. Design basics

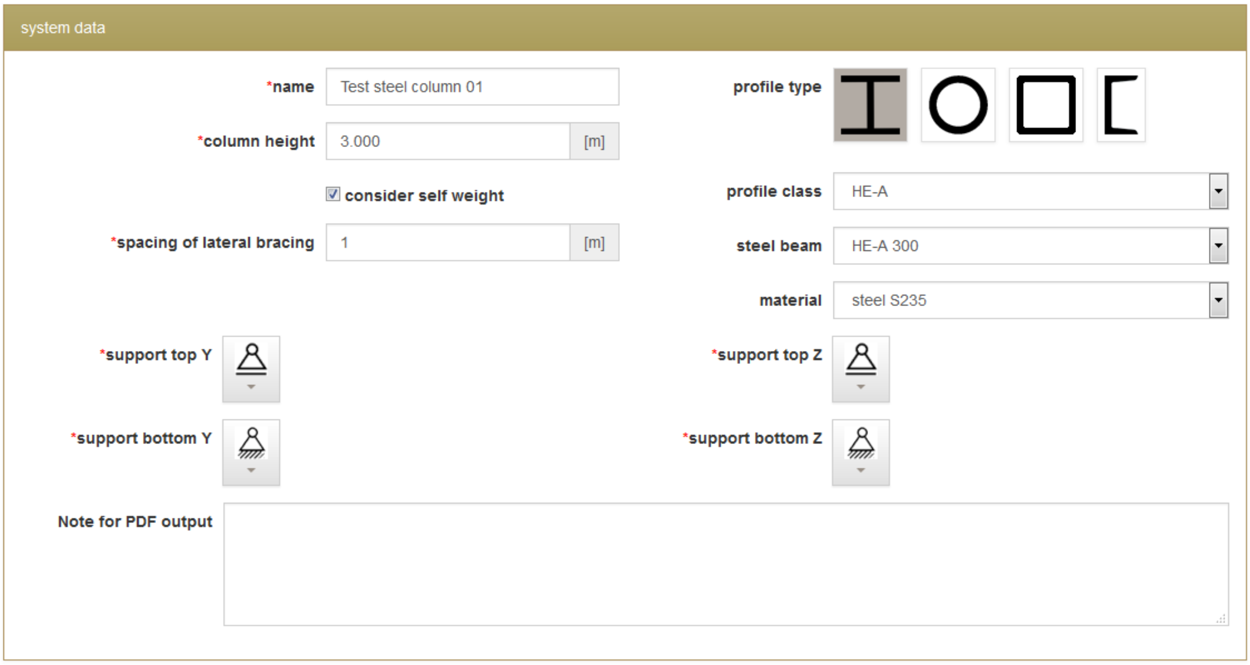
This design module performs the stability analysis according to EN 1993-1-1 [12].

7.9.2. Column details

The input in this module follows the same logic as for the regular timber column (see chapter 7.8). The significant differences and important items will be displayed below.

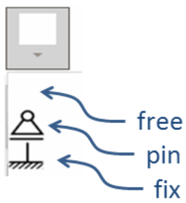
7.9.2.1. System Data:





Spacing of lateral bracing: insert the spacing at which the beam is held in lateral direction (weak axis). This value is entering the lateral torsional buckling design. The spacing could be for example the spacing of purlins or rafters that are supported by the beam. If a panels or sheathing is being fastened at the top flange of the beam, then put 0 as spacing, meaning the beam is continuously held.
Profile type selection gives the possibility to select between wide flange, circular tube, rectangular tube and channel profiles.
Depending on the selected **profile type**, a profile class (e.g.: HE-A, IPB, HE-M, etc.) can be chosen.
In the selection **steel beam** the final profile will be selected (size).
In the pull-down menu “**material**”, the steel grade can be chosen.

The **boundary conditions** of the supports need to be selected in the pull-down menu:

	 **Note:** free is displayed as white box on white background (not visible). For free, click above the pin icon.
Choice for bottom support: pin or fix	Choice for top support: free, pin or fix

7.9.3. Results

The results in this module follows a similar logic as for the CLT column (see chapter 7.7.4). The significant differences and important items will be displayed below.

7.9.3.1. ULS design results

Ultimate limit state (ULS) - design results (29 %)

compressive force design

Qkl	$N_{c,Rd}$	N_{Ed}	utilization
[-]	[kN]	[kN]	
1	2643.75	-504.88	19 %

flexural design

Qkl	$M_{y,c,Rd}$	$M_{y,Ed}$	utilization
[-]	[kNm]	[kNm]	
1	325.01	30.15	9 %

shear analysis

Qkl	A_v	$V_{c,Rd}$	V_{Ed}	utilization
[-]	[kN]	[kN]	[kN]	
1	0.00	505.40	15.08	3 %

flexural design + shear analysis

Qkl	$V_{pl,Rd}$	$M_{y,c,Rd}$	V_{Ed}	$M_{y,c,Ed}$	utilization
[-]	[kN]	[kNm]	[kN]	[kNm]	
1	505.40	325.01	15.08	30.15	9 %

flexural design + axial force design + shear analysis

Qkl	$Q_{z,c,Rd}$	$N_{y,c,Rd}$	$M_{y,pl,Rd}$	$M_{zpl,Rd}$	$Q_{z,c,Ed}$	$N_{y,c,Ed}$	$M_{y,c,Ed}$	$M_{z,c,Ed}$	utilization
[-]	[kN]	[kN]	[kN]	[kN]	[kN]	[kN]	[kNm]	[kNm]	
1	505.40	2643.75	325.01	150.68	15.08	-504.88	30.15	0.00	10 %

buckling design

Qkl	λ_y	λ_z	χ_y	χ_z	$N_{b,y,Rd}$	$N_{b,z,Rd}$	N_{Ed}	utilization
[-]	[-]	[-]	[-]	[-]	[kN]	[kN]	[kN]	
1	15.70	26.70	1.00	0.96	2643.75	2530.38	-504.88	19 %

Lateral torsional buckling design

Qkl	χ_t	$N_{b,y,Rd}$	N_{Ed}	utilization
[-]	[-]	[kN]	[kN]	
1	0.95	2508.50	-504.88	20 %

lateral torsional buckling design

Qkl	$N_{y,Rd}$	$N_{z,Rd}$	$M_{z,Rd}$	$M_{y,Rd}$	$C_{m,y}$	$C_{m,z}$	$C_{m,LT}$	K_{yy}	K_{zz}	K_{yz}	K_{zy}	N_{Ed}	V_{Ed}	$M_{y,Ed}$	$M_{z,Ed}$	utilization
[-]	[kN]	[kN]	[kNm]	[kNm]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[kN]	[kN]	[kNm]	[kNm]	
1	2643.75	2530.38	150.68	291.63	0.90	0.60	0.90	0.89	0.60	0.36	0.88	-504.88	15.08	30.15	0.00	29 %

The ULS design is covering all relevant chapters from EN 1993-1-1 [12].

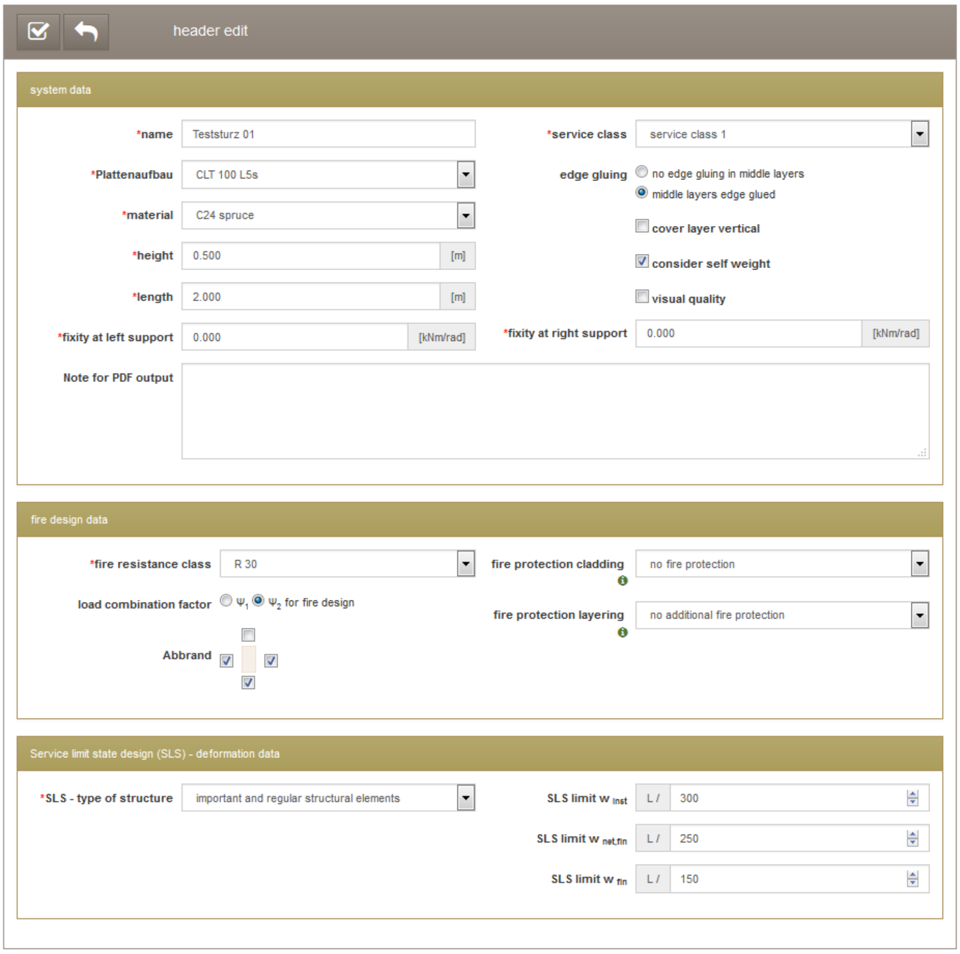
7.10. CLT beam with loading in plane (e.g.: window header)

The module CLT beam is made for CLT with loading, in the plane of the CLT (e.g.: window or door header, etc.). Since that type of CLT beams that receive loading in plane of the CLT are mostly headers, we refer to this type of beam as header in this document and the software.
The module is limiting the header design to **single span** beams. This will cover the need of engineers in most cases of a daily work routine. In case a CLT beam with loading in plane needs to be analyzed that has more than 1 span and might even cantilever, or have voids too, we suggest to use the module CLT wall and deep beam design – see chapter 7.11.

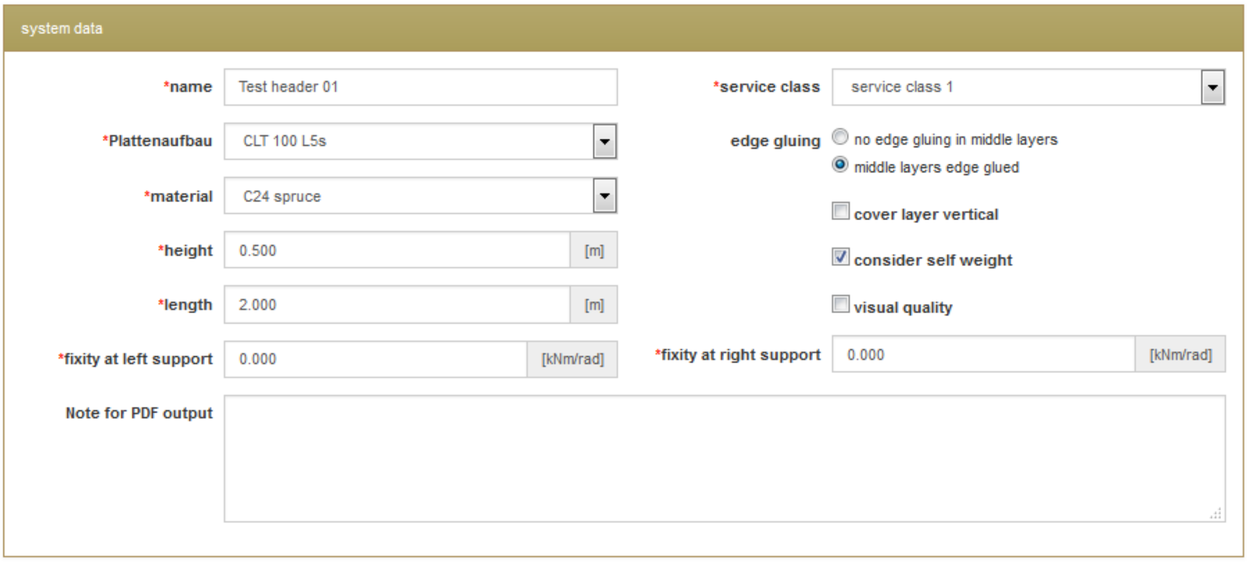
7.10.1. Design basics

To describe the flexural analysis of a CLT beam with loading in plane in a very simple way, one could say, that the section is being analyzed as homogeneous, rectangular section, just taking the lamination in principal direction into account, disregarding the cross layers (vertical layers).
The shear analysis is being done according to the technical expertise by Prof Blass on shear in the plane of CLT [18].

7.10.2. Header details



7.10.2.1. System Data:



Height and **length** are determining the geometry of the header. Note: this module was made for single span beams (typical headers). For more complex cases, use the module CLT wall and deep beam design – see chapter 7.11.
Fixity at left (or right) support: in case the header is fixed at the end and not supported by a pin support, a degree of fixity can be defined [kNm/rad].
By default the cover layer of the CLT panel in this module is assumed to be horizontal. Is this not the case, the box "**cover layer vertical**" needs to be checked.

The fire design data and SLS data is analogous to other software modules.

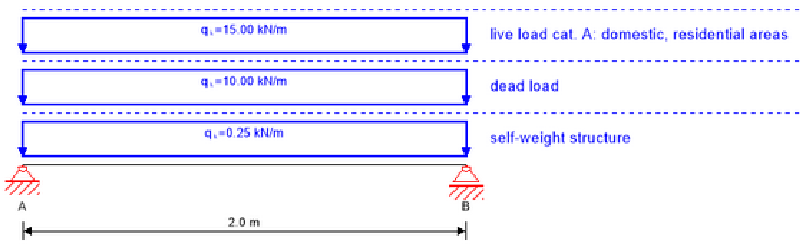
7.10.3. Loading

Entering load data is analogous to the module CLT panel with loading out of plane – see chapter 7.1.5.

7.10.4. Results

The user has the choice to either see only the design relevant results by clicking “results” or the entire list of results can be displayed by clicking “detailed result”.

System:



The geometry with all the loading will be displayed.

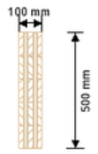
Utilization rates:

utilization ratios					
global utilization ratio					53 %
ULS	53 %	ULS fire	33 %	SLS	10 %

All design relevant utilization rates are being displayed. Those higher than 100% are highlighted in red.

Section:

section CLT 100 L5s



layer	thickness	type	material
1	20.0 mm	L	C24 spruce
2	20.0 mm	C	C24 spruce
3	20.0 mm	L	C24 spruce
4	20.0 mm	C	C24 spruce
5	20.0 mm	L	C24 spruce

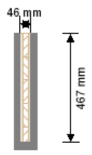
	area	moment of inertia	section modulus
	[mm²]	[mm⁴]	[mm³]
net	30,000	625,000,000	2,500,000
total	50,000	1,041,667,000	4,166,667

Z	static moment
-50	0
-30	400,000
-10	400,000
0	425,000
10	400,000
30	400,000
50	0

The section with all its relevant properties is being displayed.

Section fire design:

section fire CLT 100 L5s



fire protection layering: no additional fire protection

layer	thickness	type	material	$\beta_{0,v}$	$\beta_{n,v}$
2	13.0 mm	C	C24 spruce	0.63	0.86
3	20.0 mm	L	C24 spruce	0.63	0.86
4	13.0 mm	C	C24 spruce	0.63	0.86

k_0	d_0	$d_{char,0,h}$	$d_{ef,h}$
[-]	[mm]	[cm]	[cm]
1	7	20.0	27.0

	area	moment of inertia	section modulus
	[mm²]	[mm⁴]	[mm³]
net	9,344	169,964,100	727,586
total	21,491	390,917,500	4,459,190

Z	static moment
-23	0
-10	0
0	23,360
10	0
23	0

The section for the fire design is being displayed.

Material values:

material values

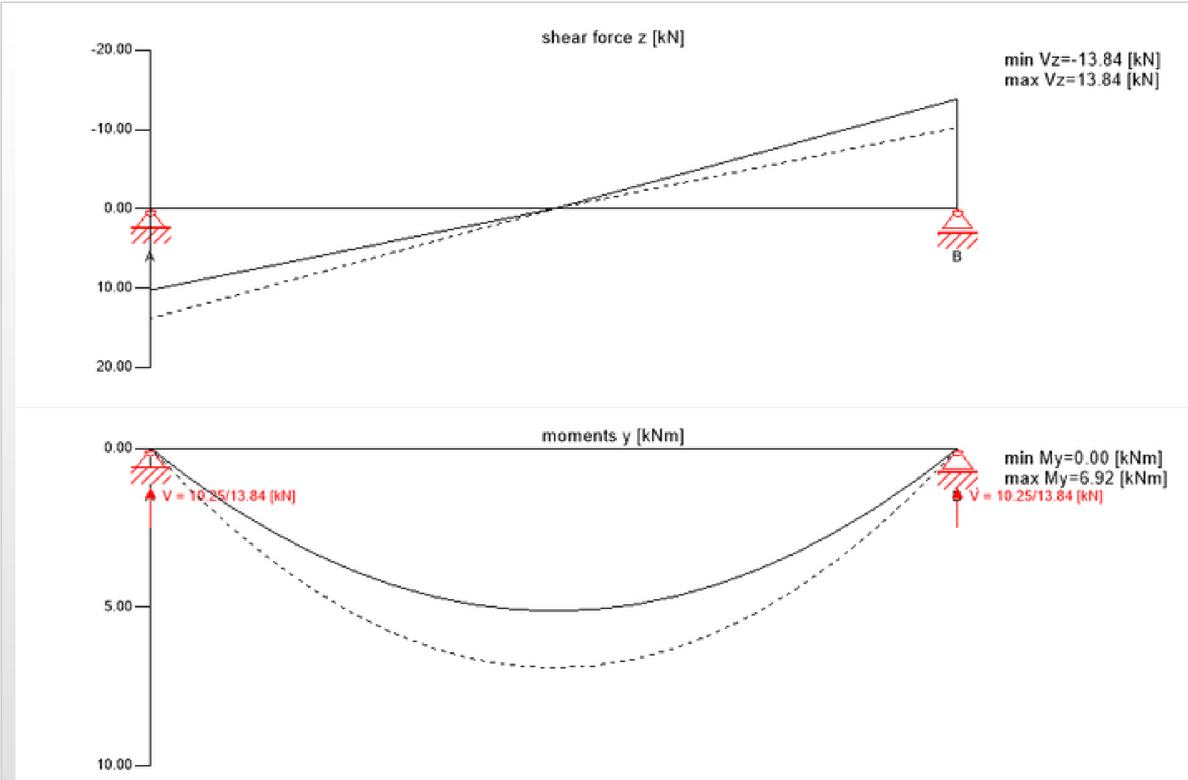
material	$f_{m,k}$	$f_{t,0,k}$	$f_{t,90,k}$	$f_{c,0,k}$	$f_{c,90,k}$	$f_{v,k}$	$f_{r,k\ min}$	$E_{0,mean}$	G_{mean}	$G_{r,mean}$
	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]
C24 spruce	24.00	14.00	0.12	21.00	2.50	4.00	1.25	12,500.00	690.00	50.00

Material values used for the analysis are being displayed.

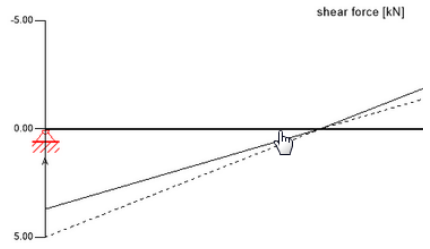
Diagrams of all load groups and all load combinations for the respective design (ULS, SLS, fire) are being displayed:

Ultimate limit state (ULS) - results of all load combinations

combination: 1.35/1.00 * LC2:self-weight structure + 1.35/1.00 * LC3:dead load



The maximum and minimum values are given in the diagrams. Other values from intermediate points along the beam can be retrieved in a table by clicking the respective curve or diagram:



value for 1.35/1.00 * LC1:dead load + 1.35/1.00 * LC3:self-weight structure

Distanz	min W	max W	min φ	max φ	min Qz	max Qz	min My	max My
0.0	0.0	0.0	-0.003842	-0.002846	3.700	4.995	0.000	0.000
0.2	0.000654	0.000883	-0.003787	-0.002805	3.330	4.496	0.703	0.949
0.4	0.001284	0.001733	-0.003627	-0.002687	2.960	3.996	1.332	1.798
0.6	0.001875	0.002531	-0.003375	-0.0025	2.590	3.497	1.887	2.547
0.8	0.002414	0.003258	-0.003043	-0.002254	2.220	2.997	2.368	3.197
1.0	0.00289	0.003901	-0.002642	-0.001957	1.850	2.498	2.775	3.746
1.2	0.003294	0.004446	-0.002182	-0.001617	1.480	1.998	3.108	4.196
1.4	0.003618	0.004884	-0.001677	-0.001242	1.110	1.499	3.367	4.545
1.6	0.003855	0.005205	-0.001137	-0.000842	0.740	0.999	3.552	4.795
1.8	0.004003	0.005404	-0.000574	-0.000425	0.370	0.499	3.663	4.945
2.0	0.004058	0.005479	0.0	0.0	0.000	0.000	3.700	4.995
2.2	0.00402	0.005427	0.000426	0.000574	-0.500	-0.370	3.663	4.945
2.4	0.003888	0.005249	0.000842	0.001137	-0.999	-0.740	3.552	4.795
2.6	0.003667	0.00495	0.001242	0.001677	-1.499	-1.110	3.367	4.545
2.8	0.003359	0.004535	0.001617	0.002182	-1.998	-1.480	3.108	4.196
3.0	0.002972	0.004012	0.001957	0.002642	-2.498	-1.850	2.775	3.746
3.2	0.002512	0.003392	0.002254	0.003043	-2.997	-2.220	2.368	3.197
3.4	0.00199	0.002686	0.0025	0.003375	-3.497	-2.590	1.887	2.547
3.6	0.001415	0.001911	0.002687	0.003627	-3.996	-2.960	1.332	1.798
3.8	0.000802	0.001083	0.002805	0.003787	-4.496	-3.330	0.703	0.949
4.0	0.0	0.0	0.002846	0.003842	-4.995	-3.700	0.000	0.000

close

7.10.4.1. Results ULS design and ULS fire design:

The design results and all relevant data are being summarized in tables for Ultimate Limit State design and fire design..

Ultimate limit state (ULS) - design results (53 %)

flexural design

dist.	$f_{m,k}$	$f_{c,k}$	$f_{t,k}$	γ_m	k_{mod}	$k_{sys,y}$	$f_{m,y,d}$	$f_{c,d}$	$f_{t,d}$	$M_{y,d}$	$M_{z,d}$	$N_{c,d}$	$N_{t,d}$	$\sigma_{m,y,d}$	$\sigma_{m,z,d}$	$\sigma_{c,d}$	$\sigma_{t,d}$	utilization
[m]	[N/mm²]	[N/mm²]	[N/mm²]	[-]	[-]	[-]	[N/mm²]	[N/mm²]	[N/mm²]	[kNm]	[kNm]	[kN]	[kN]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	
1.0	24.00	21.00	14.00	1.25	0.80	1.10	16.90	13.44	8.96	18.17	0.00	0.00	0.00	7.27	0.00	0.00	0.00	43 %

shear design in plane of CLT - gross section

dist.	$f_{IP,Gross,k}$	γ_m	k_{mod}	$f_{IP,Gross,d}$	V_d	$\tau_{v,d}$	utilization
[m]	[N/mm²]	[-]	[-]	[N/mm²]	[kNm]	[N/mm²]	
0.0	3.50	1.25	0.80	2.24	36.34	1.09	49 %

shear design in plane of CLT - net section

dist.	$f_{IP,Net,k}$	γ_m	k_{mod}	$f_{IP,Net,d}$	$V_{Net,d}$	$\tau_{v,Net,d}$	utilization
[m]	[N/mm²]	[-]	[-]	[N/mm²]	[kNm]	[N/mm²]	
0.0	8.00	1.25	0.80	5.12	36.34	2.73	53 %

torsional shear design in plane of CLT - in face glued surfaces

$f_{T,Node,k}$	γ_m	k_{mod}	$f_{T,Node,d}$	$V_{delta,d}$	I_p	$\tau_{t,d}$	utilization
[N/mm²]	[-]	[-]	[N/mm²]	[kN]	[mm⁴]	[N/mm²]	
2.50	1.25	0.80	1.60	36.34	84375010.00	0.40	25 %

buckling design

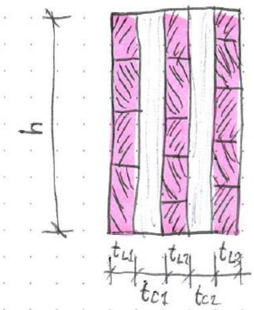
dist.	$f_{m,k}$	$f_{c,k}$	γ_m	k_{mod}	$k_{sys,y}$	$k_{sys,z}$	$l_{k,y}$	$l_{k,z}$	λ_y	λ_z	$\lambda_{rel,y}$	$\lambda_{rel,z}$	β_c
[m]	[N/mm²]	[N/mm²]	[-]	[-]	[-]	[-]	[m]	[m]	[-]	[-]	[-]	[-]	[-]
1.0	24.00	21.00	1.25	0.80	1.10	1.00	2.000	0.000	14	0	0.22	0.00	0.1

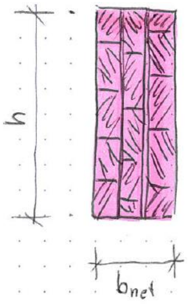
dist.	k_y	k_z	$k_{c,y}$	$k_{c,z}$	$f_{m,y,d}$	$f_{c,d}$	$M_{y,d}$	$M_{z,d}$	$N_{c,d}$	$\sigma_{c,d}$	$\sigma_{m,y,d}$	$\sigma_{m,z,d}$	utilization
[m]	[-]	[-]	[-]	[-]	[N/mm²]	[N/mm²]	[kNm]	[kNm]	[kN]	[N/mm²]	[N/mm²]	[N/mm²]	
1.0	0.52	0.49	1.00	1.00	16.90	13.44	18.17	0.00	0.00	0.00	7.27	0.00	43 %

Flexural design

flexural design																		
dist.	$f_{m,k}$	$f_{c,k}$	$f_{t,k}$	γ_m	k_{mod}	$k_{sys,y}$	$f_{m,y,d}$	$f_{c,d}$	$f_{t,d}$	$M_{y,d}$	$M_{z,d}$	$N_{c,d}$	$N_{t,d}$	$\sigma_{m,y,d}$	$\sigma_{m,z,d}$	$\sigma_{c,d}$	$\sigma_{t,d}$	utilization
[m]	[N/mm²]	[N/mm²]	[N/mm²]	[-]	[-]	[-]	[N/mm²]	[N/mm²]	[N/mm²]	[kNm]	[kNm]	[kN]	[kN]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	
1.0	24.00	21.00	14.00	1.25	0.80	1.10	16.90	13.44	8.96	18.17	0.00	0.00	0.00	7.27	0.00	0.00	0.00	43 %

The flexural design is being done, using the net section:





Shear design – gross section [18]

shear design in plane of CLT - gross section							
dist.	$f_{IP,Gross,k}$	γ_m	k_{mod}	$f_{IP,Gross,d}$	V_d	$\tau_{v,d}$	utilization
[m]	[N/mm²]	[-]	[-]	[N/mm²]	[kNm]	[N/mm²]	
0.0	3.50	1.25	0.80	2.24	36.34	1.09	49 %

For this shear failure mode it is assumed that the shear can be transferred between adjacent lamination plates within a CLT layer, due to edge gluing. In that case the effective section for the shear design is the gross section.

The characteristic shear strength for this failure mode is $f_{IP,Gross,k}$ = 3,5 N/mm²

Note: for homogenous wood beams (glulam, solid timber, LVL, etc.), the shear design does not have to be done at the point of the absolute maximum shear (at the support), but can be done in a distance of h (height of the section) from the support – see Austrian National annex to Eurocode 5, part 1 [9], chapter 6.1.7 (2). **This is for all shear design verifications <u>not applicable for CLT beams</u> with loading in the plane of CLT.**

Shear design – net section [18]

shear design in plane of CLT - net section							
dist.	$f_{IP,Net,k}$	γ_m	k_{mod}	$f_{IP,Net,d}$	$V_{Net,d}$	$\tau_{v,Net,d}$	utilization
[m]	[N/mm²]	[-]	[-]	[N/mm²]	[kNm]	[N/mm²]	
0.0	8.00	1.25	0.80	5.12	36.34	2.73	53 %

For this failure mode it is assumed that adjacent lamination plates do not have edge gluing, or the edge gluing opened up and is not effective. Therefore all the shear transfer between lamination layers happens through torsional shear in the face glued intersecting surfaces of CLT. This creates shear forces in each lamination layer that acts perpendicular to the grain of the lamination plates. This shear force occurs equally in total in the longitudinal layers and in the cross layers. Design governing will be the effective net width of the CLT section with the minimum thickness.

The characteristic shear strength for this failure mode (shear perpendicular to the grain) is $f_{IP,Net,k}$ = 8,0 N/mm²

Shear design – torsional shear in face glued intersecting surfaces [18]

torsional shear design in plane of CLT - in face glued surfaces							
$f_{T,Node,k}$	γ_m	k_{mod}	$f_{T,Node,d}$	$V_{delta,d}$	I_p	$\tau_{t,d}$	utilization
[N/mm²]	[-]	[-]	[N/mm²]	[kNm]	[mm⁴]	[N/mm²]	
2.50	1.25	0.80	1.60	36.34	84375010.00	0.40	25 %

For this failure mode it is assumed that adjacent lamination plates do not have edge gluing, or the edge gluing opened up and is not effective. Therefore all the shear transfer between lamination layers happens through torsional shear in the face glued intersecting surfaces of CLT.

The characteristic shear strength for this failure mode is $f_{IP,T,k}$ = 8,0 N/mm²

Buckling design

buckling design													
dist.	$f_{m,k}$	$f_{c,k}$	γ_m	k_{mod}	$k_{sys,y}$	$k_{sys,z}$	$l_{k,y}$	$l_{k,z}$	λ_y	λ_z	$\lambda_{rel,y}$	$\lambda_{rel,z}$	β_c
[m]	[N/mm²]	[N/mm²]	[-]	[-]	[-]	[-]	[m]	[m]	[-]	[-]	[-]	[-]	[-]
1.0	24.00	21.00	1.00	1.00	1.10	1.00	2.000	0.000	15	0	0.24	0.00	0.1

dist.	k_y	k_z	$k_{c,y}$	$k_{c,z}$	$f_{m,y,d}$	$f_{c,d}$	$M_{y,d}$	$M_{z,d}$	$N_{c,d}$	$\sigma_{c,d}$	$\sigma_{m,y,d}$	$\sigma_{m,z,d}$	utilization
[m]	[-]	[-]	[-]	[-]	[N/mm²]	[N/mm²]	[kNm]	[kNm]	[kN]	[N/mm²]	[N/mm²]	[N/mm²]	
1.0	0.52	0.49	1.00	1.00	30.36	24.15	7.38	0.00	0.00	0.00	10.14	0.00	33 %

The stability analysis is done according to EN 1995-1-1, chapter 6.3 [8].

7.10.4.2. Results SLS design - deformation

SLS design is analogous to chapter 7.1.6.3.

Service limit state design (SLS) - design results (10 %)

initial deflection [w_{char}]				
K_{def}	L_{ref}	limit	$w_{calc.}$	utilization
	[m]	[mm]	[mm]	
0.8	2.0	L/300 = 6.7	0.7	10 %

final deflection [$w_{char}+w_{q.p.}*k_{def}$]				
K_{def}	L_{ref}	limit	$w_{calc.}$	utilization
	[m]	[mm]	[mm]	
0.8	2.0	L/150 = 13.3	1.0	7 %

net final deflection [$w_{q.p.}*(1+k_{def})$]				
K_{def}	L_{ref}	limit	$w_{calc.}$	utilization
	[m]	[mm]	[mm]	
0.8	2.0	L/250 = 8.0	0.7	9 %

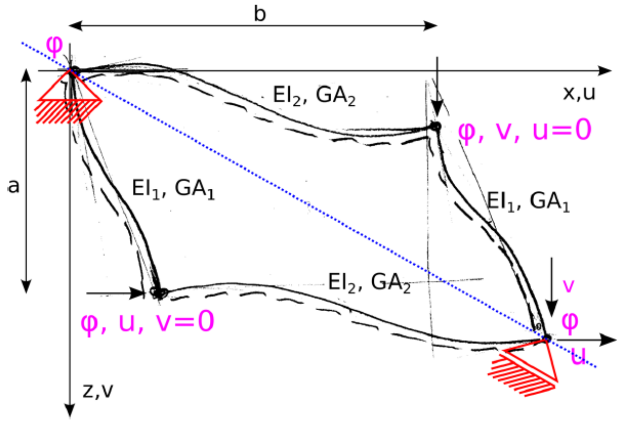
7.11. CLT wall / CLT deep beam

The module CLT wall / CLT deep beam is made for CLT panels with loading in the plane of the CLT (wall, CLT beam, deep CLT beam, etc.) and out of plane of the CLT.
The CLT element can include voids for door and window openings as well.

7.11.1. Design basics

This would be normally a case for a finite elements analysis. The goal was to create a design module that can handle an analysis under the given boundary conditions as mentioned above, but using a simplified engineering approach. The solution to this approach was the creation of a grid model, similar to the module for the 2-way cantilever CLT panel – see chapter 7.6. With the help and expertise of Holzbau Forschungs GmbH (TU-Graz), an analysis model could be elaborated, that can describe the rigidity of a CLT wall (for all standard CLT sections of Stora Enso). Details about that model are described in the report "Berechnung von BSP-Wandscheiben mit Gitterrostmodellen" (Engl.: Analysis of CLT shear walls with beam grid models) [19].

Beam grid model:
The figure below describes the boundary conditions for the beam grid model.



The beam grid model was based on the Bernoulli beam theory with a certain correction coefficient.
The global equation matrix for the beam grid model is as follows:

$$\begin{bmatrix} \frac{24\cdot EI_1}{a^3} & 0 & -\frac{24\cdot EI_1}{a^2} & a \\ 0 & \frac{24\cdot EI_2}{b^3} & \frac{24\cdot EI_2}{b^2} & -b \\ -\frac{24\cdot EI_1}{a^2} & \frac{24\cdot EI_2}{b^2} & \frac{24\cdot EI_1}{a}+\frac{24\cdot EI_2}{b} & 0 \\ a & -b & 0 & 0 \end{bmatrix} \cdot \begin{bmatrix} u \\ v \\ \varphi \\ Z \end{bmatrix} = \begin{bmatrix} 2\cdot t\cdot a \\ 2\cdot t\cdot b \\ 0 \\ 0 \end{bmatrix}$$

Boundary condition for the equation above:
$u * a = v * b \rightarrow u * a - v * b = 0$

Solving the equation leads to the following result:

$$\begin{bmatrix} u \\ v \\ \varphi \end{bmatrix} = \begin{bmatrix} \dfrac{\left(a^2 \cdot b^4 \cdot EI_1 + a^3 \cdot b^3 \cdot EI_2\right) \cdot t}{12 \cdot \left(a^2 + b^2\right) \cdot EI_1 \cdot EI_2} \\ \dfrac{\left(a^3 \cdot b^3 \cdot EI_1 + a^4 \cdot b^2 \cdot EI_2\right) \cdot t}{12 \cdot \left(a^2 + b^2\right) \cdot EI_1 \cdot EI_2} \\ \dfrac{a \cdot b \cdot \left(EI_1 \cdot b^3 - EI_2 \cdot a^3\right) \cdot t}{12 \cdot \left(a^2 + b^2\right) \cdot EI_1 \cdot EI_2} \end{bmatrix}$$

The restraint force Z is in that case 0.
Both flexural rigidities EI_1 and EI_2 shall be adjusted with a calibration factor f, so the shear strain in a shell element is equal to the shear strain in the beam grid element.
Shear strain in a shell element:

$$\gamma_{Scheibe} = \frac{t}{c_{xy}}$$

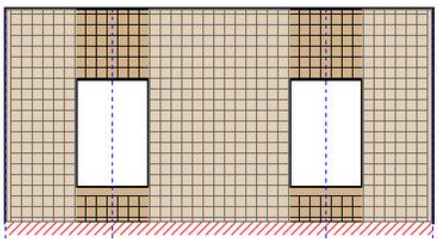
Shear strain in the beam grid model:

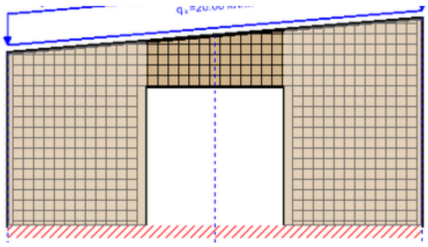
$$\gamma_{Gitterstab} = \frac{u(t)}{a} + \frac{v(t)}{b} = \frac{\left(a^2 \cdot b^4 \cdot f \cdot EI_1 + a^3 \cdot b^3 \cdot f \cdot EI_2\right)}{12 \cdot \left(a^2 + b^2\right) \cdot f^2 \cdot EI_1 \cdot EI_2} \cdot \frac{t}{a} + \frac{\left(a^3 \cdot b^3 \cdot f \cdot EI_1 + a^4 \cdot b^2 \cdot f \cdot EI_2\right) \cdot t}{12 \cdot \left(a^2 + b^2\right) \cdot f^2 \cdot EI_1 \cdot EI_2} \cdot \frac{t}{b}$$

Equating these two shear strains leads to the calibration factor f:

$$f = \frac{a \cdot b \cdot c_{xy} \cdot \left(EI_1 \cdot b + EI_2 \cdot a\right)}{12 \cdot EI_1 \cdot EI_2}$$

In a comparative study of several different shear walls, the deviation to a FE solution has been analyzed. Generally the results of the derived beam grid model were deviating from the FE solution to a maximum extent of about 15%. In all these cases the results of the beam grid model were on the conservative side. In comparisons that include a sloped top edge, the deviations approached the 30%. This was caused by the cut beam grid elements at the top that were cantilevering and were not supported in horizontal direction. This aspect relativizes the high deviation. Given the fact that a practical engineering method had to be found in order to substitute a FE solution, the resulting method with deviations of about 15% on the conservative side are satisfactory.
More details about the analysis method can be found in the report “Berechnung von BSP-Wandscheiben mit Gitterrostmodellen” [19].
Additionally to the analysis of internal forces and rigidity analysis in the plane of CLT, according to “Berechnung von BSP-Wandscheiben mit Gitterrostmodellen” [19], the stability of the panel is being analyzed according to EN 1995-1-1, chapter 6.3 [8]. Generally for the stability analysis (buckling) it was assumed, that the effective length (buckling length) is equal to the wall height in that part of the wall, where the stability analysis is being conducted. This is a conservative approach.
For the buckling design, only parts of a wall with no openings are being analyzed. These parts are being shaded in the system sketch in a lighter color (beige). Areas above window openings that are not included in the buckling design are shaded a bit darker. All loading out of plane will therefore be redistributed to areas that are being analyzed for buckling. The symmetry axis for this load distribution is indicated at the center of openings (blue dashed line). All loading until the blue dashed line shall be part of the tributary area for loading, for the stability analysis.

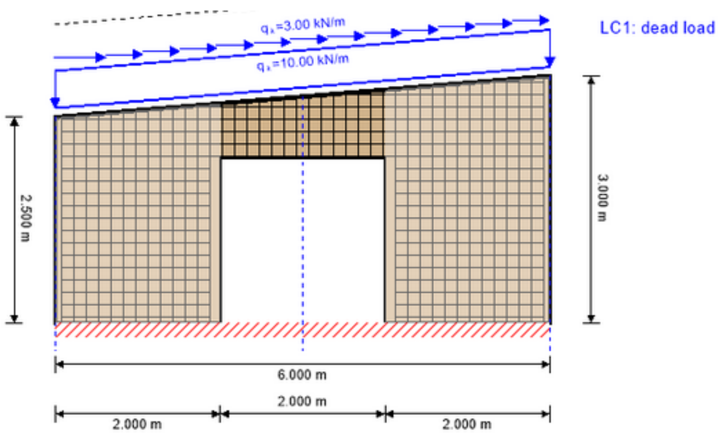


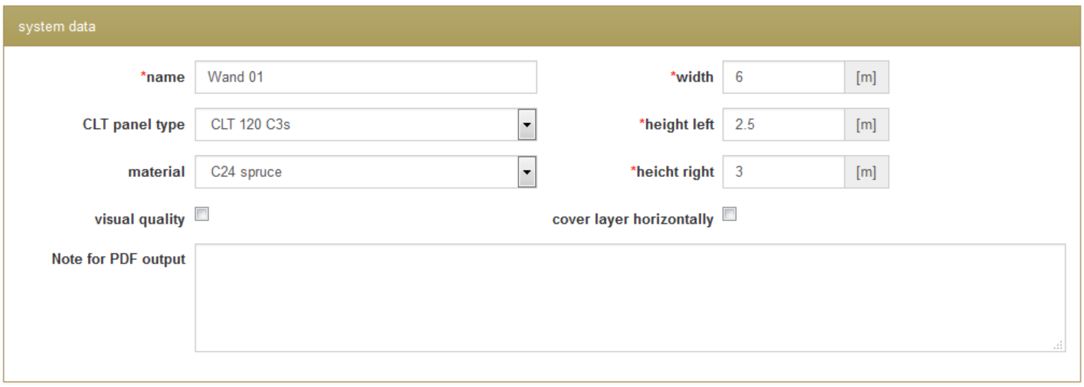


7.11.2. Wall details

Click the edit button in the “continuous beams details” box in order to edit the data:

7.11.2.1. System Data





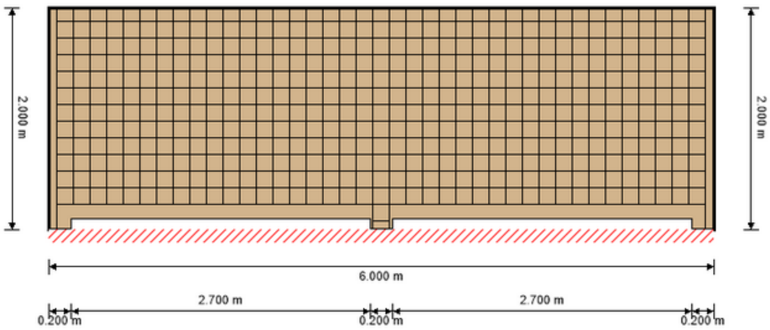
width: insert the width of the entire wall/beam (> 1,00 m)
height left/right: insert the height at the left end and the right end (> 1,00 m). If the top edge is sloped, these values are different (e.g. wall underneath a roof).

cover layer horizontally: by default the cover layer is assumed to be vertically (ideal for walls with a continuous support at the bottom). If that shall not be the case, check the box “cover layer horizontally” (ideal for deep beams)
Visual quality needs to be checked, if the panels are visual grade. The lamination width of visual grade is 100 mm and the lamination width of non-visual grade is 150 mm. This is determining the mesh width of the grid model.

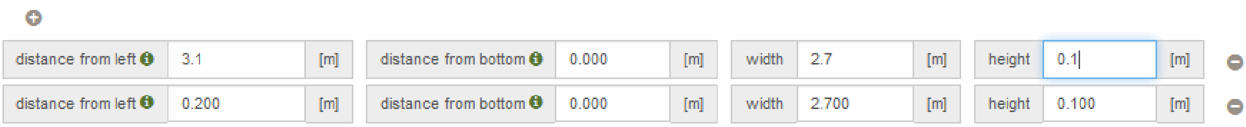
7.11.2.2. supports

If no data is being entered in this box, then the CLT element will be supported on the entire length of the bottom edge (typical for walls. The linear support in that case is a pin support out of plane (M=0). The support will take tension and compression. A non-linear support condition (e.g.: taking compression only, but not tension) is currently not possible in this design tool (possible future development).
Entering data in the boxes for point supports will place supports at the entered distance from the **point of origin**, which is the **bottom left corner of the panel**. The supports can be chosen either fixed or pinned.

In case of too high force concentration at point supports, the following can be done. Make the model 10 cm taller and place at the bottom edge voids with a height of 10cm in the length of the clear span of the (deep) beam. This will create a beam with linear supports. For a 6 m long beam with 3 supports (each 20 cm long), the solution could look like that:



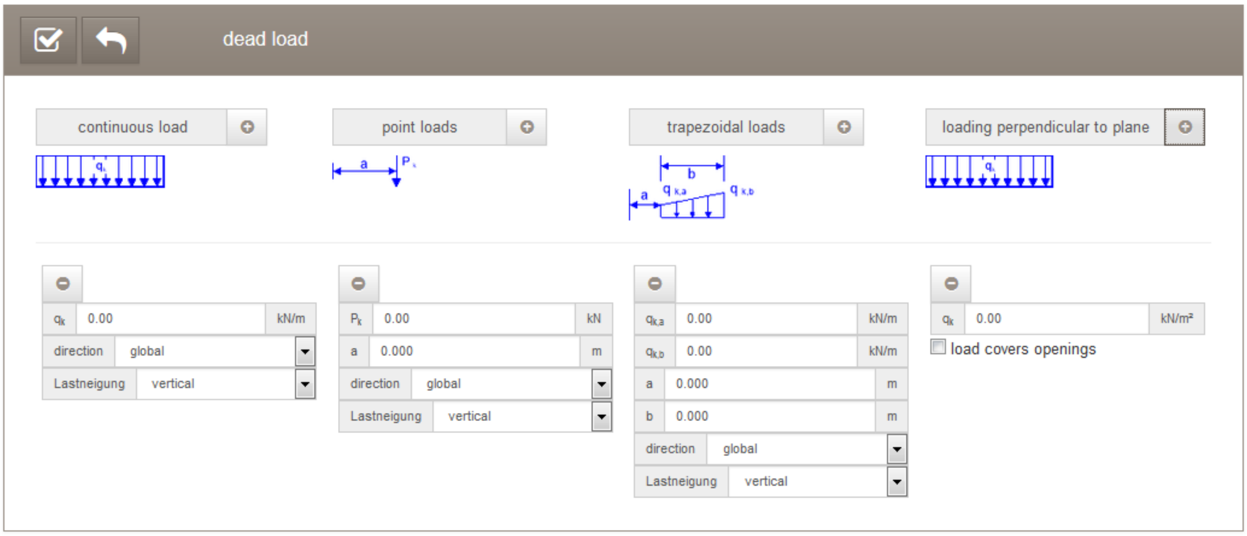
This is the data, that was entered for the voids:



7.11.3. Voids

To enter a void it the CLT element, click the "+" icon and enter the values for the void:
The **reference point** for each void is the bottom left corner of the void. Only rectangular voids are possible.
distance from left: is the horizontal distance from the point of origin (left bottom corner of the CLT panel) to the reference point of the void (bottom left corner of the void).
distance from bottom: is the vertical distance from the point of origin (left bottom corner of the CLT panel) to the reference point of the void (bottom left corner of the void).
width: width of the void
height: height of the void

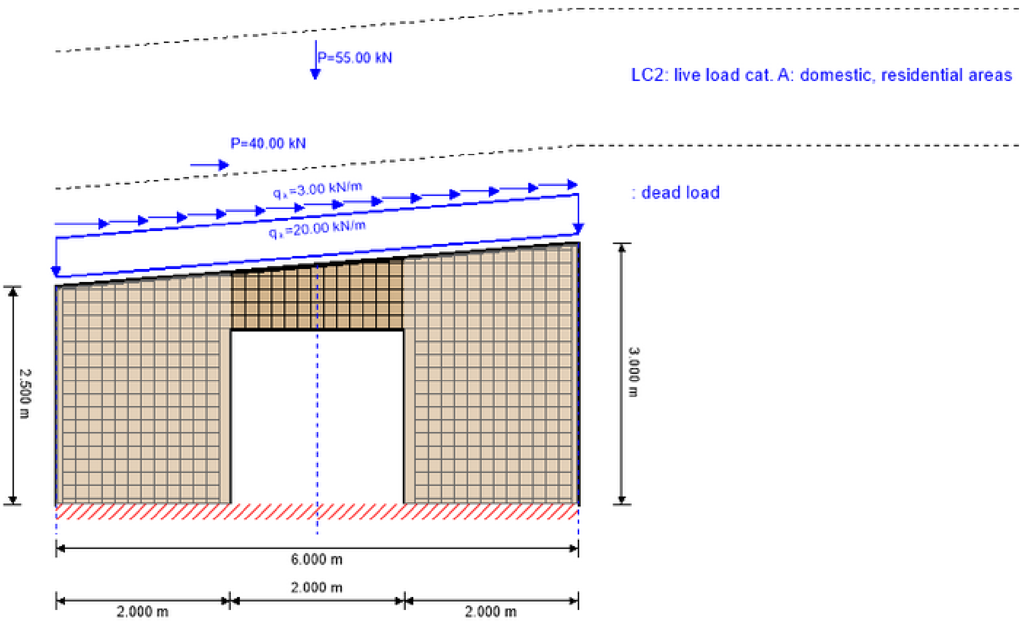
7.11.4. Loading



Continuous load: will place a continuous load at the top edge of the panel. The load can be either vertical or horizontal with reference to the global coordinate system, local coordinate system or as projected load. For more information about loading see chapter 7.1.5.
Point load: will put a point load at the top edge of the panel, in a horizontal distance a from the left edge of the panel. The load can be either vertical or horizontal with reference to the global coordinate system, local coordinate system or as projected load.
Trapezoidal load: will put a trapezoidal load at the top edge of the CLT panel in distance a from the left vertical panel edge. The length of the trapezoidal load is the variable b and shall be entered by the user. The load can be either vertical or horizontal with reference to the global coordinate system, local coordinate system or as projected load.
Loading perpendicular to plane: will put a constant surface load to the CLT. This could be for example a wind load.

By checking the box “**load covers openings**” the user can choose, to apply the load also over wall openings (e.g.: wind load would usually be applied over openings too, if they are glazed).

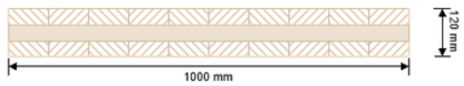
7.11.5. Results



As for all other modules, the system graphic with loading is part of the result page.

Section properties and element properties:

section CLT 120 C3s



layer	thickness	type	material
1	40.0 mm	C	C24 spruce
2	40.0 mm	L	C24 spruce
3	40.0 mm	C	C24 spruce

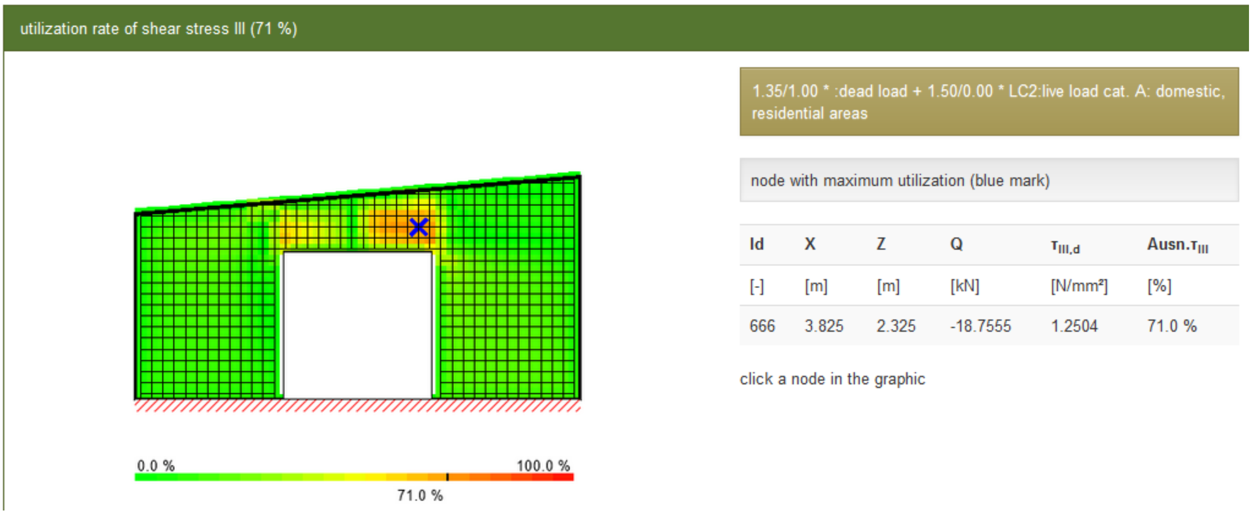
Dicke	$Dicke_h$	$Dicke_v$	EI_h	EI_v	$Fläche_h$	$Fläche_v$	EA_h	EA_v	Schubsteifigkeit	f	n_x	n_y	n_{xy}
[m]	[m]	[m]	[kN*m²]	[kN*m²]	[m²]	[m²]	[kN]	[kN]	[kN/m]	[-]	[kN/m]	[kN/m]	[kN/m]
0.12	0.04	0.08	140.625	281.25	0.006	0.012	75000	150000	24300	0.0729	960	1920	160

In this module, not only the section properties are given, but also the properties of the entire element, such as the rigidity in plane.

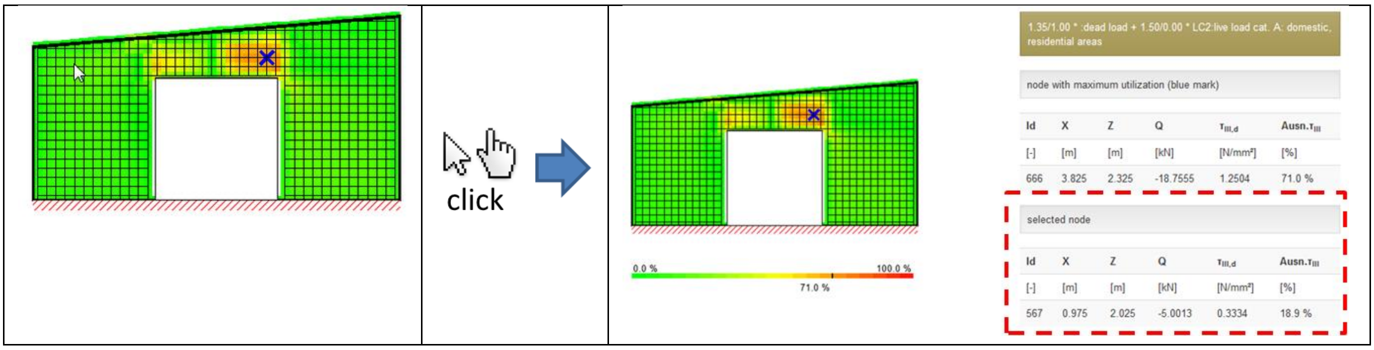
Same properties are given for the section after fire, if fire design is part of the analysis.

7.11.5.1. Results – ULS design

The results of the analysis are shown graphically. It was chosen to show for different internal forces the utilization rate and the design results of the maximum utilized spot. This spot is being indicated with a blue cross mark.



If any other design values shall be displayed, just a simple click in the graphic at the point of interest is required, to display the result in this very node. That way, the design result of any of the nodes can be displayed. This applies to all graphics within this module.



The following internal forces are being displayed:

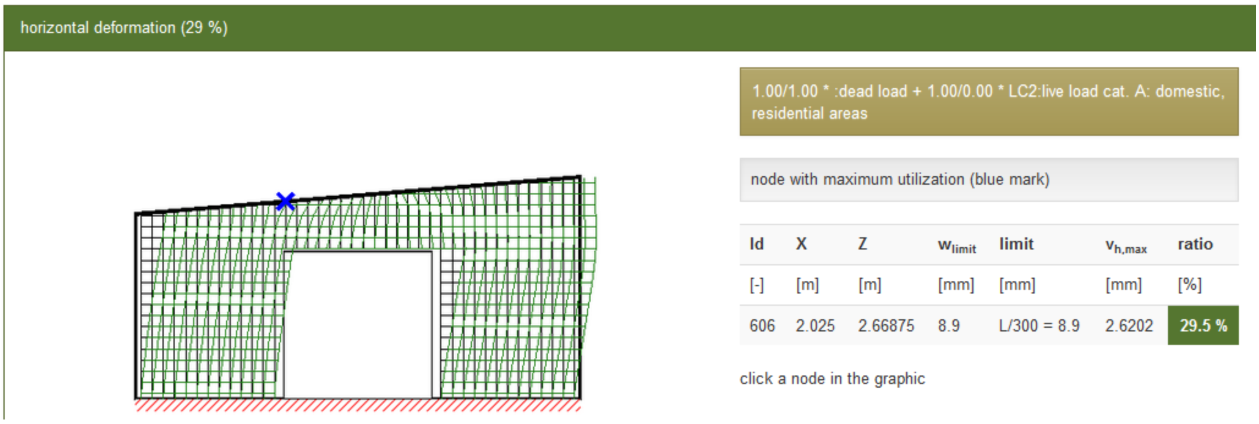
- Shear in plane on the gross section of CLT
- Shear in plane on the net section of CLT (shear perpendicular to the grain)
- Torsional shear in the face glued surfaces at the lamination intersections
- Axial stress in horizontal lamination
- Axial stress in vertical lamination
- Stability analysis of panel portions with no voids (loading from portions with voids are being transferred to adjacent portions without voids, where the stability analysis is being executed).

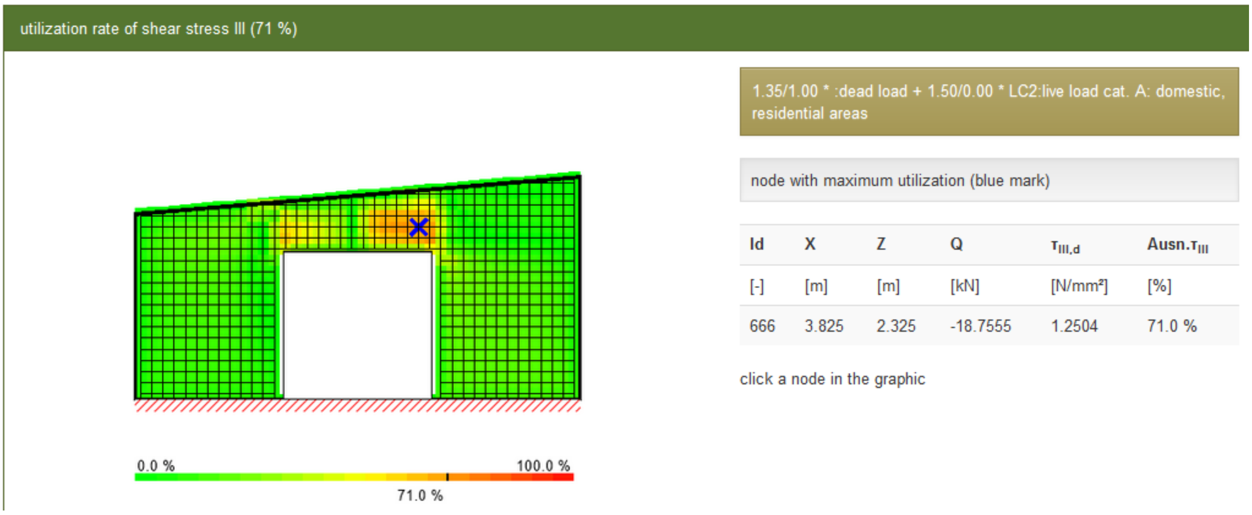
7.11.5.2. Results – SLS design

The results of the analysis are shown graphically. The following graphics are being displayed:

The image for horizontal deformation shows actually the graphic of the design governing deformation of the entire panel. The point of the maximum utilization regarding a horizontal deformation is indicated with the blue cross mark.

Note: the maximum utilization at the horizontal deformation does not necessarily mean the absolute maximum deformation. The utilization rate of the horizontal deformation is derived from the ratio of deformation to a deformation limit (H/300) – see ÖNORM B 1990-1:2003, item 8.3 [20]. This limit for horizontal deformation in plane was applied to all other country settings as well. Therefore the maximum utilization is dependent on the height of the element at a given point. If the display of the deformation at any other point is desired, just click that point in the graphic and the values will be displayed.





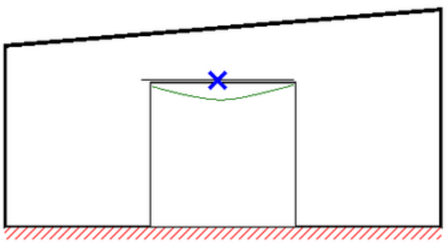
The following other deformation results are being displayed for vertical deformations in voids:

- Initial deflection
- Final deflection
- Net final deflection

These deflections are being compared to the applicable limits in the respective national annex of EN 1995-1-1.

final deflection [$w_{char}+w_{q.p.}*k_{def}$] (41 %)

1.00/1.00 * :dead load + 1.00/0.00 * 0.30 * LC2:live load cat. A: domestic, residential areas



node with maximum utilization (blue mark)

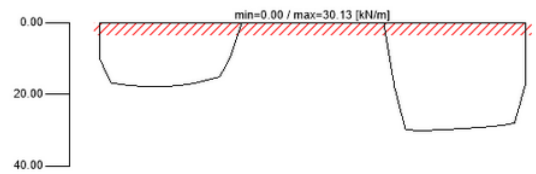
Id	X	Z	K_{def}	L_{ref}	limit	w_{limit}	$w_{calc.}$	ratio
[-]	[m]	[m]		[m]	[-]	[mm]	[mm]	
580	2.925	2.025	0.8	2.0	1/150	13.3	5.4	41 %

click a node in the graphic

7.11.5.3. Results – support reactions

The support reactions are being displayed in graphics too. The maximum is automatically displayed. Any other values along the support reaction diagram can be retrieved by a click into the diagram.

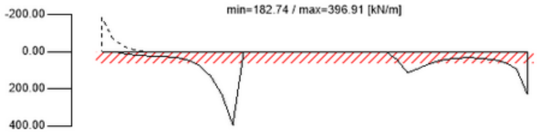
support reaction horizontal min/max (0 %)



selected node

Id	X	Z	Min	Max
[-]	[m]	[m]	[kN/m]	[kN/m]
29	4.275	0	0	29.73418

support reaction vertical min/max (0 %)



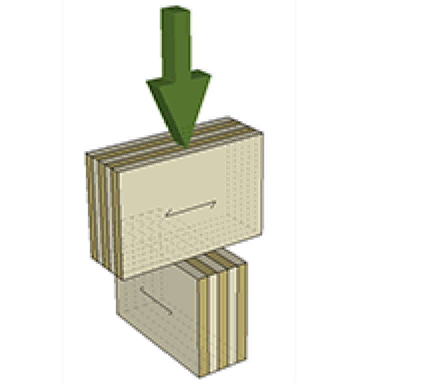
selected node

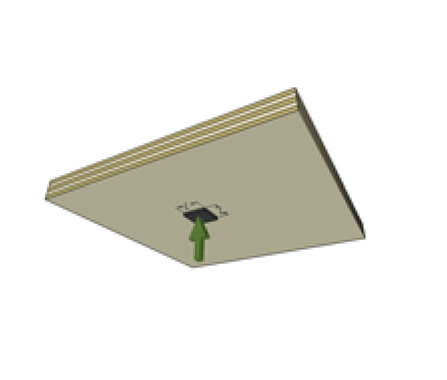
Id	X	Z	Min	Max
[-]	[m]	[m]	[kN/m]	[kN/m]
39	5.775	0	0	94.84458

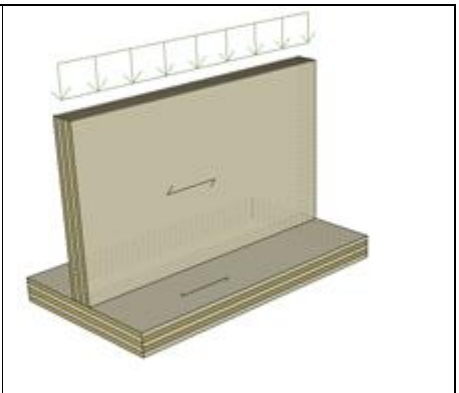
7.12. Bearing pressure analysis and point support

The design module is divided in 3 categories:

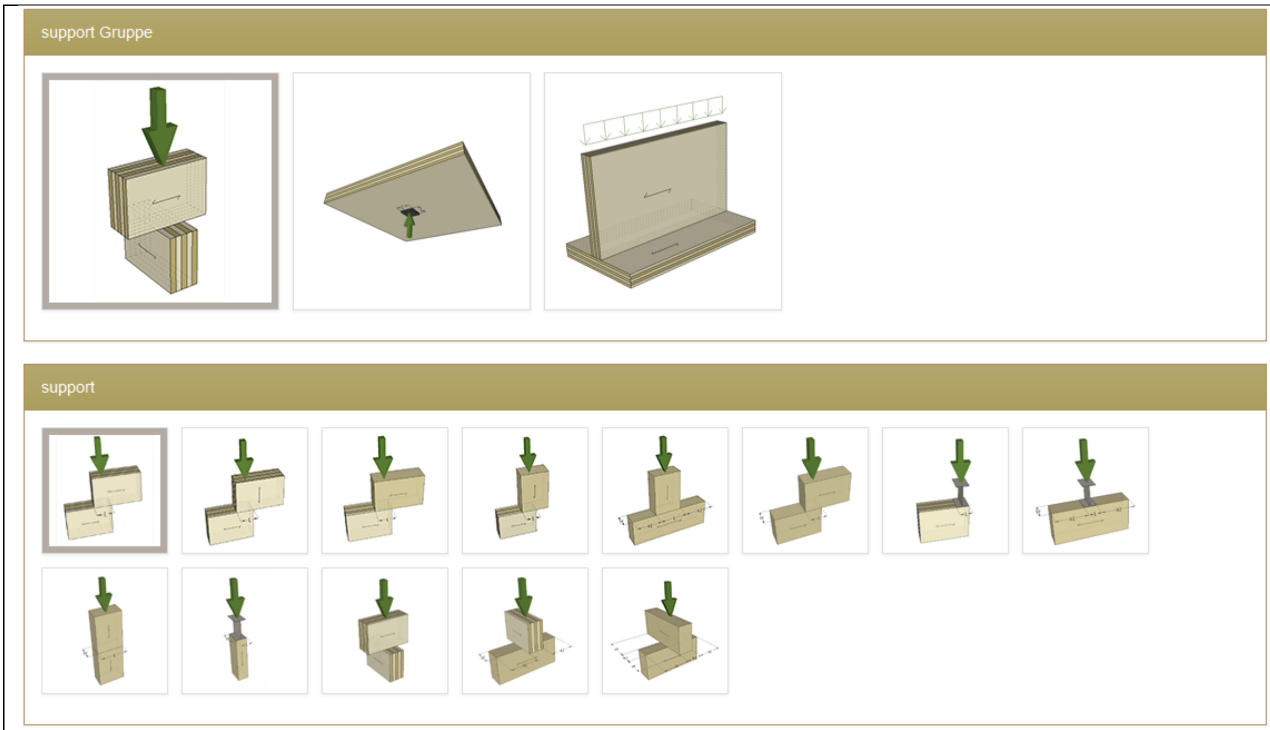
- Point supports of linear elements (wall elements and/or beam elements – in line or crossed)
- Point supports of CLT panels, out of plane
- Linear support of CLT panels


Point supports of linear elements


Point supports of CLT panels, out of plane

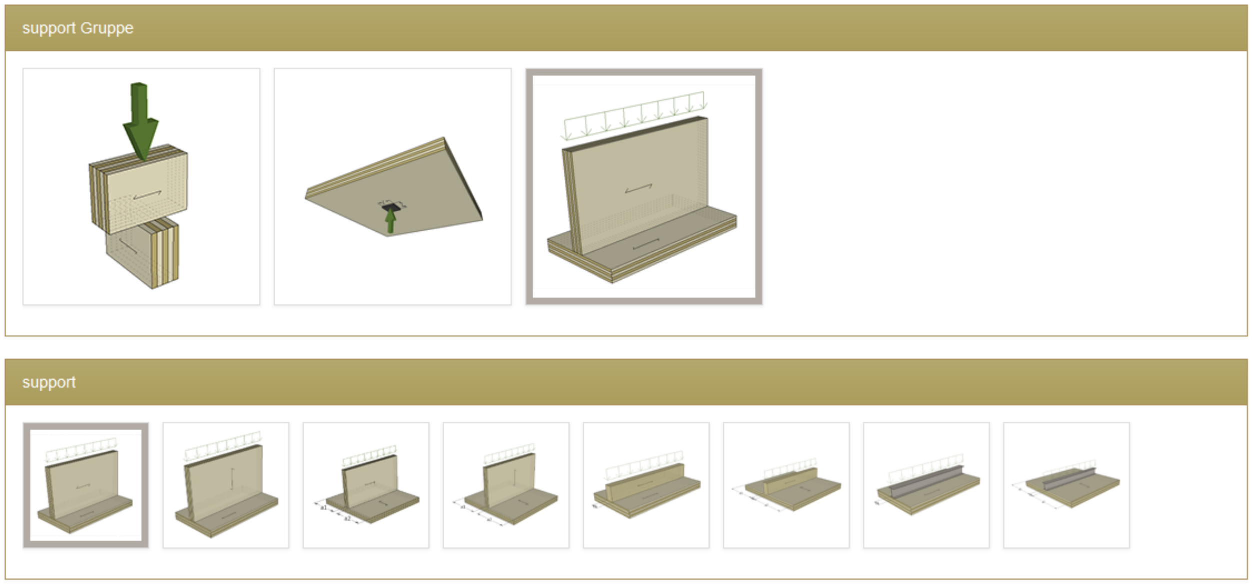

Linear support of CLT panels

The user has to select first the support category that shall be analyzed, by clicking the respective icon and then select the support type:



Point supports of linear elements

Point supports of CLT panels, out of plane



Linear support of CLT panels

At first glance the exact system on the icons might be hard to read, but once a support type is selected, it will be displayed in the design interface below. This will show the user the precise features of the selected system.

7.12.1. Point support of linear elements and linear panel support

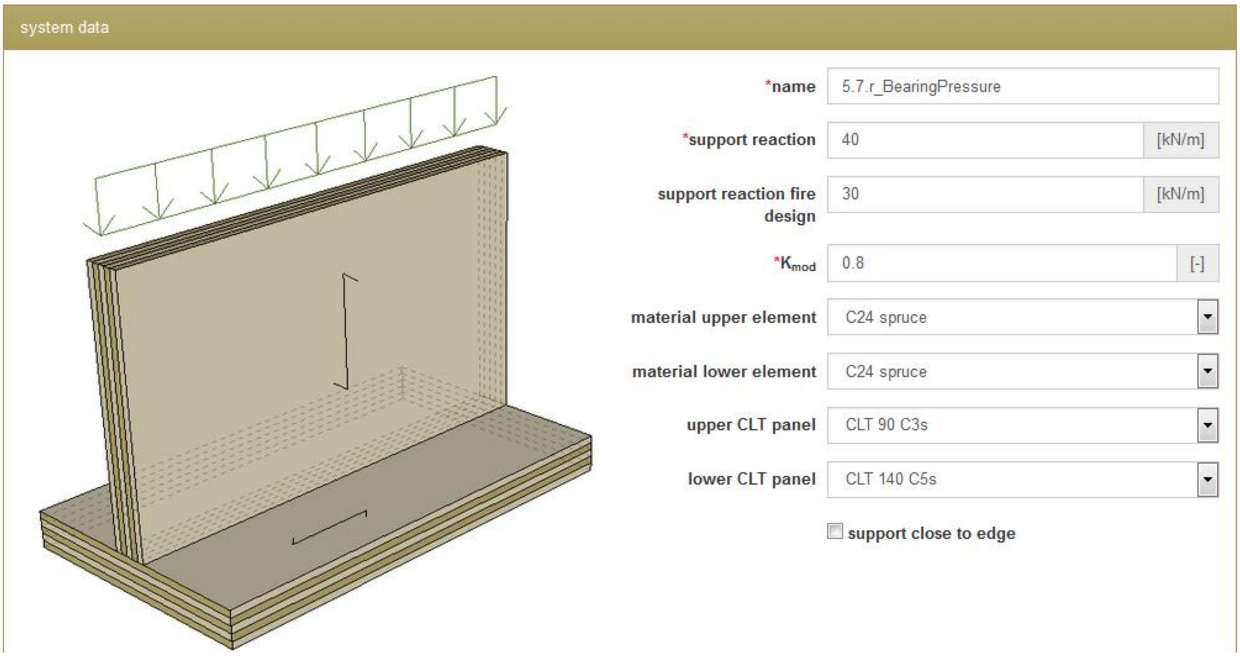
All design modules are performing a bearing pressure analysis. Either bearing pressure acting parallel to the grain, or perpendicular to the grain. In case of CLT it is not always clear, if the bearing pressure, acting on a net section with strength parallel to the grain would be able to resist a higher load than the entire gross section with strength perpendicular to the grain. The software will analyze both cases and will pick the design governing condition.

7.12.1.1. Support details

The support pressure analysis is rather similar for all the modules. A typical example will be described below.

However, the support design for point supported elements requires a few more explanation, which can be found in chapter 7.12.2.

7.12.1.2. System Data:



Once a system is selected, design relevant data can be entered.
Support reaction is the design value of the support reaction, that a given support needs to resist for an ULS design.
Support reaction fire design is the fire design value of the support reaction, that a given support needs to resist for the fire design.
$\mathbf{k_{mod}}$ is the applicable k_{mod} factor for ULS design.
Material upper/lower element: pick from the pulldown menu the material of the lamination of the CLT (typically C24 spruce).
Upper/Lower CLT panel: choose a CLT panel from the pull-down menu.
a1, a2: edge distances for the vertical (upper) CLT panel

7.12.1.3. Results

The results of a bearing pressure analysis are displayed as shown in the figure below:

results

upper element

name	width	length	extension	area	k_{mod}	γ_m	$k_{c,90,k}$	$f_{c,k}$	$f_{c,d}$	V_{max}	$\sigma_{c,d}$	utilization
	[mm]	[mm]	[mm]	[cm²]	[-]	[-]	[-]	[N/mm²]	[N/mm²]	[kN]	[N/mm²]	
CLT 90 C3s	90	1000	0	900.00	0.80	1.25	1.00	2.50	1.60	40.00	0.44	28 %

lower element

name	width	length	extension	area	k_{mod}	γ_m	$k_{c,90,k}$	$f_{c,k}$	$f_{c,d}$	V_{max}	$\sigma_{c,d}$	utilization
	[mm]	[mm]	[mm]	[cm²]	[-]	[-]	[-]	[N/mm²]	[N/mm²]	[kN]	[N/mm²]	
CLT 140 C5s	90	1000	0	900.00	0.80	1.25	1.50	2.50	2.40	40.00	0.44	19 %

In case, the effective support surface can be extended, according to EN 1995-1-1, item 6.1.5 [9], the respective value (either 30 mm, or 60 mm) will be listed in the column “extension” among the results.

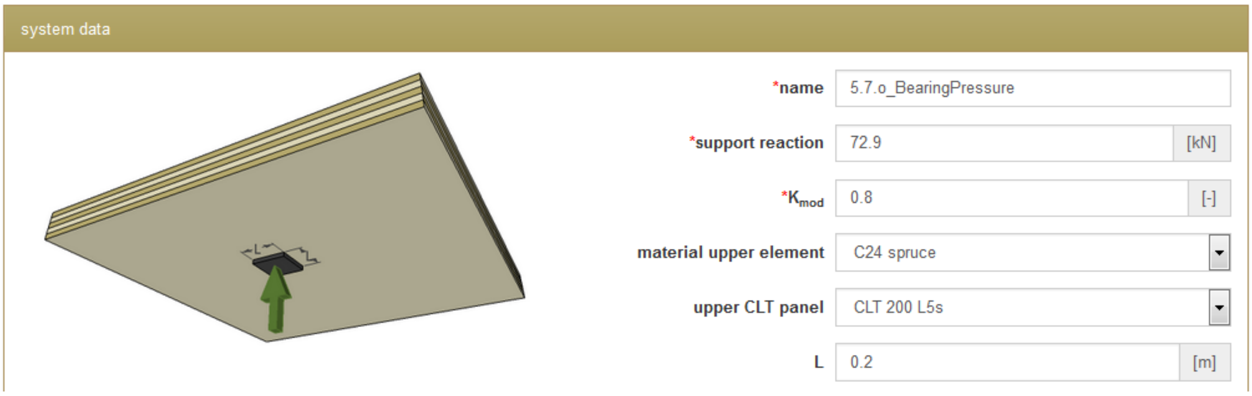
7.12.2. Design basics – point supported CLT panels

The design module for point supports is not only analyzing the bearing pressure (pressure perpendicular to the grain of the CLT), but also the shear transfer (rolling shear) from the bearing plate to the CLT panel. This shear analysis is based on the doctoral thesis of Peter Mestek [22]. The research of these thesis was conducted under some restrictive boundary conditions as follows:

- Bearing plate is square (side length of the bearing plate = L)
- CLT has a minimum of 5 layers
- Thickness of CLT lamination in X-direction = thickness of CLT lamination in Y-direction
  → all lamination has same thickness

Stora Enso is offering among the standard panels only 2 panels that match the criterions above: CLT 100 L5s and CLT 200 L5s. However, on request it is possible to have other panel types produced by Stora Enso, e.g. a 5 layer panels with a lamination thickness of 30 mm and a total thickness of 150 mm.
The software contains only standard panels in the panel list. For the generation of a new panel type, follow the instructions in chapter 9.1.
As soon as research delivers more engineering methods on the shear analysis for CLT panels with varying lamination thickness, this knowledge will be implemented in the software, making it more flexible.
This module is dealing with the very specific analysis procedure for point supports (bearing pressure and shear analysis). This module will not do the flexural stress analysis. Flexural stress, deformation, etc. widely depends on the geometry, loading and boundary conditions of a CLT panel. This analysis has to be done by some simplified approach, applying simple beam theory and using the help of other modules from this software (7.1). If a FE analysis was used, in order to determine the internal forces in the CLT panel, the support analysis can be done with the help of this module. If the FE software is not capable of designing CLT, the section calculator of this software will do the CLT design part and will do the remaining flexural stress analysis – see chapter 7.14.

7.12.2.1. System Data:



Once a system is selected (3 different point support types are possible: central support, edge support and corner support), design relevant data can be entered.

Support reaction is the design value of the support reaction, that a given support needs to resist for an ULS design.

k_{mod} is the applicable k_{mod} factor for ULS design.

Material upper element: pick from the pulldown menu the material of the lamination of the CLT (typically C24 spruce).

Upper CLT panel: choose a CLT panel from the pull-down menu.

L: side length of the bearing plate

7.12.2.2. Results

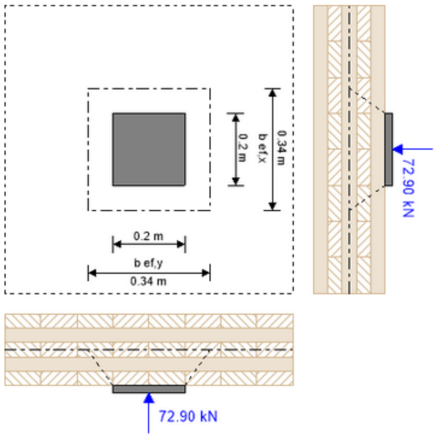
results

upper element

name	width	length	extension	area	k_{mod}	γ_m	$k_{c,90,k}$	$f_{c,k}$	$f_{c,d}$	V_{max}	$\sigma_{c,d}$	utilization
	[mm]	[mm]	[mm]	[cm²]	[-]	[-]	[-]	[N/mm²]	[N/mm²]	[kN]	[N/mm²]	
CLT 60 C3s	200	200	60	520.00	0.80	1.25	1.80	2.50	2.88	72.90	1.40	49 %

point support - shear analysis

name	k_{mod}	γ_m	$f_{r,k}$	$f_{r,d}$	V_{max}	$V_{xz,d}$	$V_{yz,d}$	$b_{ef,x}$	$b_{ef,y}$	$\tau_{r,xz,d}$	$\tau_{r,yz,d}$	utilization
	[-]	[-]	[N/mm²]	[N/mm²]	[kN]	[kN]	[kN]	[mm]	[mm]	[N/mm²]	[N/mm²]	
	0.80	1.25	1.05	0.67	72.90	20.69	15.76	340.04	340.04	0.38	0.58	86 %

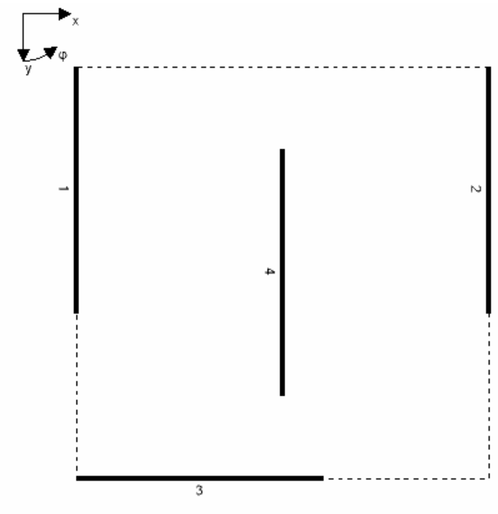


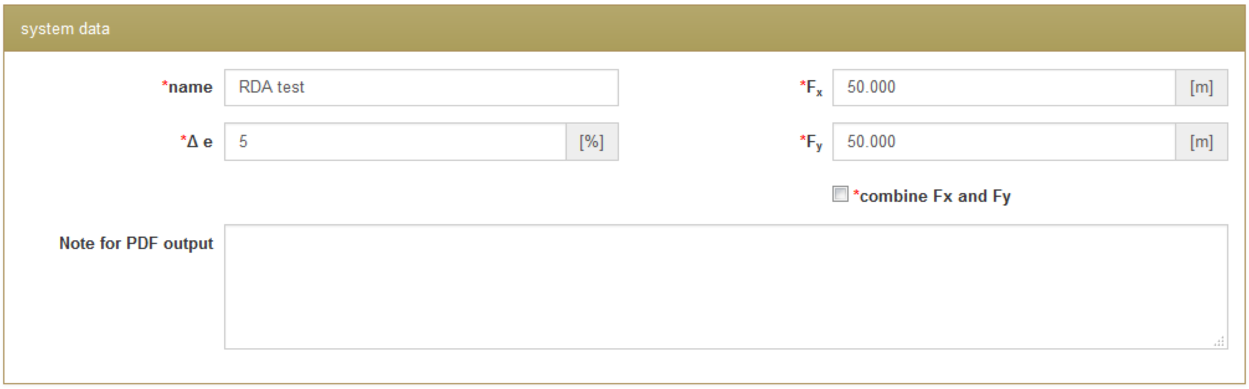
The figure above displays the result of the point support design module, for a central support and delivers results for the bearing pressure perpendicular to the grain and for the rolling shear at the point support.

7.13. Rigid diaphragm analysis (RDA)

The module rigid diaphragm analysis (RDA) shall help the engineer to distribute a resulting horizontal load that applies to a story in a building, to all the shear walls. Such a horizontal load is usually an earthquake load or a wind load. Earthquake and wind loads usually act on the center of mass of the floor above the analyzed story. Generally such a rigid diaphragm analysis (RDA) is performed on the shear walls of a story and the floor that is sitting on top of these shear walls.
Forces that act on the floor in horizontal direction (in plane of the floor) are being spread out through the rigid diaphragm. Such a spread of forces is only possible, if the diaphragm is rigid. For CLT floor, this can usually be assumed. Light framed timber floors (joists and sheathing on top) would be normally classified as flexible diaphragm. In a flexible diaphragm, tributary loads to walls can be distributed by simple geometric breakdown in tributary areas of the floor.
Is the diaphragm rigid, the force in the diaphragm (total force) is being distributed to the shear walls, dependent on their rigidity (openings in shear walls, panel type, wood grade, geometry of the wall, etc.), relative location to the center of mass or center of gravity and their orientation (angle between the direction of force and the direction of the wall).

7.13.1. System data





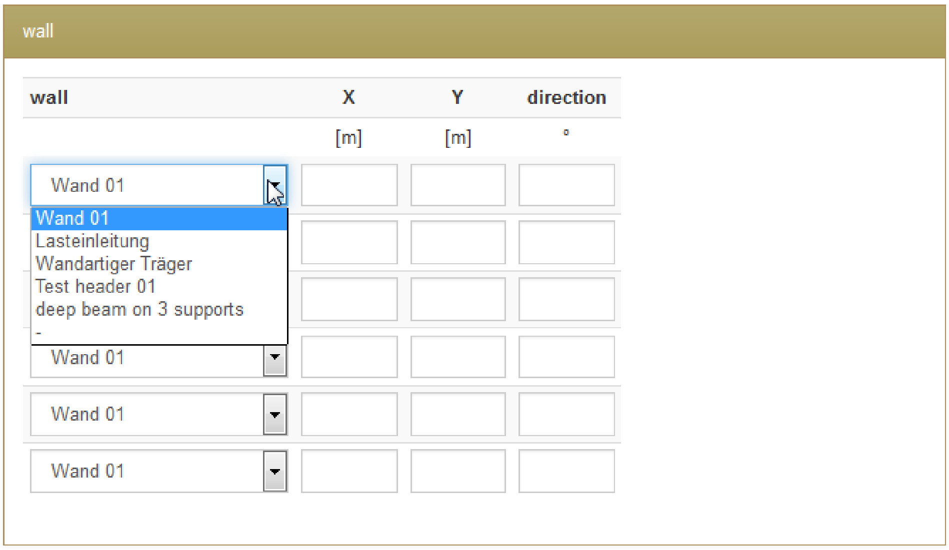
Δ_e is the accidental eccentricity in the diaphragm. This is usually a percentage of the overall length and overall width of the building in plan view. For seismic loading, this is usually 5% - see EN 1998-1, item 4.3.2 [21]. For wind loading this can be different and is not regulated in all countries. Therefore this value is to be entered by the user.

F_x is the horizontal force in X direction.

F_y is the horizontal force in Y direction. (usually equal to the force F_x)

Combine F_x and F_y needs to be checked, it the force in X and the force in Y direction are acting simultaneously.

7.13.2. Wall details



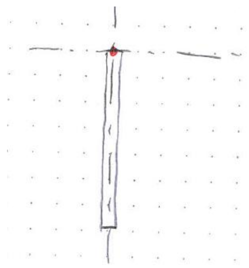
For each wall that shall be placed in the building plan, a wall type shall be selected in the pull-down menu. The **walls** listed in this menu are all walls that are entered in the module "CLT wall / deep beam" – see chapter 7.11. If a wall is not entered in the module "CLT wall / deep beam", it will not be available in this RDA module. The reason for the need to enter walls in the "CLT wall / deep beam" module is the analysis of the rigidity of the respective wall panel, including all voids and support boundary conditions. It is possible to select one wall type from the "CLT wall / deep beam" module more than once for the RDA. A wall that appears several times in the plan with the same dimensions therefore only needs to be entered once in the "CLT wall / deep beam" module (as far as it concerns the RDA).

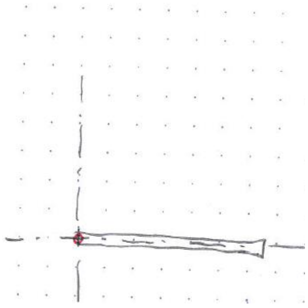
All walls entered in the module "CLT wall / deep beam" have their reference point at the bottom left corner. This is the point that the RDA module refers to, when entering the coordinates X and Y in the RDA module.

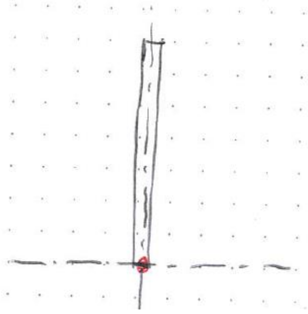
X is the X coordinate of the reference point of the respective wall.

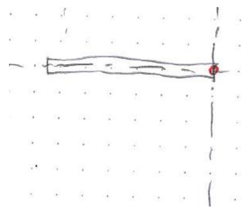
Y is the Y coordinate of the reference point of the respective wall.

Direction gives the orientation of the wall in degree – see figure below:


0°


90°

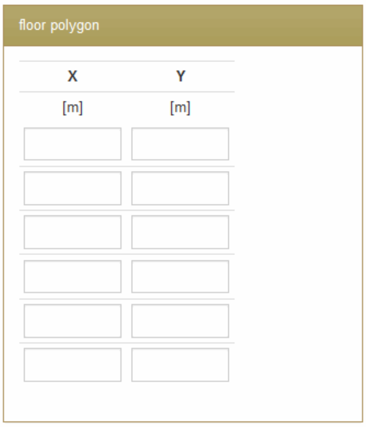

180°


270°

7.13.3. Floor perimeter

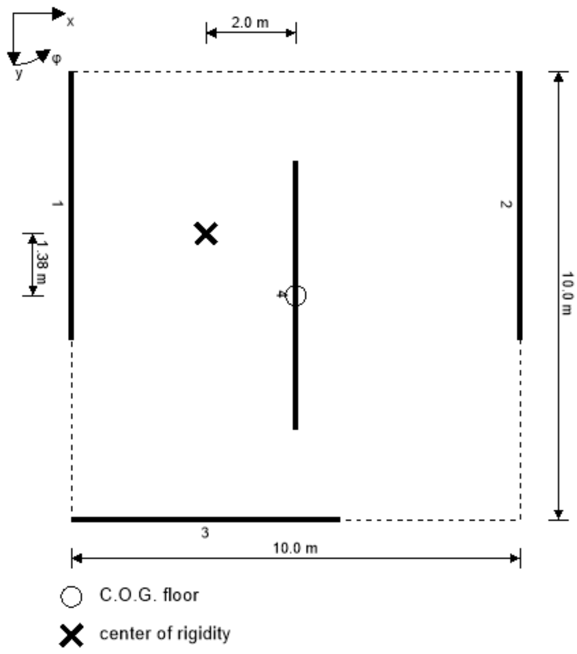
The perimeter of the floor above needs to be entered with the coordinates of the floor polygon.

Note: the coordinates need to be entered, **following strictly the polygon** – either clockwise or counterclockwise. The last point of the polygon will be automatically connected to the first point entered. No need to enter one point twice.



7.13.4. Results

The results include a system sketch, lining out the plan of the building at the respective level with the floor above (dashed line).



The general results of the RDA module give values of the maximum dimensions, coordinates for C.O.G and center of rigidity, accidental eccentricity, total eccentricity and the stiffness:

	X	Y	
maximum floor dimension	10.000	10.000	[m]
C.O.G. floor	5.000	5.000	[m]
center of rigidity	3.000	3.620	[m]
Δe	0.500	0.500	[m]
e	2.500	1.880	[m]
Σ stiffness	6.867	15.960	[kN/m]
Σ stiffness * d²	452.795	402.779	[kNm]
T	125.000	93.987	[kNm]

The load results display as indicated below:

F_x

Pos	name	width	center$_x$	center$_y$	R	R_x	R_y	d_x	d_y	$F_{x,i}$	$F_{y,i}$	F_i	f_i
		[m]	[m]	[m]	[kN/m]	[kN/m]	[kN/m]	[m]	[m]	[kN]	[kN]	[kN]	[kN/m]
1	Wand 01	6	0.000	3.000	4.950	0.000	4.950	2.500	1.120	0.000	19.346	19.346	3.224
2	Wand 01 copy	6	10.000	3.000	6.061	0.000	6.061	7.500	1.120	0.000	33.094	33.094	5.516
3	Lasteinleitung	6	3.000	10.000	6.867	6.867	0.000	0.500	8.120	65.394	0.000	65.394	10.899
4	Wand 01	6	5.000	5.000	4.950	0.000	4.950	2.500	3.120	0.000	19.346	19.346	3.224

F_y

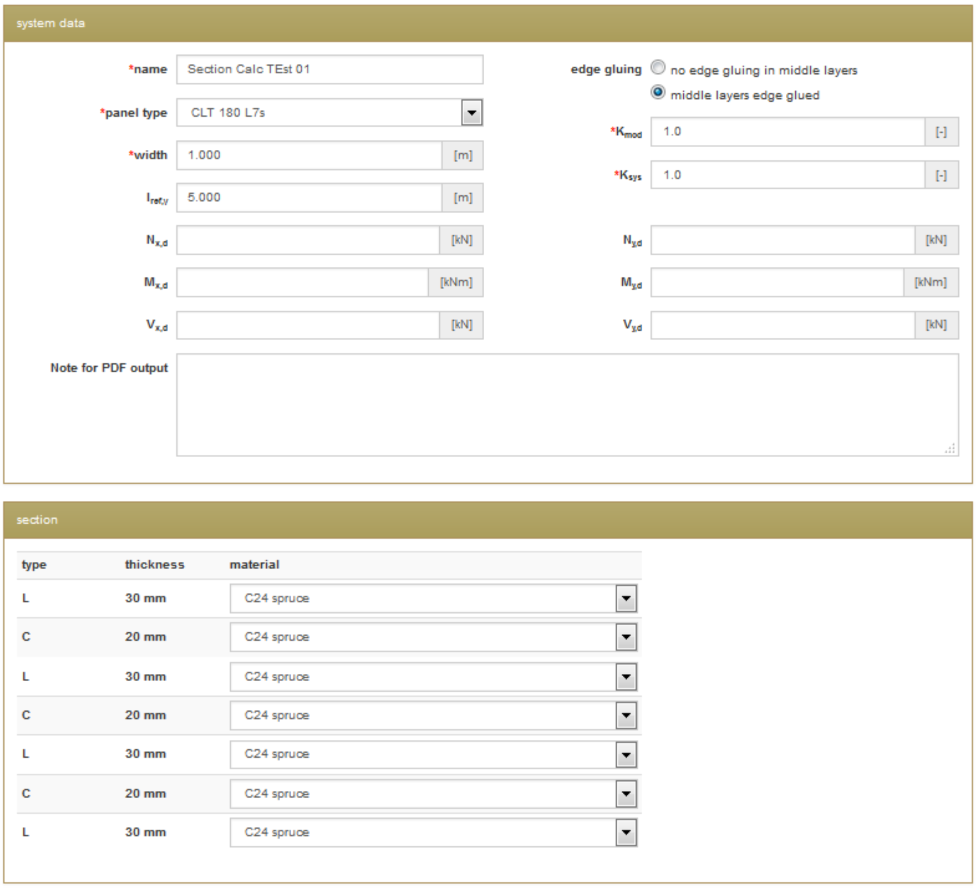
Pos	name	width	center$_x$	center$_y$	R	R_x	R_y	d_x	d_y	$F_{x,i}$	$F_{y,i}$	F_x	f_i
		[m]	[m]	[m]	[kN/m]	[kN/m]	[kN/m]	[m]	[m]	[kN]	[kN]	[kN]	[kN/m]
1	Wand 01	6	0.000	3.000	4.950	0.000	4.950	2.500	1.120	0.000	18.394	18.394	3.066
2	Wand 01 copy	6	10.000	3.000	6.061	0.000	6.061	7.500	1.120	0.000	29.594	29.594	4.932
3	Lasteinleitung	6	3.000	10.000	6.867	6.867	0.000	0.500	8.120	61.574	0.000	61.574	10.262
4	Wand 01	6	5.000	5.000	4.950	0.000	4.950	2.500	3.120	0.000	18.394	18.394	3.066

The results are split for force in x and in y direction, if these forces do not act simultaneously. If they do act at same time, the result includes only 1 table.
Center x and y give the coordinates of the center of rigidity of the respective wall.
R is the rigidity of the respective wall.
Rx and **Ry** are the x and y components of the rigidity of the respective wall.
dx and **dy** are relative distances from the wall´s center of rigidity to the total center of rigidity
$F_{x,i}$ and **$F_{y,i}$** are the resulting force components in x and in y direction that the wall is receiving.
F_i is the resulting force that the wall is receiving in direction of the wall.
f_i is the force **F_i** expressed in kN per linear meter of the wall.

7.14. Section calculator

The section calculator shall give information about the most important section properties of a CLT panel, before and after fire. These section properties are moment of inertia, section modulus, etc. Additionally the module can calculate an utilization rate, at given internal forces.

7.14.1. Section edit

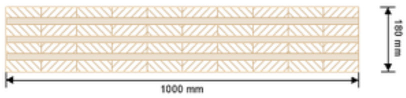


Width: enter the section width (recommended: 1,00 m)
$\mathbf{l_{ref,\gamma}}$ is the reference length for the derivation of γ-values.
$\mathbf{N_{x,d}}$ is the design axial force in X direction.
$\mathbf{N_{y,d}}$ is the design axial force in Y direction.
$\mathbf{M_{x,d}}$ is the design moment about X axis.
$\mathbf{M_{y,d}}$ is the design moment about Y axis.
$\mathbf{V_{x,d}}$ is the design shear force in X direction.
$\mathbf{V_{y,d}}$ is the design shear force in Y direction.
$\mathbf{k_{sys}}$ is the system factor.
$\mathbf{k_{mod}}$ is the applicable k_{mod} for the given design internal forces.

In this module, the wood grade of each lamination layer can be edited separately.

7.14.2. Results – section X and Y direction

section CLT 180 L7s Y



layer	thickness	type	material
1	30.0 mm	L	C24 spruce
2	20.0 mm	C	C24 spruce
3	30.0 mm	L	C24 spruce
4	20.0 mm	C	C24 spruce
5	30.0 mm	L	C24 spruce
6	20.0 mm	C	C24 spruce
7	30.0 mm	L	C24 spruce

analysis using net section

	area	moment of inertia	section modulus	EIy,netto	shear strength
	[mm^2]	[mm^4]	[mm^3]	[kNm^2]	[kN]
net	120,000	384,000,000	4,266,666	4800	14385.83
total	180,000	486,000,100	5,400,001		

z	static moment
[mm]	[mm^3]
-90	0
-60	2,250,000
-40	2,250,000
-10	3,000,000
0	3,000,000
10	3,000,000
40	2,250,000
60	2,250,000
90	0

analysis according to Gamma method

$\gamma_{ref,length}$	Iy,eff	W_{yy}	static moment	EIy,netto	shear strength
[m]	[cm^4]	[cm^3]	[cm^3]	[kNm^2]	[kN]
5	34,971	3,886	2717.768	4371.403	10149.19

type	thickness	γ	E	G	eccentricity from C.O.G.	partial surface	Iy steiner portion	individual moment of inertia
	[mm]	[-]	[N/mm^2]	[N/mm^2]	[mm]	[mm^2]	[mm^4]	[mm^4]
L	30.0 mm	0.9103	12,500	690	-75.0	30,000	168,749,800	2,250,000
C	20.0 mm	0.0000	0	50	-50.0	20,000	49,999,920	666,666
L	30.0 mm	0.8927	12,500	690	-25.0	30,000	18,749,950	2,250,000
C	20.0 mm	0.0000	0	50	0.0	20,000	0	666,667
L	30.0 mm	0.8927	12,500	690	25.0	30,000	18,750,040	2,250,000
C	20.0 mm	0.0000	0	50	50.0	20,000	50,000,040	666,666
L	30.0 mm	0.9103	12,500	690	75.0	30,000	168,750,100	2,250,000

The section properties are given separately for X and for Y direction and for the case before and after fire. The values in “analysis using net section” are the section properties, as they would be used for a CLT design, using the Timoshenko beam theory.
The values in “results according to Gamma method” are the section properties according to gamma method, along with the gamma values.

If internal forces are entered at the input page, the section will be designed for the given forces (flexural stress and shear stress). This function is only applicable for loading out of plane and axial forces in plane (no shear in plane). Serviceability and stability are not covered in that module. A typical output for given internal forces (moment, shear force and axial force) could look as displayed in the image below.

Y direction

flexural design

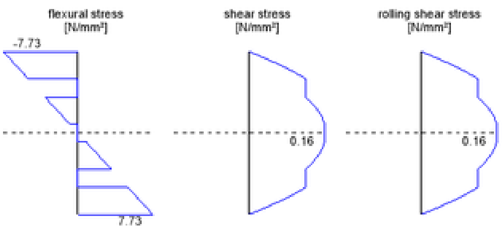
dist.	$f_{m,k}$	$f_{o,k}$	$f_{t,k}$	γ_m	k_{mod}	$k_{sys,y}$	$f_{m,y,d}$	$f_{o,d}$	$f_{t,d}$	$M_{y,d}$	$M_{z,d}$	$N_{o,d}$	$N_{t,d}$	$\sigma_{m,y,d}$	$\sigma_{m,z,d}$	$\sigma_{o,d}$	$\sigma_{t,d}$	utilization
[m]	[N/mm²]	[N/mm²]	[N/mm²]	[-]	[-]	[-]	[N/mm²]	[N/mm²]	[N/mm²]	[kNm]	[kNm]	[kN]	[kN]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	
0.0	24.00	0.00	0.00	1.25	1.00	1.10	21.12	16.80	11.20	33.00	0.00	0.00	0.00	7.73	0.00	0.00	0.00	37 %

shear analysis

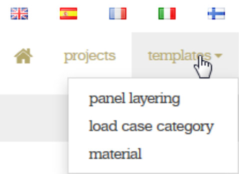
dist.	$f_{v,k}$	γ_m	k_{mod}	$f_{v,d}$	V_d	$\tau_{v,d}$	utilization
[m]	[N/mm²]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]	
0.0	4.00	1.25	1.00	3.20	20.00	0.16	5 %

rolling shear

dist.	$f_{r,k}$	γ_m	k_{mod}	$f_{r,d}$	V_d	$\tau_{r,d}$	utilization
[m]	[N/mm²]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]	
0.0	1.25	1.25	1.00	1.00	20.00	0.16	16 %



9. Templates



The following templates shall help the user, to pick among common panel layups, load case categories and materials, that are specific for a given country. By default, some basic data is already included in the templates. The user can add on to the existing template, clicking the "+" icon:

…and delete items later on, if they are not being used any more, clicking the "x" icon:

Note 1: default data cannot be deleted.

Note 2: only items (load case categories, materials, panel layups) can be deleted, if they do not exist in any saved project. This means, the user needs to get rid of the analysis or project first, that involves the item that needs to be deleted. Then the item itself can be deleted.

Although all values in the templates have been entered with the uttermost attention and the consideration of all relevant design codes for the related country, errors can still occur. All software users need to check the input values, no matter if they originate from a template, or if they are entered directly by the user within the design session. We kindly ask all users to report any errors in the templates and in the software in general, using the contact function in the software.

9.1. Panel layering

This library contains all panel layups. The individually created ones are listed in *italic* letters.
Clicking the "+" icon opens the menu for adding a new panel layup. Insert the following information:

- Panel type (whether the panel shall be a L or C panel …meaning if the cover layers are oriented in principal direction = L panel or if the cover layers are oriented in cross direction = C panel)
- Name for the new layup
- Final thickness of the layup (adding up all the layer thicknesses)
- Number of layers
  Note: if 2 adjacent layers are oriented in the same direction, enter them separately, not at one layer
- Click the check mark icon to confirm the now entered data
- Choose for each layer the orientation (L or C)
- Choose for each layer the thickness
- Click the check mark icon to confirm

9.2. Load case category

This templates library contains all load case categories. They are listed per country. Select in the pull-down menu the country for which the load case category shall apply and then click the search (magnifying glass) icon:

All relevant load case categories are being displayed. To view the details of a template, click the item in the list. The “plus” icon will add a new load case category to the list with user defined data. Enter the values in the respective boxes:

- Load case category name
- Type of loading (e.g. permanent, variable, accidental)
- γ-superior
- γ-inferior
- ψ-values
- Duration
- Design standard that the load case category originates from (related to the design country)
- Default direction of loading (e.g.: snow loading would have as default direction setting “projective”, wind loading would be local, etc.)
- Put a check mark in the respective box, if the load is of a kind that would apply to continuous beams spanwise independent. Live loading would usually be spanwise independent, because one cannot say, if all the loading would occur in only one field at the time, in all fields, or only in every other field. The “spanwise independent” function is analyzing automatically all possible variations.
- Choose the ψ-factor for fire design
- Click the check mark icon to save the entered data

Now the newly entered load case category can be found in the table.

9.3. Material

This template library contains all design materials.
All material templates are categorized, according to the following table. Some material categories and sub categories have structural design values, some have building physics design values and some have both.

Category	Sub category	Material, such as:	structural	building physics
wood and wood based materials	wood and wood based materials	MDF, OSB, etc.		■
	wood	Hardwood panel		■
	CLT material	C24 spruce	■	■
	solid timber & glulam	C16, GL 24h, etc.	■	
concrete, screed and concrete blocks	concrete, screed and concrete blocks	Light weight concrete, reinforced concrete		■
	concrete	C25/30, etc.	■	
brick and blocks	bricks	Masonry bricks etc.		■
	blocks	Masonry blocks, etc.		■
insulation	insulation			■
	mineralwool			■
	wood fibre			■
	EPS			■
	fire protection cladding			■
waterproofing and vapor barrier	waterproofing			■
	vapor barrier			■
granular fill	granular fill			■
wall and ceiling cladding, plaster, stucco	wall and ceiling cladding, plaster, stucco			■
roofing	roofing			■
flooring	flooring	tiles		■
miscelaneous	miscelaneous			■

9.3.1. Structural values

General and strength values (timber related):

is glulaminated ☐	Click this check box, if the material is glulaminated	
density	This is the density of the material for the calculation of the self weight	
ρ_k	Characteristic density according to EN 1995-1-1 and EN 338	
ρ_{mean}	Mean density according to EN 1995-1-1 and EN 338	
$E_{0,mean}$	Mean value of modulus of elasticity parallel to the grain	
$E_{0,5}$	Fifth percentile value of modulus of elasticity	
E_{90}	Mean value of modulus of elasticity perpendicular to the grain	
G_{mean}	Mean shear modulus	
$G_{r,mean}$	Mean rolling shear modulus	
G_{90}	Mean value of shear modulus perpendicular to the grain	
$G_{0,5}$	Fifth percentile value of shear modulus	
$f_{c,0,k}$	Characteristic compressive strength, parallel to the grain	
$f_{c,90,k}$	Characteristic compressive strength, perpendicular to the grain	
$f_{m,k}$	Characteristic flexural strength	
$f_{r,k,min}$	Minimum characteristic rolling shear strength	According to expertise by J. Blass [6]
$f_{r,k,base}$	Characteristic base rolling shear strength	$f_{r,k} = min\left\{f_{r,k,min} \middle\| f_{r,k,base} - \frac{thicknes\ cross\ layer\ [mm]}{100}\right\} \cdot k_{bt}$
k_{bt}	Decrease factor for rolling shear strength	
$f_{t,0,k}$	Characteristic tensile strength, parallel to the grain	
$f_{t,90,k}$	Characteristic tensile strength, perpendicular to the grain	
$f_{v,k}$	Characteristic shear strength, parallel to the grain	
$f_{t,node,k}$	Characteristic torsional shear strength in face gluing surface, in the plane of CLT	
$f_{IP,gross,k}$	Characteristic shear strength in gross section, in the plane of CLT	
$f_{IP,net,k}$	Characteristic shear strength in net section, in the plane of CLT	

Concrete properties

These properties are necessary to specify the concrete composite elements.

If concrete is being specified, sill in these values – otherwise leave these boxes empty

E_{cm}	mean Young´s modulus for concrete according to EN 1992
f_{ck}	characteristic compressive strength for concrete f_{ck} nach EN1992-1-1
f_{cm}	mean compressive cylinder strength for concrete f_{cm} according to EN1992-1-1
f_{ctm}	mean value of axial tensile strength of concrete f_{ctm} according to EN1992-1-1
G	Shear modulus of concrete, using a Poisson ratio of 0,2

Safety coefficients, etc.

γ_M	partial safety coefficient for wood material	
$\gamma_{M,fi}$	partial safety coefficient for wood material in fire design	
k_{fi}	factor for 20% fractile for fire design (EN1995-1-2_2.3(3))	
k_{sys}	System factor according to EN 1995-1-1_6.6, or according to the related ETA document	
$k_{c,90}$	crack factor for bearing design perpendicular to the grain in centrally located compression zones	
$k_{c,90,randnah}$	crack factor for bearing design perpendicular to the grain in compression zones, close to an edge	
k_{cr}	crack factor (EN1995-1-1_6.1.7)	
k_{bt}	Decrease factor for rolling shear strength	
$k_{h,min}$	Minimum depth factor (EN1995-1-1_3.3 & 3.4)	$k_h = min\left\{k_{h,min} \middle\| \left(\frac{k_{h,zähler}}{h}\right)^{k_{h,exponent}}\right\}$
$k_{h,zähler}$	numerator for depth factor (EN1995-1-1_3.3 & 3.4)	
$k_{h,Exponent}$	exponent for depth factor (EN1995-1-1_3.3 & 3.4)	
β_c	imperfection coefficient: 0,2 for solid timber; 0,1 for glulam & LVL (EN1995-1-1_6.3.2)	

Fire design related values

$\beta_{0,h}$	design charring rate for one-dimensional charring under standard fire exposure on horizontal surfaces
$\beta_{0,v}$	design charring rate for one-dimensional charring under standard fire exposure on vertical surfaces
$\beta_{1,h}$	increased design charring rate for one-dimensional charring under standard fire exposure on horizontal surfaces
$\beta_{n,h}$	design notional charring rate under standard fire exposure for horizontal surfaces
$\beta_{n,h}$	design notional charring rate under standard fire exposure for vertical surfaces
Abbrandtiefe erhöht	design notional charring rate under standard fire exposure for vertical surfaces
Min Lamellen Stärke	minimum lamination thickness of CLT, to be structurally effective

9.3.2. Building physics values

The values in this part of the material description can be in some cases contradictory to the structural design values. This is in most cases related to the difference in design codes, where these values originate from. The values in this section are only being applied to the building physics portion of the software and are not mixed with the structural part of the software.

Thomas Demschner
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Ybbs a.d. Donau, 02.11.2015

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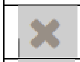
B. Icon key

Icon	Name	Function / description
	Log off	Log off, or sign out of the software. All data is being saved and available to the user, when signing in again.
	User information	Displays all the user information (contact data, etc.). Password can be changed here.
	Info icon	Here the documentation can be found (user manual, tutorial videos, etc.).
	Email icon	Sends an email to the administrator. Use this function in order to get in touch with Stora Enso on software related issues.
	Home icon	Brings the user back to the home screen with the list of current projects that are not finished yet. Finished projects can be found in the "projects" menu.
	Check mark	Saves the entered data. In most of the analysis modules, this function will initiate at the same time the analysis and show the new result for the just entered values.
	List	The list icon will put the user one level higher in the structure of the software. When being in an analysis module, the list icon will put the user back to the list of design modules within the given project. When now the list icon is being clicked again, the user will be put in to the level of the project list, where all projects are being listed. This applies in a similar way to all other modules, lists, and libraries.
	plus	Add a new item to a list. This can be a project,
	Flags	The flag icons on top of the page are for the language settings for the user interface and for the printed report. They do not reflect the design code settings.
	Delete	Clicking this icon will delete the respective position.
	Edit	Editing the respective item (e.g.: project information in the project list)
	Copy	Makes a copy of the respective item (e.g. the current project, analysis, etc.)
	PDF icon	Makes a PDF report of the current analysis, when being within an analysis module. On project level, this function makes a printed summary of all analysis items in the respective project.