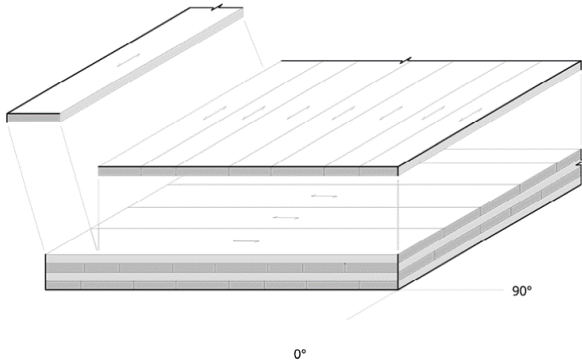# Cross laminated timber (CLT): the building method of the future?

Cross laminated timber (CLT) are flat solid wood products that can be used as structural elements. Thanks to its favorable environmental, aesthetic and energy properties, it is sometimes called the material of the future.

The innovative board-shaped product with a laminated structure and interesting physical-mechanical properties consists of at least 3 board layers glued alternately at 90 degrees to each other. The individual boards are mainly 40 mm to 300 mm wide and 6 mm to 45 mm thick.
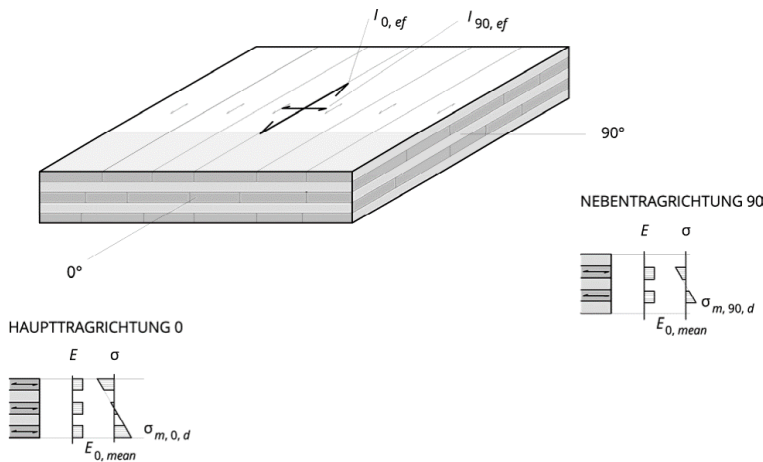

CLT boards are nothing new, they have been produced since 1995 but have not been included in standards until now. Their use in the construction industry was regulated by technical guidelines at European level (ETA: European Technical Assessment). With the second generation of Eurocode 5, CLT will immediately become part of that same standard, so that structural engineers finally have a way to design and test such structures in accordance with the standard. In the draft version of the new Eurocode 5, expected around 2025, CLT is woven into every check (where applicable) of the standard.

The application possibilities of CLT plates are quite broad. The load-bearing properties can be used to act as:

- Floor element
- Roof element
- Wall element
- Rib-element of a floor
- ...

CLT panels are orthotropic because the load-bearing properties are different in the two directions (0° and 90°). This is a direct consequence of the number of plates and the positioning of the plate elements in a respective

direction. The figure below illustrates the orthotropy using the bending stresses in both directions (0° = main bearing direction, 90° secondary bearing direction):
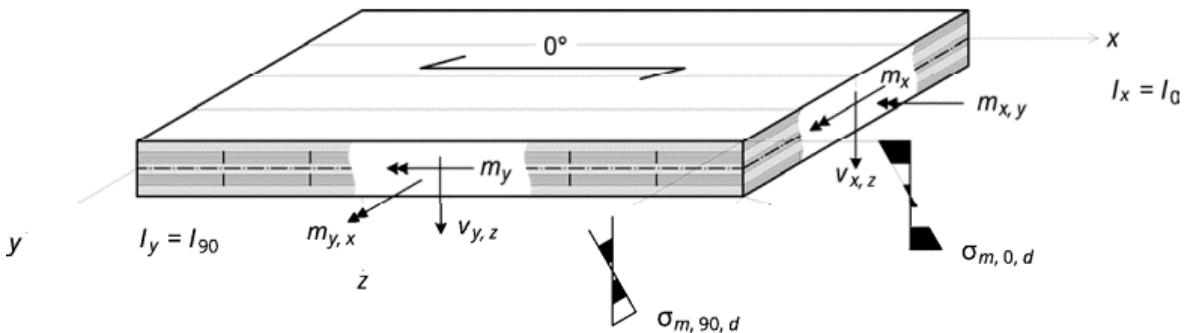

For the bending stresses, only the layers oriented in the respective direction are taken into account. The layers oriented in the other direction act as spacers and are only loaded on shear in the main load direction.

CLT in SCIA Engineer

Until now there is no check for CLT panels in SCIA Engineer, because of the lack of guidelines in the current Eurocode 5. They can be modelled as an orthotropic plate to take their stiffness into account in the model. Afterwards they can be checked (e.g. using Excel sheets) based on the internal forces which are available after the analysis.

The calculation of the orthotropic parameters can be done as follows based on the Mindlin plate theory that accounts for shear force deformation via D44 & D55:

Plate stiffness parameters (bending and shear)

Bending stiffness in the x-direction: $D_{11} = \frac{E_{0,mean}*I_{0,net}}{(1-v_{x,y}*v_{y,y})}$; in practice: $D_{11} = E_{0,mean} * I_{0,net}$

Bending stiffness in the y-direction: $D_{22} = \frac{E_{0,mean}*I_{90,net}}{(1-v_{x,y}*v_{y,y})}$; in practice: $D_{22} = E_{0,mean} * I_{90,net}$

Bending moment influenced by transverse strain: $D_{12} = D_{21} = \sqrt{v_{x,y} * v_{y,y} * D_{11} * D_{22}}$; in practice (no Poisson effects): $D_{12} = D_{21} = 0$

Torsional stiffness: $D_{33} = k_{twist} * G_{0,mean} * \dfrac{b*d^3}{12}$

Shear stiffness: $D_{44} = \dfrac{1}{\kappa_{0,z}} * G_{0,mean} * A_{0,net}$

Shear stiffness: $D_{55} = \dfrac{1}{\kappa_{90,z}} * G_{0,mean} * A_{90,net}$

With:

$E_{0,mean}$: Mean E-modulus in the main bearing direction (0°)

$G_{0,mean}$: Mean G-modulus in the main bearing direction (0°)

$\nu_{x,y}$ & $\nu_{y,y}$: Poisson ratios

In practice, one ignores the Poisson effects, as if planks are 'unglued' next to each other in the same plane → $\nu_{x,y} = \nu_{y,y} = 0$

$I_{0,net}$: Net moment of inertia in the main bearing direction (0°), i.e. only the layers in the main bearing direction should be taken into account using the formula below:

$$I_{0,net} = \sum_{i=1}^{n} \frac{E_i}{E_c} \cdot \frac{b * d_i^3}{12} + \sum_{i=1}^{n} \frac{E_i}{E_c} \cdot b * d_i * a_i^2$$
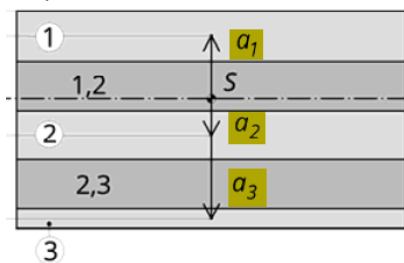
Where:

E_i: E-modulus of the respective layer

E_c: Reference E-modulus (if all layers have the same E-modulus E_i/E_c =1)

b: For the width, a unit width of 1 m can be used

d_i: Thickness of the respective layer

a_i: Distance between the centre of gravity of the whole CLT panel and the centre of gravity of the layer in question

$I_{90,net}$: Net moment of inertia in the secondary bearing direction (90°), i.e. only the layers in the secondary bearing direction should be taken into account using the formula below:

$$I_{90,net} = \sum_{i=1}^{n} \frac{E_i}{E_c} \cdot \frac{b * d_i^3}{12} + \sum_{i=1}^{n} \frac{E_i}{E_c} \cdot b * d_i * a_i^2$$

k_{twist}: Reduction factor to torsional stiffness

$k_{twist} \approx 0.65$

d: Thickness of the CLT panel (total thickness)

$\kappa_{0,z}$: Correction factor for shear (out-of-plane) for the main bearing direction (0°)

$$\kappa_{0,z} = \frac{\sum G * A}{\left(E \cdot I_{0,net}\right)^2} * \int_h \frac{\left[E_{(z)} * S_{(z)}\right]^2}{G_{(z)} * b} dz$$

Guideline values for CLT panels with standard slats of different thicknesses (20, 30, 40 mm) for κ_0=1/κ_(0,z) :

Type 3s: $0.15 \leq \kappa_0 \leq 0.18$

Type 5s: $0.18 \leq \kappa_0 \leq 0.20$

Type 7s: $0.25 \leq \kappa_0 \leq 0.29$

Type 9s: $0.26 \leq \kappa_0 \leq 0.29$

Guideline values for CLT panels with standard slats of equal thickness and strength and a ratio in G-modulus of $\frac{G_{90}}{G_0} = \frac{1}{10}$::

One layer: κ_0 = 0.83

Three layers: κ_0 = 0.21

Five layers: κ_0 = 0.24

Seven layers: κ_0 = 0.26

Nine layers: κ_0 = 0.27

$\kappa_{90,z}$: Correction factor for shear (out-of-plane) for the secondary bearing direction (90°)

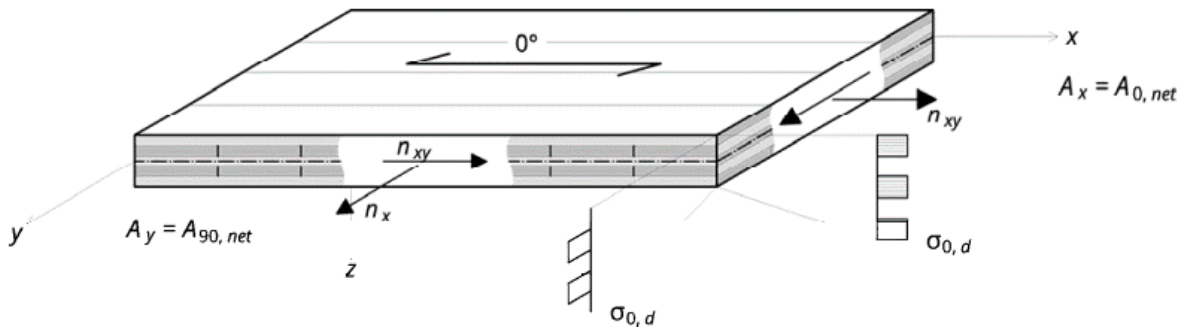$$\kappa_{90,z} = \frac{\sum G * A}{\left(E \cdot I_{90,net}\right)^2} * \int_h \frac{\left[E_{(z)} * S_{(z)}\right]^2}{G_{(z)} * b} dz$$

The same guideline values as above also apply here but for $\kappa_{90} = \frac{1}{\kappa_{90,z}}$

$A_{(0,net)}$: Net area in the main bearing direction

$A_{(90,net)}$: Net area in the secondary bearing direction

Wall stiffness parameters (normal force)

Normal stiffness in the x-direction: $d_{11} = E_{0,mean} * A_{0,net}$

Longitudinal strain influenced by transverse strain (Poisson effect) $d_{12} = \nu * d_{11}$; in practice: $d_{12} = 0$
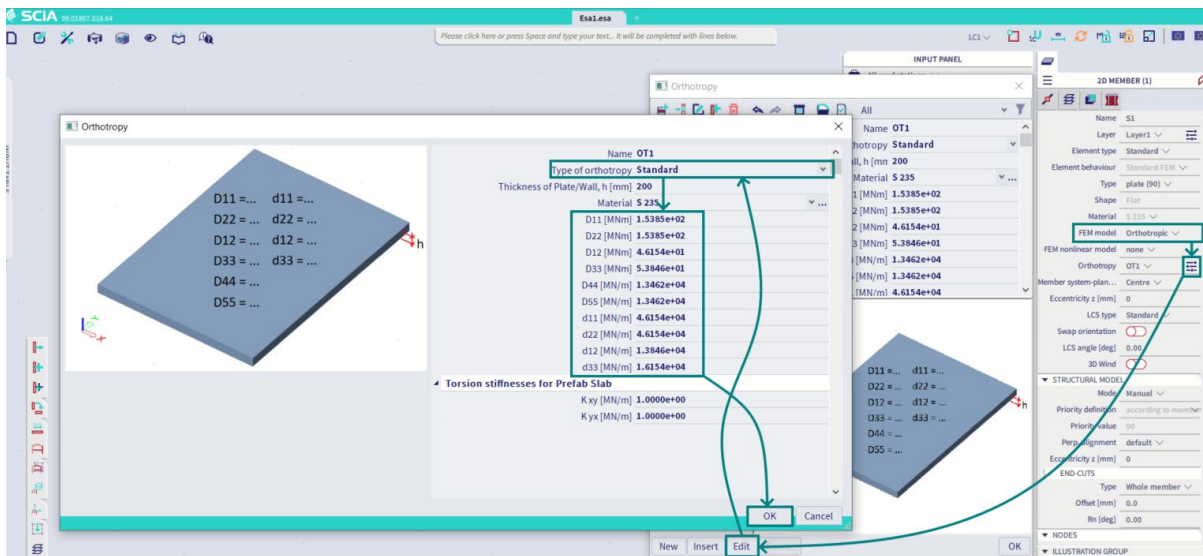
Normal stiffness in the y-direction: $d_{22} = E_{0,mean} * A_{90,net}$

Shear stiffness: $d_{33} = G_{s,mean} * A_{brutto} \approx 0.75 * G_{0,mean} * A_{brutto}$

Input in SCIA Engineer

As soon as the stiffness parameters are calculated and known, they can be entered in SCIA Engineer via orthotropy. This is done by selecting the plate element in question in SCIA Engineer and subsequently changing the FEM model to orthotropic in the properties.

Subsequently you can enter the stiffness parameters directly as soon as you have selected the orthotropy type 'standard'. See the summary figure below:

When you calculate the model, you correctly include the stiffnesses of the CLT panels in the analysis. The next step is then to evaluate the resulting internal forces by means of self-made checks. Here we strongly recommend the publication by proHolz Austria (2014): Cross-Laminated Timber Structural Design) in which you can find methods to check a CLT panel.

Sources: proHolz Austria (2014): Cross-Laminated Timber Structural Design

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