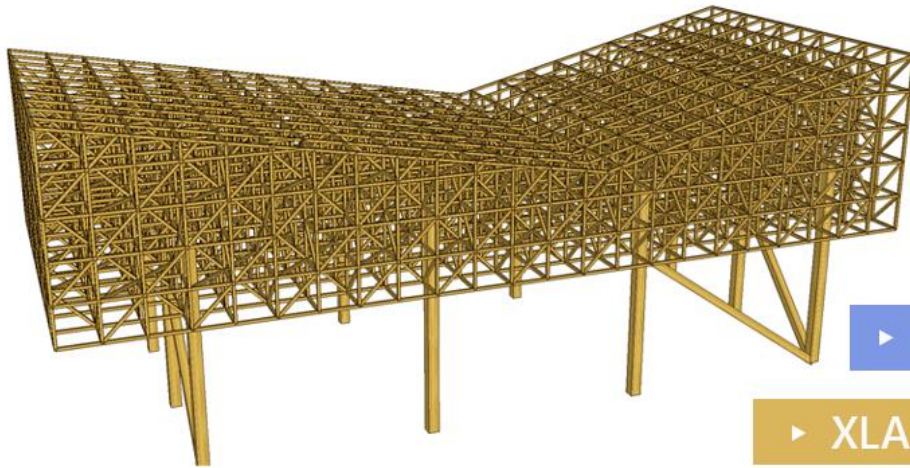
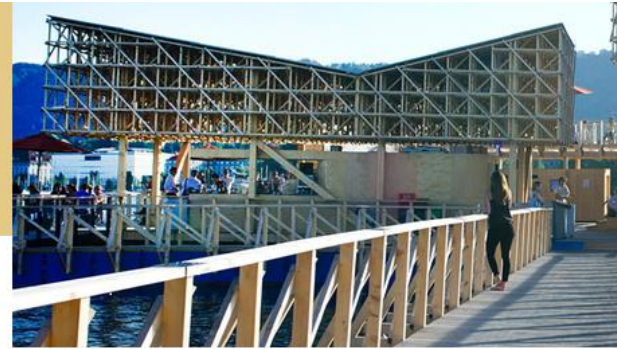


TIMBER DESIGN WITH

AXISVM
STRUCTURAL ANALYSIS & DESIGN PROGRAM



► SOFTWOOD, HARDWOOD,
GLULAM BEAM DESIGN

► FIRE RESISTANCE CHECK

► CROSS-SECTION OPTIMISATION

► XLAM(CLT) MODELING AND DESIGN

Timber & XLAM/CLT Design in AxisVM summary

1. Timber design for beam structures

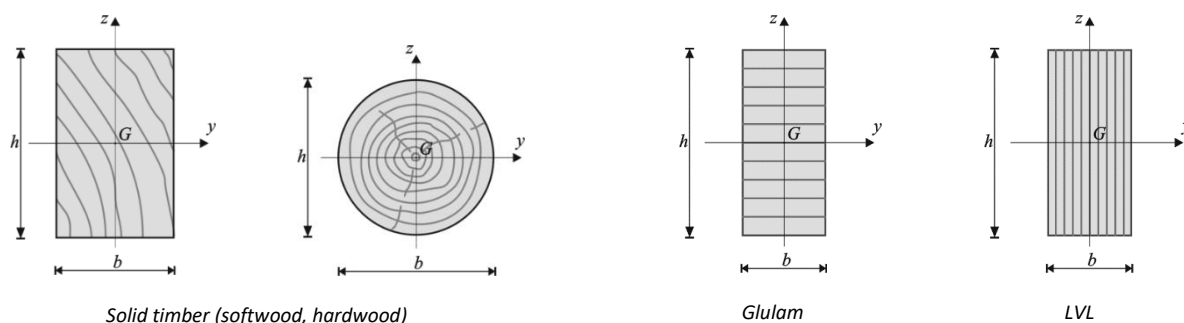
1.1. Timber beam design – TD1 module

EUROCODE 5

(EN 1995-1-1:2004)

The timber beam design module can be applied to the following cross-sections and timber materials:

- a) Rectangle for solid timber, Glued laminated timber (Glulam) and for Laminated veneer lumber (LVL)
- b) Round for solid timber



Material properties

The material database contains the solid, Glulam and LVL timber material properties according to the related EN standard. (Solid timber: EN338, Glulam: EN 1194)

Characteristic strength	Notation
Bending strength	$f_{m,k}$
Tensile strength parallel to grain	$f_{t,0,k}$
Tensile strength perpendicular to grain	$f_{t,90,k}$
Compression strength parallel to grain	$f_{c,0,k}$
Compression strength perpendicular to grain in y direction*	$f_{c,90,k,y}$
Compression strength perpendicular to grain in z direction*	$f_{c,90,k,z}$
Shear strength perpendicular to the grain in y direction*	$f_{v,k,y}$
Shear strength perpendicular to the grain in z direction*	$f_{v,k,z}$

*In case of solid and Glulam timber $f_{v,k,z} = f_{v,k,y} = f_{v,k}$ and $f_{c,90,k,z} = f_{c,90,k,y} = f_{c,90,k}$

Modulus of elasticity	Notation
Mean value parallel to grain	$E_{0,mean}$
Mean value perpendicular to grain	$E_{90,mean}$
5% value of modulus parallel to grain	$E_{0,05}$
Mean value of shear modulus	G_{mean}

Density	Notation
Characteristic value of density	ρ_k
Mean value of density	ρ_{mean}

Partial factor	Notation
Partial factor for material	γ_M

Size effect factor	Notation
for LVL timber	s

Timber classes

Timber elements must have a service class. Service class can be set in the line elements definition dialog, at Service Class field.

Service classes (EN 1995-1-1, 2.3.1.3):

Service class 1 – where the average moisture content in most softwoods will not exceed 12%. This corresponds to a temperature of 20°C and a relative humidity of the surrounding air only exceeding 65% for a few weeks per year.

Service class 2 – where the average moisture content in most softwoods will not exceed 20%. This corresponds to a temperature of 20°C and a relative humidity of the surrounding air only exceeding 85% for a few weeks per year.

Service class 3 – where the average moisture content in most softwoods exceeds 20%.

Design strength and other design properties of the timber materials depend on the service class.

Design strength components The design values of strength is calculated from the characteristic values of strength according to the following formulas:

In case of $f_{t,90,d}, f_{c,0,d}, f_{c,90,d}, f_{v,d}$ (Solid, Glulam, LVL timbers): $f_d = k_{mod} f_k / \gamma_M$

In case of $f_{m,d}$ (Solid, Glulam, LVL timbers): $f_d = k_{mod} k_h f_k / \gamma_M$

In case of $f_{t,0,d}$ (Solid and Glulam timbers): $f_d = k_{mod} k_h f_k / \gamma_M$

In case of $f_{t,0,d}$ (LVL timber): $f_d = k_{mod} k_l f_k / \gamma_M$

where

k_{mod} is a modification factor (EN 1995-1-1, 3.1.3)

k_h is the depth factor (EN 1995-1-1, 3.2, 3.3, 3.4)

k_l is the length factor for LVL timber (EN 1995-1-1, 3.4)

f_k is the characteristic strength

γ_M is the partial factor of material (EN 1995-1-1, Table 2.3)

k_h factor The $f_{m,k}$ and $f_{t,0,k}$ characteristic strength values are determined for a reference depth of beam. In case of solid and Glulam timber if the depth (h) of the cross-section less than the reference value, the design strength is multiplied with the following factor.

Solid timber: $k_h = \min \left\{ \left(\frac{150}{h} \right)^{0.2}; 1.3 \right\}$ (if $\rho_k \leq 700 \text{ kg/m}^3$)

Glulam: $k_h = \min \left\{ \left(\frac{600}{h} \right)^{0.1}; 1.1 \right\}$

In case of LVL timber if the depth (h) of the cross-section not equal to the reference value, the design strength is multiplied with the following factor.

LVL: $k_h = \min \left\{ \left(\frac{300}{h} \right)^s; 1.2 \right\}$

(where s is the size effect exponent, h is the cross-section depth in mm.

Reference depths for solid timber is 150 mm, for Glulam it is 600 mm, for LVL it is 300 mm.

k_l factor The $f_{t,0,k}$ characteristic strength value of LVL timber is determined for a reference length of beam. If the length of the beam is not equal to the reference length, the design strength is multiplied by the following factor.

$k_l = \min \left\{ \left(\frac{3000}{l} \right)^{s/2}; 1.1 \right\}$

(where s is the size effect exponent).

l is the beam length in mm. Reference length: 3000 mm.

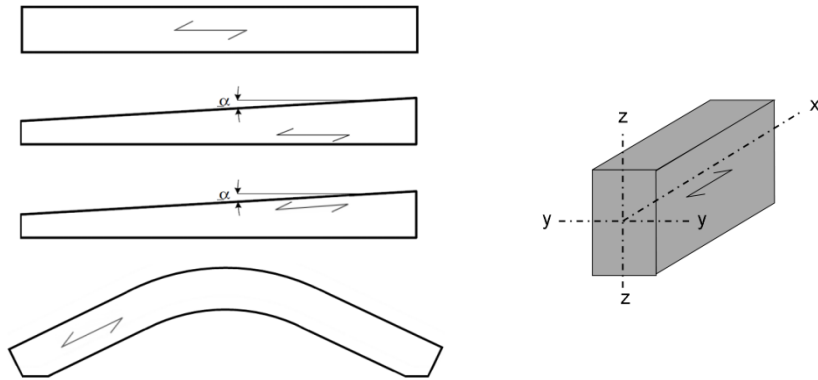
Stiffness values for analysis

Analysis type	Modulus (SLS)	Modulus (ULS)
First order, linear elastic	$E_{mean,fin} = \frac{E_{mean}}{1 + k_{def}}$	$E_{mean,fin} = \frac{E_{mean}}{1 + \psi_2 k_{def}}$
	$G_{mean,fin} = \frac{G_{mean}}{1 + k_{def}}$	$G_{mean,fin} = \frac{G_{mean}}{1 + \psi_2 k_{def}}$
Second order, linear elastic	$E_d = E_{mean} / \gamma_M$	$E_d = E_{mean} / \gamma_M$
	$G_d = G_{mean} / \gamma_M$	$G_d = G_{mean} / \gamma_M$
Frequency	E_{mean}, G_{mean}	E_{mean}, G_{mean}

Conservative way $\psi_2 = 1$ is used.

Design assumptions

- There is no hole or other weakening in the beams.
- The cross-section constant (rectangle, round) or linear changing depth along the beam (tapered beam).
- The grain parallel to the beam x axis.
- In case of tapered beam the grain parallel one of the longitudinal edge.
- The dominant bending plane is the x - z plane of the beam (moment about y axis).
- $I_y \geq I_z$
- In case of Glulam the laminates are parallel to the y axis of the cross-section.
- in case of LVL the laminates are parallel to the z axis of the cross-section.



Checks	Normal force-Bending [N-M]	(EN 1995-1-1, 6.2.3, 6.2.4)
	Compression-Bending-Buckling (in plane) [N-M-Buckling]	(EN 1995-1-1, 6.3.2)
	Normal force-Bending-Lateral tors. buckling [N-M-LT buckling]	(EN 1995-1-1, 6.3.3)
	Shear /y -Torsion /x [Vy-Tx]	(EN 1995-1-1, 6.1.7, 6.1.8)
	Shear (y) - Shear(z) - Torsion (x) [Vy- Vz-Tx]	(EN 1995-1-1, 6.1.7, 6.1.8)
	Moment /y - Shear /z (tensile stress perpendicular to the grain) [My-V z]	(EN 1995-1-1, 6.4.3)

Calculated parameters	$\lambda_{rel,y}$ Relative slenderness ratio (y) /in z-x plane of the beam/ []	
	$\lambda_{rel,z}$ Relative slenderness ratio (z) /in y-x plane of the beam/ []	
	$k_{c,y}$ Buckling (instability) factor (y) /in z-x plane of the beam/ []	(EN 1995-1-1, 6.3.2)
	$k_{c,z}$ Buckling (instability) factor (z) /in x-y plane of the beam/ []	(EN 1995-1-1, 6.3.2)
	k_{crit} Lateral torsional buckling factor []	(EN 1995-1-1, 6.3.3)
	k_h Depth factor []	(EN 1995-1-1, 3.2, 3.3, 3.4)
	k_{mod} modification factor []	(EN 1995-1-1, 3.1.3)
	$\sigma_{t,90,d}$ (tensile stress perpendicular to the grain) [N/mm ²]	(EN 1995-1-1, 6.4.3)

☞ **AxisVM performs the following checks only. All the other checks specified in the design code like supports, joints, etc. has to be completed by the user.**

Normal Force-Bending	The design value of normal force can be tension or compression. Tension and moment (EN 1995-1-1, 6.2.3)
----------------------	--

$$\frac{\sigma_{t,0,d}}{f_{t,0,d}} + \frac{\sigma_{m,y,d}}{f_{m,y,d}} + k_m \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1$$

$$\frac{\sigma_{t,0,d}}{f_{t,0,d}} + k_m \frac{\sigma_{m,y,d}}{f_{m,y,d}} + \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1$$

Compression and moment (EN 1995-1-1, 6.2.4)

$$\left(\frac{\sigma_{c,0,d}}{f_{c,0,d}} \right)^2 + \frac{\sigma_{m,y,d}}{f_{m,y,d}} + k_m \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1$$

$$\left(\frac{\sigma_{c,0,d}}{f_{c,0,d}} \right)^2 + k_m \frac{\sigma_{m,y,d}}{f_{m,y,d}} + \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1$$

where $k_m = 0.7$ in case of rectangle cross-section, $k_m = 1$ in all other cases.

Compression-Moment-Buckling	(EN 1995-1-1, 6.3.2)
-----------------------------	----------------------

$$\frac{\sigma_{c,0,d}}{k_{c,y} f_{c,0,d}} + \frac{\sigma_{m,y,d}}{f_{m,y,d}} + k_m \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1$$

$$\frac{\sigma_{c,0,d}}{k_{c,z} f_{c,0,d}} + k_m \frac{\sigma_{m,y,d}}{f_{m,y,d}} + \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1$$

where,

$k_{c,y}$ Buckling (instability) factor (y) /in z-x plane of the beam/ (EN 1995-1-1, 6.3.2)

$k_{c,z}$ Buckling (instability) factor (z) /in x-y plane of the beam/ (EN 1995-1-1, 6.3.2)

In case of tension force the $f_{c,0,d}$ is replaced with $f_{t,0,d}$ and $k_{c,y} = k_{c,z} = 1$

Normal force-Bending-LT buckling For lateral torsional buckling check the program assumptions that the beam is bending in z-x plane (about y axis). If there is simultaneous M_z moment on the beam and the compression stress from M_z reach the 3% of the $f_{c,0,d}$ a warning message appears.

Bending only (EN 1995-1-1, 6.3.3)

$$\frac{\sigma_{m,d}}{k_{crit}f_{m,d}} \leq 1$$

Compression and moment (EN 1995-1-1, 6.3.3)

$$\left(\frac{\sigma_{m,d}}{k_{crit}f_{m,d}} \right)^2 + \frac{\sigma_{cd}}{k_{c,z}f_{c,0,d}} \leq 1$$

Tension and bending

In case of small tension and bending that lateral torsional buckling could be occur, however there is no rule in EC5 for this case.

The following conservative check is used.

$$\frac{|\sigma_{mt,d}|}{k_{crit}f_{m,d}} \leq 1;$$

$$\sigma_{mt,d} = \frac{M_d}{W_y} + \frac{N_d}{A} < 0$$

where k_{crit} is the lateral buckling factor according to the following

$$\begin{aligned} \lambda_{rel,m} \leq 0.75 & \quad k_{crit} = 1 \\ 0.75 < \lambda_{rel,m} \leq 1.4 & \quad k_{crit} = 1.56 - 0.75 \cdot \lambda_{rel,m} \\ 1.4 < \lambda_{rel,m} & \quad k_{crit} = 1/\lambda_{rel,m}^2 \end{aligned}$$

Shear-Torsion There is no rule in EC5 for case of simultaneous shear force and torsional moment. In this case the program uses the interaction formula according to DIN EN 1995-1-1/NA:2010. Shear(y) , Shear(z) and torsion

$$\max \left[\frac{\tau_{v,y,d}}{f_{v,d}}; \frac{\tau_{v,z,d}}{f_{v,d}}; \frac{\tau_{tor,d}}{k_{shape}f_{v,d}} + \left(\frac{\tau_{v,y,d}}{f_{v,d}} \right)^2 + \left(\frac{\tau_{v,z,d}}{f_{v,d}} \right)^2 \right] \leq 1$$

where,

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

For round cross-section $k_{shape} = 1.2$,

for rectangular cross-section $k_{shape} = \min\{1 + 0.15 \cdot h/b; 2.0\}$

Moment-Shear In case of curved beams the program checks the tensile stress perpendicular to the grain from M_y and V_z forces. (EN 1995-1-1, 6.4.3.)
Moment(y)-Shear(z)

$$\frac{\tau_d}{f_{v,d}} + \frac{\sigma_{t,90,d}}{k_{dis}k_{vol}f_{t,90,d}} \leq 1$$

k_{dis} is a factor which takes into account the effect of the stress distribution in the apex zone ($k_{dis} = 1.4$ for curved beams)

k_{vol} is a volume factor $k_{vol} = [V_0/V]^{0.2}$

Design Parameters

For the design based on Eurocode 5, the following design parameters should be defined and assigned to the design members:



Layer thickness In case of Glued laminated timber (Glulam) arcs thickness of one layer has to be defined.

Grain direction Set of grain direction in case of tapered beam. The grain direction can be parallel with the top edge or with the bottom edge. The top edge lays in the +z direction of the cross-section.

Stability parameters

Buckling K_y, K_z : buckling length factors corresponding to the y and z axis, respectively.

$$K_y = l_{ef,y}/l; \quad K_z = l_{ef,z}/l$$

where l is the member length

$l_{ef,y}$ is the buckling length in x-z plane of the member

$l_{ef,z}$ is the buckling length in x-y plane of the member

Lateral torsional buckling K_{LT} : lateral buckling length factors corresponding to the z axis.

$$K_{LT} = l_{ef}/l$$

where l is the member length

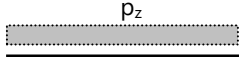
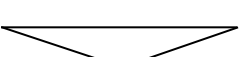
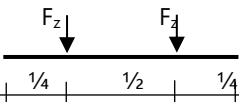
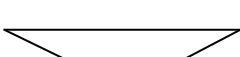
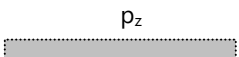
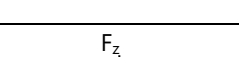
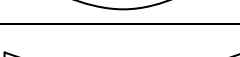
l_{ef} is the lateral buckling length of the member corresponding to the z axis.

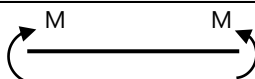
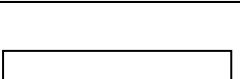
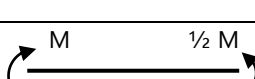
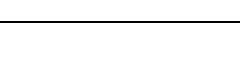
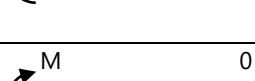
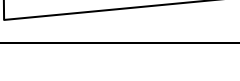
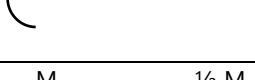
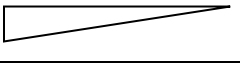
When the load not applied to the center of gravity, the program modify the lateral buckling length according to the following:

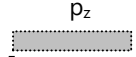
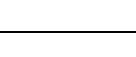
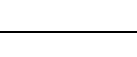
- if the load is applied to the compression edge of the member the l_{ef} is increased by $2h$
- if the load is applied to the tension edge of the member the l_{ef} is decreased by $0.5h$

Common values of K_{LT} factor.

(Some of these values can be found in EN 1995-1-1, Table 6.1)

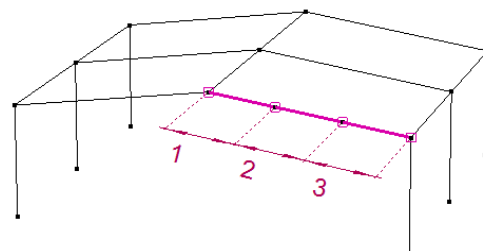
Loading type (direct load)	My moment distribution between the lateral supports	Lateral support condition (in x-y plane)
		
		0.9
		0.8
		0.96
		0.42
		0.64

Loading type (no direct load)	My moment distribution between the lateral supports	Lateral support condition (in x-y plane)
		
		1.0
		0.76
		0.53
		0.37
		0.36

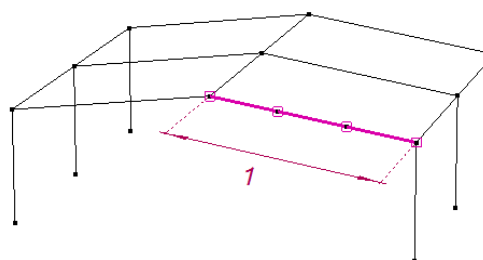
Loading type (cantilever)	My moment distribution	Lateral support condition (in x-y plane)
		
		0.5
		0.8

Design members The design is performed on design members that can consist of one or more finite elements (beams and/or ribs). A group of finite elements can become a design member only if the finite elements in the group satisfy some requirements checked by the program: to be located on the same straight line or arc, to have the same material, cross-section and to have joining local coordinate systems. The program allows two methods to define design members as follows:

Any node of a selection set of finite elements where another finite element is connected will become an end-point of a design member within the selection set of finite elements.



The finite elements in the selection set become only one design member irrespective of other finite elements connecting to its nodes.



SLS
(serviceability limit state)

The parameters for the serviceability limit state (SLS) checks can be set on the SLS tab in the Design parameters window. The program checks the deflections of beams.

Design parameters - Eurocode

Material: GL 32h (GLULAM)
Cross-section: 30x50, 30x60

ULS (Ultimate Limit State) | SLS (Serviceability Limit State)

Deflection

Allowed deflection

☐ y: L / 300

☒ z: L / 300

Pre-camber

☐ w_{cy} [mm] = 0

☒ w_{cz} [mm] = 10

x_{max} = 0,5

L =

☒ Design member length

☐ Based on connecting members and supports

☐ Custom length

Curve

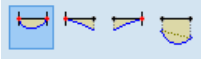
Quadratic

Pick up >> OK Cancel

☞ The program checks the final deflections (u_{fin}). When determining the deformations, the effect of creep is considered throughout the whole loading (in each SLS load combination) by using the k_{def} parameter of each beam.

☞ If the critical load combinations are generated automatically, the program performs the SLS checks in the quasi permanent load combinations.

Deflections can be checked according to the z or y local axis directions of the timber design member. The check in each direction can be activated or deactivated by checking the box in front of the limit values. The deflection limit values shall be set according to the length (L) detailed below.



Deflections can be considered in several ways: based on the actual displacements or based on the displacements relative only to the left, only to the right or to both endpoints of the design member.

Length (L) Deflections of a design member and deflection limits (e.g. $L/300$) are based on one of the following length values:

Design member length: L is equal to the length of the design member;

Based on connecting members and supports: if the *Assemble design members* parameter in the ULS tab is set to the first option, then this length is equal to the design member's length, and thus this is the same as the length above. If it is set to the second option (the selected members are checked as one design member), then the program looks for supports or connecting members along the design member in the direction of the deflection check that can prevent the deflection of the design member and defines segments between these supported nodes. The SLS check is performed for each segment. For example, if a 15 m long beam has supporting columns at the endpoints and at one-third of the beam, the program performs SLS checks separately for the first 5 m segment and the remaining 10 m segment of the beam.

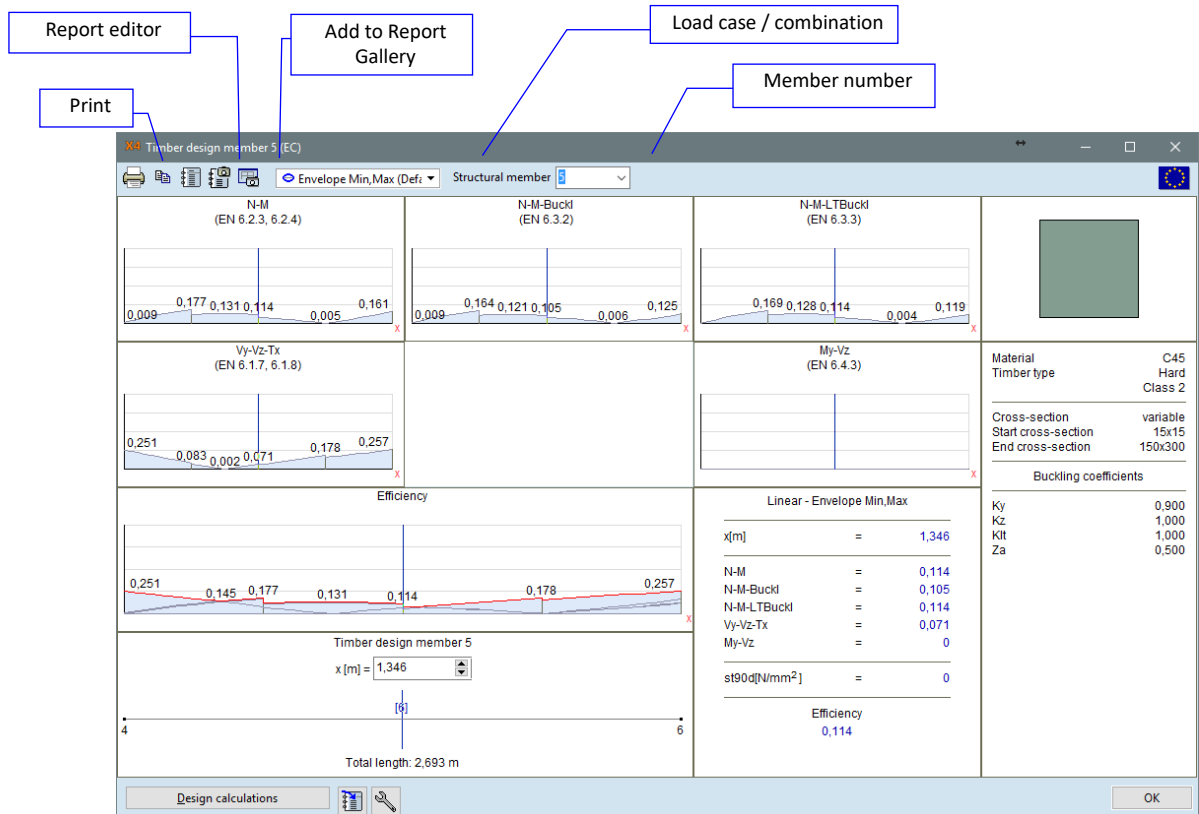
Custom length: any value can be defined.

Pre-camber Pre-camber can be defined for the design members, where the pre-camber values (w_{cz} and w_{cy}) are defined in local coordinates. The shape of the pre-camber can be set with three parameters: linear or second-order curves may be chosen, the maximal value (w) and its location along the member (x_{max}) must also be defined. If deflection is based on actual displacements (e.g. only a section of a beam is selected as a design member), then the pre-camber values are constant along the length. If the length L is set to the design member length or to a custom length, pre-camber is zero in the endpoints of the design members. If *Based on connecting members and supports* is selected, pre-camber will be zero at the endpoints and at the supported nodes in the relevant direction.



It is important to note, that the pre-camber value set here has an effect in the SLS checks only, reducing the previously calculated deflection based on the original shape.

Result diagrams By clicking on a design member the program displays the diagrams corresponding to all the checks.



Design calculations

Clicking on the *Design calculations* button a report of the calculation details can be displayed. All strength and stability checks appear as formulas completed with substituted actual values and design code references.



Clicking on the *Settings* icon beside the *Design calculations* button allows setting the basic units for force and length used in the design calculations. Important results also appear converted to standard AxisVM units.

1.2. Timber beam fire design – TD8 module

Standards AxisVM performs timber fire design according to many national codes. In case of Eurocode National Annexes that are not listed below, general rules of *EN 1993-1-2* are considered.

	Eurocode	<i>EN 1995-1-2 Eurocode 5: Design of timber structures Part 1-2: General - Structural fire design</i>
	EC German	<i>DIN EN 1995-1-2:2010-12 NA</i>
	EC Hungarian	<i>MSZ EN 1995-1-2:2013 NA</i>
	EC Romanian	<i>SR EN 1995-1-2:2004/Ac:2006</i>
	EC Czech	<i>CSN EN 1995-1-2/NA 2011</i>
	EC Slovakian	<i>STN EN 1995-1-2:2008/NA:2011</i>
	EC British	<i>BS EN 1995-1-2:2004 NA</i>
	EC Dutch	<i>NEN EN 1995-1-2/NB:2016</i>
	EC Finnish	<i>SFS-EN 1995-1-2:2004 NA</i>

Fire design of timber structures according to EN 1995-1-2

Timber beam fire design (TD8 module) is based on methods of general timber beam design ([see... 1.1 Timber beam design – TD1 module](#)), thus TD1 module is a prerequisite to use TD8.

EN 1995-1-2 (EC5-1-2) discusses fire design of timber structures. This section describes the differences between the general design and fire design.

Timber beam fire design can be performed in AxisVM if

- 1) the selected load combination includes a fire load case
- 2) if a fire effect has been assigned to any of the selected elements in that fire load case.

If different fire effects have been assigned to elements of a design member fire design cannot be performed and an error message appears.

For selected elements without fire effect the general timber design will be performed. Timber fire design parameters also has to be assigned to the elements (see below).

Member analysis

EC5-1-2 discusses different methods: member analysis, analysis of a part of the structure and analysis of the entire structure. Member analysis is the most widespread verification method due to its simplicity. Analysis of a part or whole of the structure usually requires complex nonlinear numerical models and nonlinear static analysis.

Guiding principles of member analysis according to EC5-1-2:

- Design member internal forces can be calculated with linear static analysis;
- The boundary conditions at supports may be assumed to be constant with time. (EC5-1-2, 2.4.2 (4)).

TD8 module performs member analysis. It has to be checked whether the structure/structural part can be verified with member analysis according to the guidelines of EC5-1-2.

Timber fire design parameters



Fire design based on EC5-1-2 requires fire design parameters defined and assigned to structural members. This button is available only if 1) TD8 module is part of the configuration and 2) the current design code supports timber fire design. The button adds an additional panel on the right side. If it remains hidden, fire design of the element will not be performed.

Buckling coefficients in fire

It is possible to define different buckling length coefficients in fire because deflection of the element is often prevented by other elements that may lose their stiffness or resistance in shorter period of time. The definition/calculation of buckling length is the same as in case of normal temperature design.

Reduced cross-section method

EC5-1-2 provides two different methodology to calculate the mechanical resistance in fire:

- reduced cross-section method,
- reduced properties method.

In the software, the reduced cross-section method is implemented. As a first step, the so-called effective charring depth is calculated on the following way using the notional charring depth ($d_{char,n}$)

$$d_{ef} = d_{char,n} + k_0 d_0$$

where $d_0 = 7mm$, k_0 is a coefficient

The cross-section is reduced with this effective charring depth on the exposed sides. This reduced cross-section is called effective cross-section.

Design checks in fire

The TD8 module, similarly to the TD1 module, performs the following design checks:

Axial force-Bending [N-M]	(EN 1995-1-1, 6.2.3, 6.2.4)
Compression-Bending-Buckling (in plane) [N-M-Buckling]	(EN 1995-1-1, 6.3.2)
Axial force-Bending-Lateral tors. buckling [N-M-LT buckling]	(EN 1995-1-1, 6.3.3)
Shear (y) - Shear(z) - Torsion (x) [Vy- Vz-Tx]	(EN 1995-1-1, 6.1.7, 6.1.8)
Moment /y - Shear /z (tensile stress perp. to the grain) [My-V z]	(EN 1995-1-1, 6.4.3)

The details of the calculation are presented in the previous section, thus we note only the differences in this section:

1. different strength need to be considered,
2. different stability parameters are considered.

Calculation of strength of timber

According to EC5-1-2, the timber strength is calculated on the following way:

$$f_{d,fi} = k_{mod,fi} \frac{f_{20}}{\gamma_{M,fi}}$$

$$f_{20} = k_{fi} f_k$$

where

f_{20} is the 20% fractile strength at normal temperature

$k_{mod,fi} = 1$ is the modification factor for fire

k_{fi} is a coefficient, $\gamma_{M,fi}$ is a partial factor

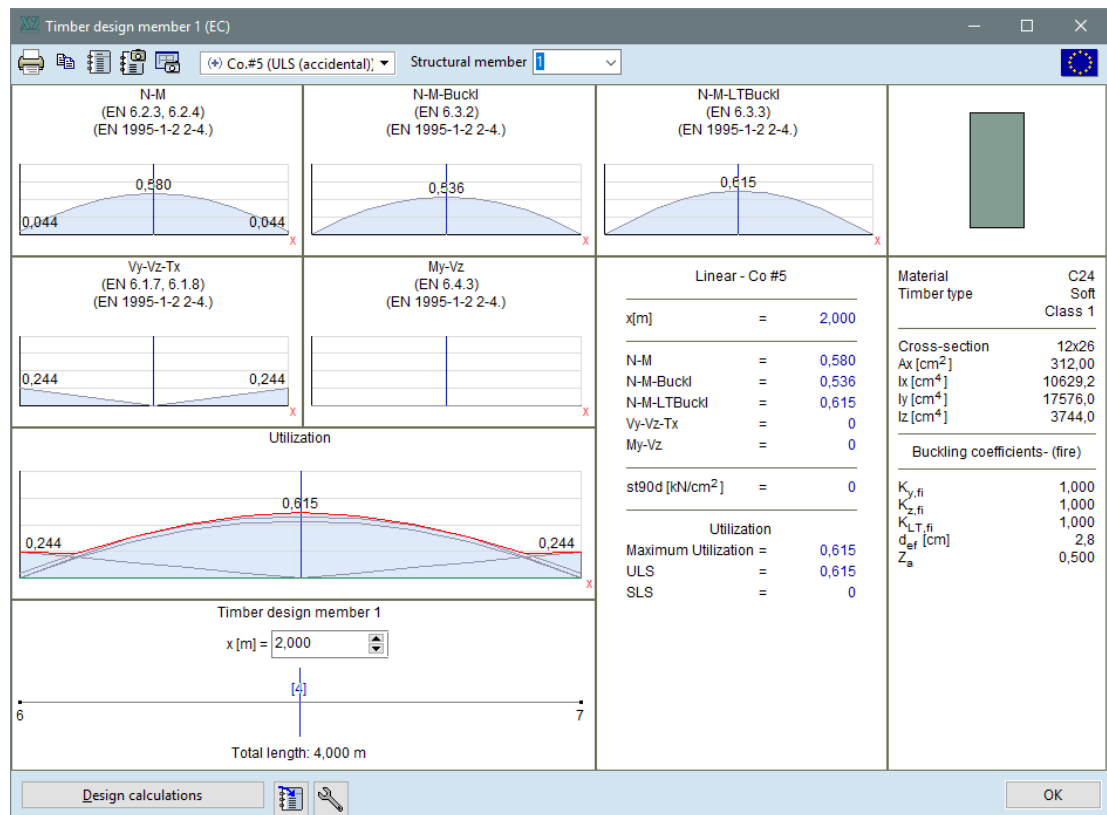
Stability checks

Buckling length ($K_{y,fi}$ and $K_{z,fi}$) and lateral torsional buckling length ($K_{LT,fi}$) coefficient given in *Design parameters window* are used to evaluate the flexural buckling and lateral torsional buckling resistances.

Result diagrams

Click on a timber design member to display diagrams for all individual checks and their envelope. Results for any position of any timber design member in any load case or combination can be obtained by setting x or dragging the tracking line. If design check cannot be performed with the current cross-section, the diagram is replaced by a cross.

If the selected or the critical combination contains fire load case and fire design was performed for the selected design member, buckling coefficients in fire and charring depth are also shown.



Design calculations

Click on *Design calculations* button to see the design details. The calculation can be saved into the documentation. In case of fire design, the type of fire curve and the calculated effective charring depth are also shown.

2. Bending (y)

EN 1995-1-1: 6.1.6

EN 1995-1-2: 2-4.

Fire curve: **Parametric fire curve**

Required time of fire resistance: **R30**

Effective charring depth: $d_{ef} = d_{char,n} + k_0 \cdot d_0 = 2,13 + 1 \cdot 0,70 = 2,83 \text{ cm}$

Critical section: $x = 0,50 \cdot L = 0,50 \cdot 400,00 = 200,00 \text{ cm}$

$$\sigma_{m,y,d,fi} = \frac{|M_y|}{W_{y,fi}} = \frac{|(-704,00)|}{438,15} = 1,61 \text{ kN/cm}^2$$

$$k_{h,y} = 1 \quad (3.1)$$

$$f_{m,y,d,fi} = \frac{k_{mod,fi} \cdot k_{h,y} \cdot f_{m,20}}{\gamma_{M,fi}} = \frac{1 \cdot 1 \cdot 3,00}{1} = 3,00 \text{ kN/cm}^2$$

$$\eta_{M,y,fi} = \frac{\sigma_{m,y,d,fi}}{f_{m,y,d,fi}} = \frac{1,61}{3,00} = 53,6 \% \quad \text{passed}$$

Result table

Among timber design result tables, *Utilization in fire* summarizes the fire design results in order to help the communication with fire safety engineers.

Table Browser

File Edit Format Report Help

Utilization in fire (Eurocode) [Linear, Co #5 (ULS (Accidental))]

	Str. elem.	Type	Material	Shape	R [min]	Fire	Fire protection	d _{ef} [cm]	Max. Loc. [m]	Analysis	Max.	Nx [kN]	Vy [kN]
1	1 (6-7)	(Beam)	C24	12x26	R30	Parametric fire c...		2,8	2,000	N-M-LTBuckl	0,615	10,00	
2	2 (3-4)	(Beam)	C24	12x26	R60	ISO fire curve	✓	4,4	0	Vy-Vz-Tx	7,779	-10,00	
3	3 (1-2)	(Beam)	GL 24c	16x73.5 / 16x16	R30	ISO fire curve		2,8	6,000	N-M-LTBuckl	8,047	0	
3	3 (1-2)	(Beam)	GL 24c	16x73.5 / 16x16	R30	ISO fire curve		2,8	6,000	N-M-LTBuckl	8,047	0	

OK Cancel

Cross-section optimization

If TD9 module is present, timber cross-section optimization can be performed for load combinations that contain fire load case with respect to fire design rules.

Further information in next chapter [1.3 Timber cross-section optimization – TD9 module](#)

1.3. Timber cross-section optimization – TD9 module



TD9 module requires TD1 module.

Cross-section optimization of timber structures makes timber design members previously defined and designed more efficient by fine-tuning cross-section dimensions and reducing self weight.

Optimization checks the design members for the same internal forces ignoring stiffness changes due to changing dimensions. In certain structures recalculation of the model may show considerable changes in internal force patterns. In these cases several consecutive optimizations may find the more efficient structure.

Optimization uses the timber design parameters previously assigned to the design members.

Cross-section types suitable for optimization are: rectangle, rounded rectangle and circular shapes. Variable cross-sections cannot be optimized.

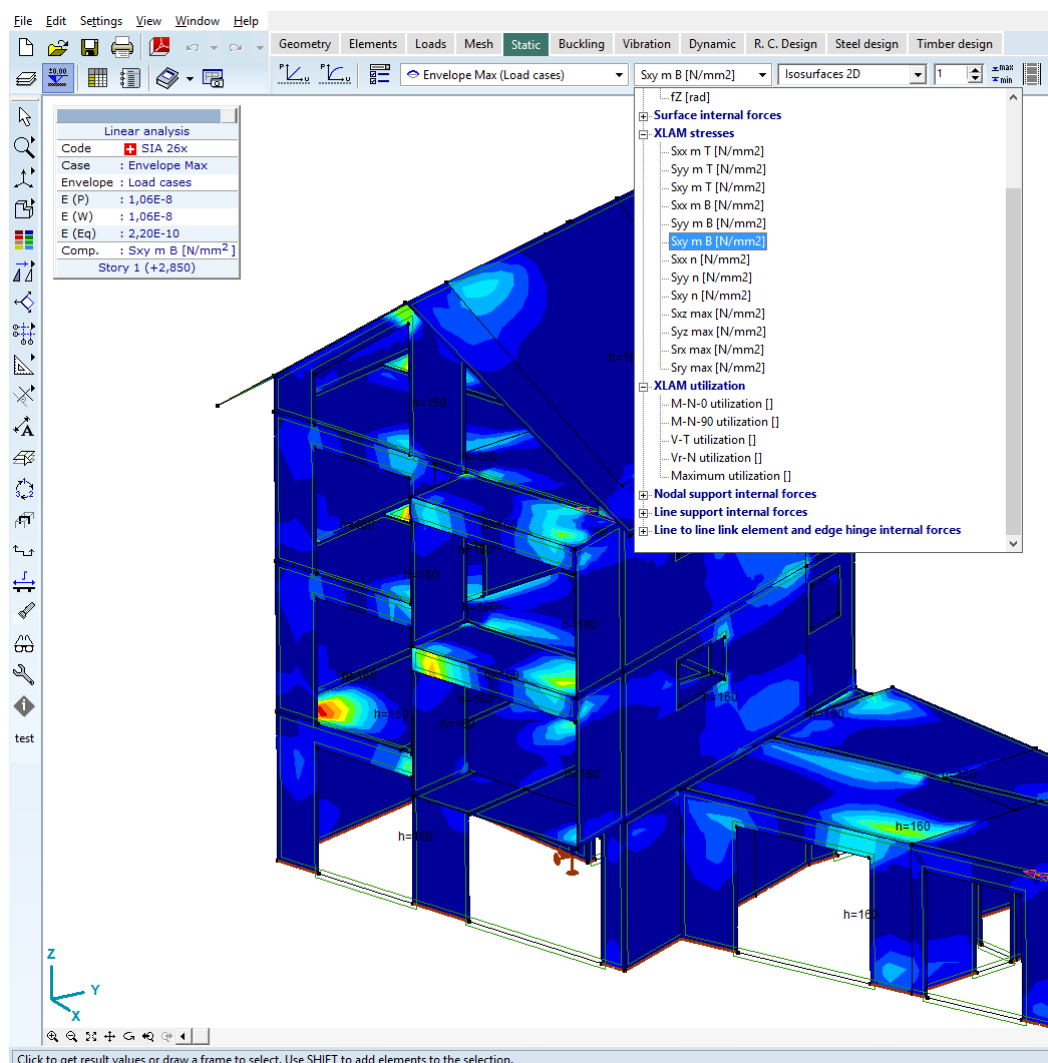
For the details of the optimization see... [AxisVM User's Manual](#) in chapter 6.6.1.4. Steel cross-section optimization – SD9 module

2. XLAM domains in AxisVM

2.1. New features in XLAM module

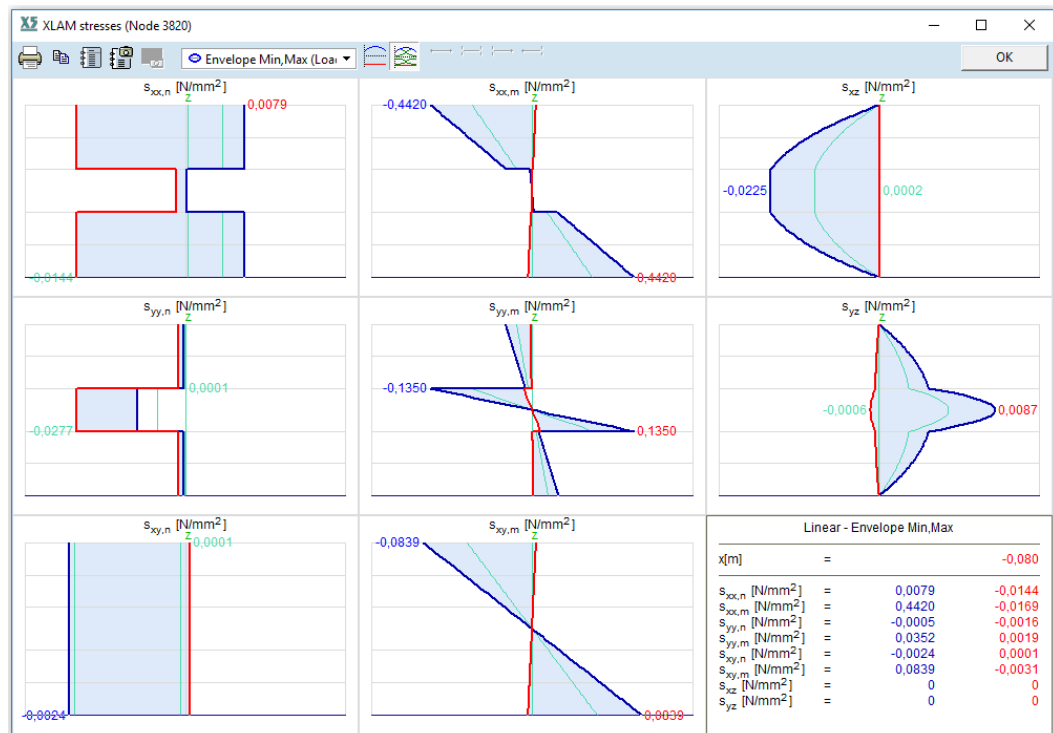
In version AxisVM X5 the performance and capabilities of X-Lam module were improved significantly. The main features of the module are:

- Improved ultimate limit state design, taking into account 'membrane-rolling shear' and 'shear-torsion' interactions.
- The new utilization categories allow for the separation of effects parallel and perpendicular to grain direction.



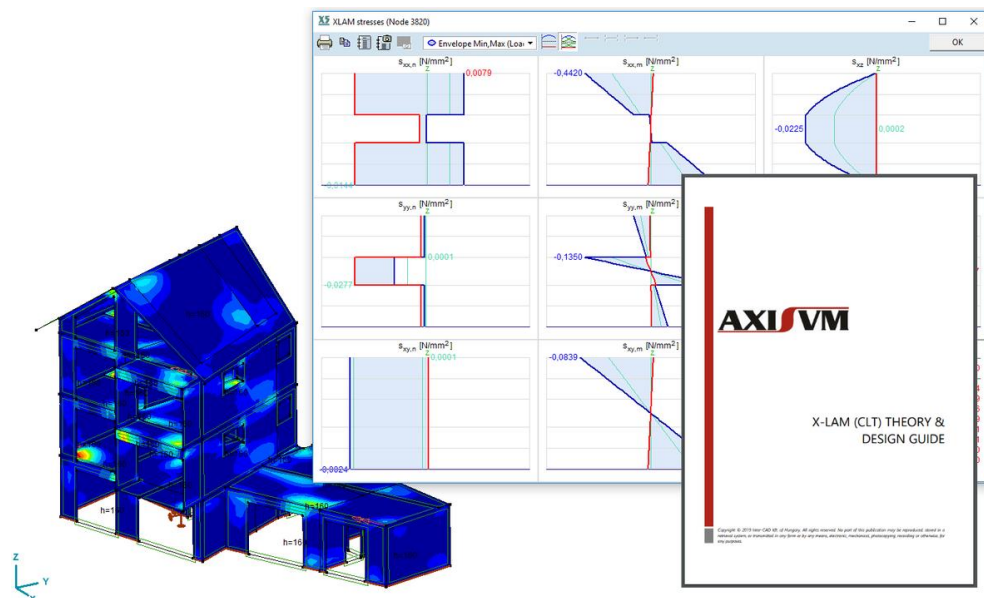
- New, dedicated 'XLAM' material with material constants based on statistical data fitting.

- New display window, showing the stress distributions at a point along the thickness.



The theory and design guide includes a documented stiffness calculation based on the Mindlin-Reissner plate theory with proper shear-correction factors in two dimensions, and the implemented design procedure based on relevant research and ETA documents.

You can find further, detailed information in [X-LAM \(CLT\) Theory and Design Guide](#).



2.2. Definition of XLAM domains

Handling of XLAM (CLT) panels is managed through the definition of XLAM (CLT) domains.

This domain type requires the XLM module.

AxisVM offers a library of many common products but custom layer structure can also be entered.

Analysis provides displacements, forces, stresses and utilizations in XLAM domains.

Definition

Browse XLAM libraries



AxisVM has a wide variety, built-in databases from the XLAM manufacturers, which is constantly expanding.

XLAM layer structure can be loaded from libraries

Manufacturer	KLH	8(300)ssTL	/ ⊥
Binderholz	5(200)sTL	4,0	
X-Lam Dolomiti	7(200)sTL	4,0	
Norica	7(200)ssTL	3,0	⊥
MM	7(210)ssTL	4,0	
KLH	7(220)sTL	4,0	
StoraEnso CLT	7(220)ssTL	3,0	⊥
	7(230)ssTL	4,0	
	7(240)sTL	4,0	
	7(240)ssTL		
	7(250)ssTL		
	7(260)ssTL		
	7(280)ssTL		
	8(300)ssTL		
	8(320)ssTL		

Panel Structure Editor



	h [cm]		⊥
1	4,0	✓	
2	4,0		✓
3	4,0	✓	
4	4,0		✓
5	4,0	✓	

This editor allows to define custom layer structure.

The *Name* field contains the name of the panel structure.

Thickness is the calculated total thickness of the panel.

The *Number of layers* is always odd, the layer structure can be symmetrical or asymmetrical. Besides the thicknesses of the individual layers, the user can change the orientation as well.

Service Class

This is a classification based on the moisture content of the material and the relative humidity. For details see **Service class** in [1.1 Timber beam design – TD1 module](#).

Top layer grain direction

k_{sys}

When checked, the system strength factor is taken into consideration when calculating the strength properties of the member. For further information see the [X-LAM \(CLT\) Theory and Design Guide](#).

k_{fin}

When checked, the flexural strength is taken into account with reduced value. Check it on if the lamellas are finger-jointed. For further information see the [X-LAM \(CLT\) Theory and Design Guide](#).

Calculation Layered structures built from homogenous layers an equivalent orthotropic material stiffness matrix can be calculated. This method converts the geometric inhomogeneity into material orthotropy. Material stiffness of a general shell element can be described with the following system of equations

$$\begin{Bmatrix} \{N\} \\ \{M\} \end{Bmatrix} = \begin{bmatrix} \mathcal{A} & \mathcal{B} \\ \mathcal{B}^T & \mathcal{D} \end{bmatrix} \begin{Bmatrix} \{\epsilon_0\} \\ \{\kappa\} \end{Bmatrix}; \quad \begin{Bmatrix} Q_y \\ Q_x \end{Bmatrix} = K_s \begin{bmatrix} A_{44} & A_{45} \\ A_{45} & A_{55} \end{bmatrix} \begin{Bmatrix} \gamma_y \\ \gamma_x \end{Bmatrix}$$

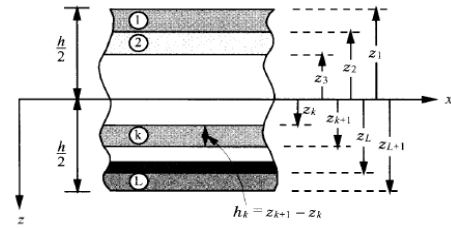
where

$$\mathcal{A} = \begin{bmatrix} A_{11} & A_{12} & A_{16} \\ A_{12} & A_{22} & A_{26} \\ A_{16} & A_{26} & A_{66} \end{bmatrix}; \quad \mathcal{B} = \begin{bmatrix} B_{11} & B_{12} & B_{16} \\ B_{12} & B_{22} & B_{26} \\ B_{16} & B_{26} & B_{66} \end{bmatrix}; \quad \mathcal{D} = \begin{bmatrix} D_{11} & D_{12} & D_{16} \\ D_{12} & D_{22} & D_{26} \\ D_{16} & D_{26} & D_{66} \end{bmatrix}$$

matrices can be derived from the 6x6 stiffness matrix of the Hooke model for orthotropic materials. $\mathcal{B}$ represents the material relation between normal forces and bending. K_s denotes the shear correction factor, which is uniquely determined for each lamination scheme. AxisVM handles symmetric and asymmetric cases as well, the layer orientations must be aligned with one of the local coordinate directions of the domain.

The above matrices are calculated as

$$\begin{aligned} A_{ij} &= \sum_{k=1}^L (\bar{Q}_{ij})_{(k)} (z_{k+1} - z_k), \\ B_{ij} &= \frac{1}{2} \sum_{k=1}^L (\bar{Q}_{ij})_{(k)} (z_{k+1}^2 - z_k^2) \\ &= 0, \\ D_{ij} &= \frac{1}{3} \sum_{k=1}^L (\bar{Q}_{ij})_{(k)} (z_{k+1}^3 - z_k^3) \end{aligned}$$



Lamination pattern. (Reddy, J. *Mechanics of Laminated Composite Plates and Shells*. CRC Press 2004)

where $\bar{Q}_{ij}$ is the Hooke-modell value transformed into the panel coordinate system. For further details on the stiffness calculation procedure, check the [X-LAM \(CLT\) Theory and Design Guide](#).

2.3. Design of XLAM domains

Design codes There is no currently valid, overall design regulation for XLAM (CLT) panels. For further details on the detailed calculation procedure and the references see the [X-LAM \(CLT\) Theory and Design Guide](#).

Material properties There is a dedicated XLAM material in the material library with predefined stiffness and strength properties. If the user wishes, the material properties can be arbitrarily modified in the material library associated with the model.

Characteristic values of material parameters	Denotement
Bending strength	$f_{m,k}$
Tensile strength parallel to the grain direction	$f_{t,0,k}$
Tensile strength perpendicular to the grain direction	$f_{t,90,k}$
Compressive strength parallel to the grain direction	$f_{c,0,k}$
Compressive strength perpendicular to the grain direction (y)	$f_{c,90,k}$
Compressive strength perpendicular to the grain direction (z)	$f_{c,90,k}$
Torsional strength	$f_{T,k}$
Shear strength in y direction	$f_{v,k}$
Shear strength in z direction	$f_{v,k}$
Rolling shear strength	$f_{r,k}^*$

*assumed as 1.0 N/mm², independently of the strength class

Stiffness values	Denotement
Mean value of Young's modulus parallel to the grain direction	$E_{0,mean}$
Mean value of the Young's modulus perpendicular to the grain direction	$E_{90,mean}$
Young's modulus parallel to the grain direction for the significance level of 0.05	$E_{0,05}$
Mean value of the shear modulus	G_{mean}
Mean value of the rolling shear modulus	$G_{R,mean}^*$

*it is assumed that $G_{R,mean}/G_{mean} = 0,1$ holds, independently of the strength class

Density	Denotement
Apparent density	ρ_k
Mean value of the density	ρ_{mean}

Partial safety factor	Denotement
Partial safety factor of the material	γ_M

Service classes See in chapter [1.1 Timber beam design – TD1 module](#)

Load duration classes See in chapter [1.1 Timber beam design – TD1 module](#)

Characteristic value of strength The stress values are determined independently due to bending, normal, shear and torsional actions.

$\sigma_{mx,t}$ – relevant value of the normal stress in x direction due to bending, on the upper half of the region (the side of the region associated with the positive direction of the local z axis).

$\sigma_{mx,b}$ – relevant value of the normal stress in x direction due to bending, on the lower half of the region (the side of the region associated with the negative direction of the local z axis).

$\sigma_{my,t}$ – relevant value of the normal stress in y direction due to bending, on the upper half of the region (the side of the region associated with the positive direction of the local z axis).

$\sigma_{my,b}$ – relevant value of the normal stress in y direction due to bending, on the lower half of the region (the side of the region associated with the negative direction of the local z axis).

σ_{nx} – relevant value of the normal stress in x direction due to normal forces.

σ_{ny} – relevant value of the normal stress in y direction due to normal forces.

$\tau_{n,xy}$ – relevant value of in plane shear stress from normal force.

$\tau_{m,xy}$ – relevant value of in plane shear stress from twisting moment.

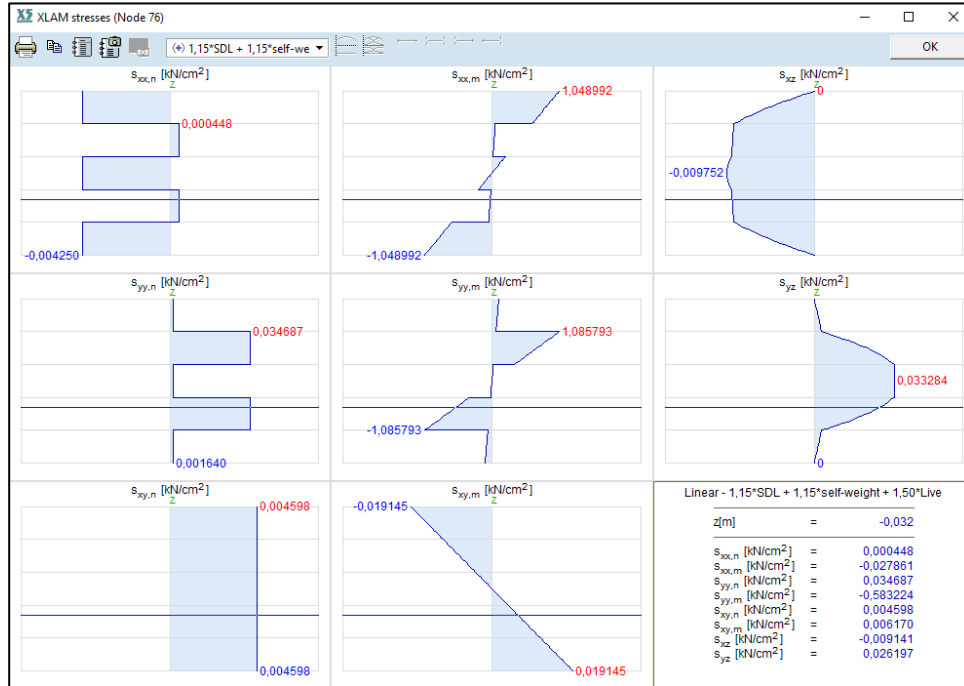
$\tau_{xz,max}$ – relevant shear stress acting in direction z on the plane whose normal is in direction x.

$\tau_{yz,max}$ – relevant shear stress acting in direction z on the plane whose normal is in direction y.

$\tau_{rx,max}$ – relevant rolling shear stress acting in direction z on the plane whose normal is in direction x.

$\tau_{ry,max}$ – relevant rolling shear stress acting in direction z on the plane whose normal is in direction y.

When clicking on a node, one can see the distribution of each calculated stress component through the thickness:



Design value of strength

The design values of strength can be calculated according to the formula:

$$f_{c0d}, f_{c90d}, f_{vd}, f_{rd}: f_d = k_{mod} f_k / \gamma_M$$

$$f_{m90d}, f_{t0d}, f_{t90d}: f_d = k_{sys} k_{mod} f_k / \gamma_M$$

$$f_{m0d}: f_d = k_{sys} k_{mod} k_{fin} f_k / \gamma_M$$

where,

k_{mod} modification factor for duration of load and moisture content (EN 1995-1-1, 3.1.3)

k_{sys} system strength factor

k_{fin} bending strength reduction factor

f_k characteristic value of strength

γ_M partial safety factor of the material (EN 1995-1-1, Table 2.3)

k_{sys} factor $k_{sys} = \min\{1 + 0.025 \cdot n; 1.2\}$ (n denotes the numbers of layer, but $n > 1$)

Interactions

Normal force-Bending moment in grain direction [M-N-0]

Normal force-Bending moment perpendicular to grain direction [M-N-90]

Shear-Torsion [V-T]

Normal force – Rolling shear [Vr-N]

Normal force –

In case of tension

Bending moment
in grain direction
(M-N-0)

$$\frac{\sigma_{t,0,d}}{f_{t,0,d}} + \frac{|\sigma_{m,0,d}|}{f_{m,0,d}} \leq 1$$

In case of compression

$$\left(\frac{\sigma_{c,0,d}}{f_{c,0,d}} \right)^2 + \frac{|\sigma_{m,0,d}|}{f_{m,0,d}} \leq 1$$

Normal force – In case of tension

Bending moment
perpendicular to
grain direction (M-
N-90)

In case of compression

$$\frac{\sigma_{t,90,d}}{f_{t,90,d}} + \frac{|\sigma_{m,90,d}|}{f_{m,90,d}} \leq 1$$

$$\left(\frac{\sigma_{c,90,d}}{f_{c,90,d}} \right)^2 + \frac{|\sigma_{m,90,d}|}{f_{m,90,d}} \leq 1$$

Shear – Torsion
(V-T)

$$\frac{|\tau_{T,d}|}{f_{T,d}} + \left(\frac{\tau_d}{f_{v,d}} \right)^2 + \left(\frac{\tau_{r,d}}{f_{r,d}} \right)^2 \leq 1$$

Rolling shear – In grain direction
Normal force (Vr-
N)

$$\frac{\sigma_{t,90,d}}{f_{t,90,d}} + \frac{|\tau_{r,d}|}{f_{r,d}} \leq 1 ; \quad \frac{|\sigma_{c,90,d}|}{f_{c,90,d}} + \frac{|\tau_{r,d}|}{f_{r,d}} \leq 1$$

Parallel to grain direction

$$\frac{\sigma_{t,0,d}}{f_{t,0,d}} + \frac{|\tau_{r,d}|}{f_{r,d}} \leq 1 ; \quad \frac{|\sigma_{c,0,d}|}{f_{c,0,d}} + \frac{|\tau_{r,d}|}{f_{r,d}} \leq 1$$

When clicking on a node, one can see the distribution of the calculated utilization component through the thickness:

