Linear members made of cross-laminated timber (CLT)

Marcus Flaig
Research scientist
KIT - Holzbau und Baukonstruktionen
Karlsruhe, Germany

Summary

As a cross-laminated product, CLT has a number of advantages over glued-laminated timber (glulam). In particular the tensile strength perpendicular to the beam axis is considerably higher and therefore CLT has a much lower sensitivity to cracks causing numerous damages to glulam components in the past. The basic idea of this research project is hence to develop linear CLT components like beams able to replace glulam members where large tensile stresses perpendicular to the grain occur, e.g. beams with notches or holes, members with connections loaded perpendicular to the grain and tapered or double tapered beams.

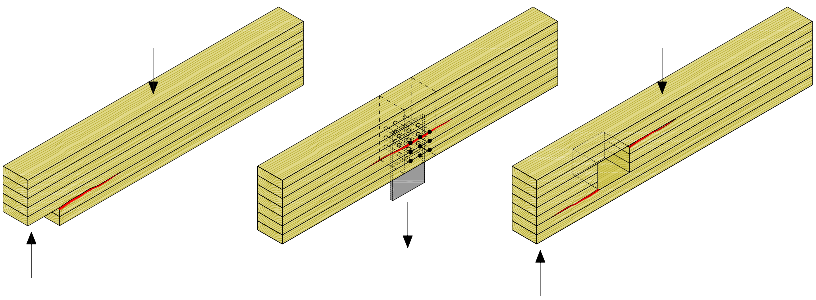

Fig. 1: Components made of glued-laminated timber are prone to cracking when exposed to tensile stresses perpendicular to the grain

In glulam components tensile stresses perpendicular to the grain often result in uneconomically large cross-sections or require cost-intensive reinforcement measures. In CLT components the cross-layers, as an integral element of the product, will provide sufficient reinforcement if they are suitably arranged and dimensioned. Since cross-layers are present over the entire length of CLT components, beams made of cross-laminated timber are also less sensitive to cyclic climatic stresses. Thus they are considered more robust than glued-laminated timber components.

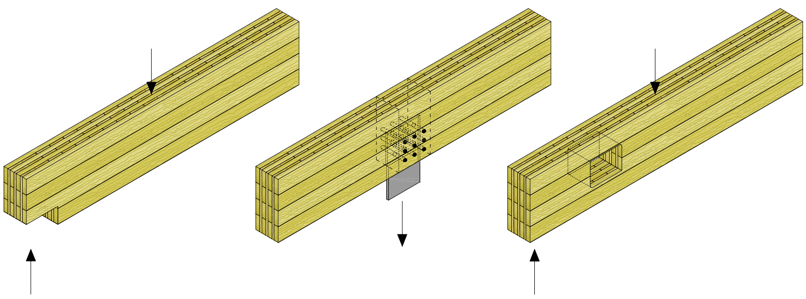

Fig. 2: Cross-laminated timber beams are less susceptible to cracking since cross-layers oriented orthogonally to the beam axis take effect of reinforcement

In longitudinal direction the load-bearing capacity and the stiffness of CLT-beams are rather poor compared to glulam beams with the same dimensions. In order to make linear CLT components more competitive these characteristics have to be improved. This can be achieved by reducing the proportion of cross-layers to a required minimum and by exploiting homogenisation effects resulting from the parallel alignment of multiple lamellae at the edge of a cross section.

1 State of knowledge

1.1 Bending strength of CLT-beams

In current technical documentations for CLT-products the bending strength of edgewise loaded CLT-members is calculated by means of simplified design rules as e.g. given in [1]. Usually the homogenisation due to the parallel alignment of multiple boards is taken into consideration only by the use of conservative approaches since no systematic studies into increasing strength in parallel systems with multiple boards have been conducted yet.

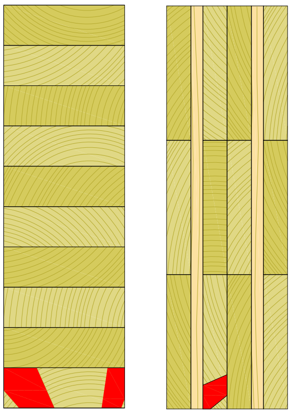

Fig. 3: Homogenisation due to parallel alignment of boards

The very high strength values in the direction of longitudinal layers as stipulated in technical approvals for multiple-layer boards do however indicate a high and as yet unexploited potential. However, the extremely high economic costs of determining the homogenisation effect by experiments, while also taking into consideration board quality and lay-up, does not appear feasible.

1.2 Load-bearing capacity of CLT-beams with notches or holes and tapered CLT-beams

Current technical documentations do not provide rules for the design of CLT-beams with notches or holes and tapered CLT-beams since only few tests or in the case of tapered beams even no tests have been conducted yet. However existing test results indicate very high load-bearing capacities for CLT-beams with notches or holes [2].

2 Approach of the ongoing research project

2.1 Simulation of bending strength and stiffness

A possible alternative for the determination of strength and stiffness values by tests is to calculate these properties using suitable computational models which in addition provide the possibility of quantifying homogenisation and size effects.

For the simulation of glulam beams a computational model has been developed at the Chair of Timber Construction and Structural Engineering at KIT (Karlsruhe Institute of Technology) as early as 25 years ago [3]. Since both glulam and CLT are products built up from finger-jointed softwood lamellae considerable parts of this model can be used for the simulation of CLT-beams as well.

Within the computational model Monte Carlo simulations are used to generate strength and stiffness properties of individual board sections on the basis of experimentally obtained frequency distributions of various wood properties and regression equations describing the relationship between these properties and the characteristic strength values to be generated.

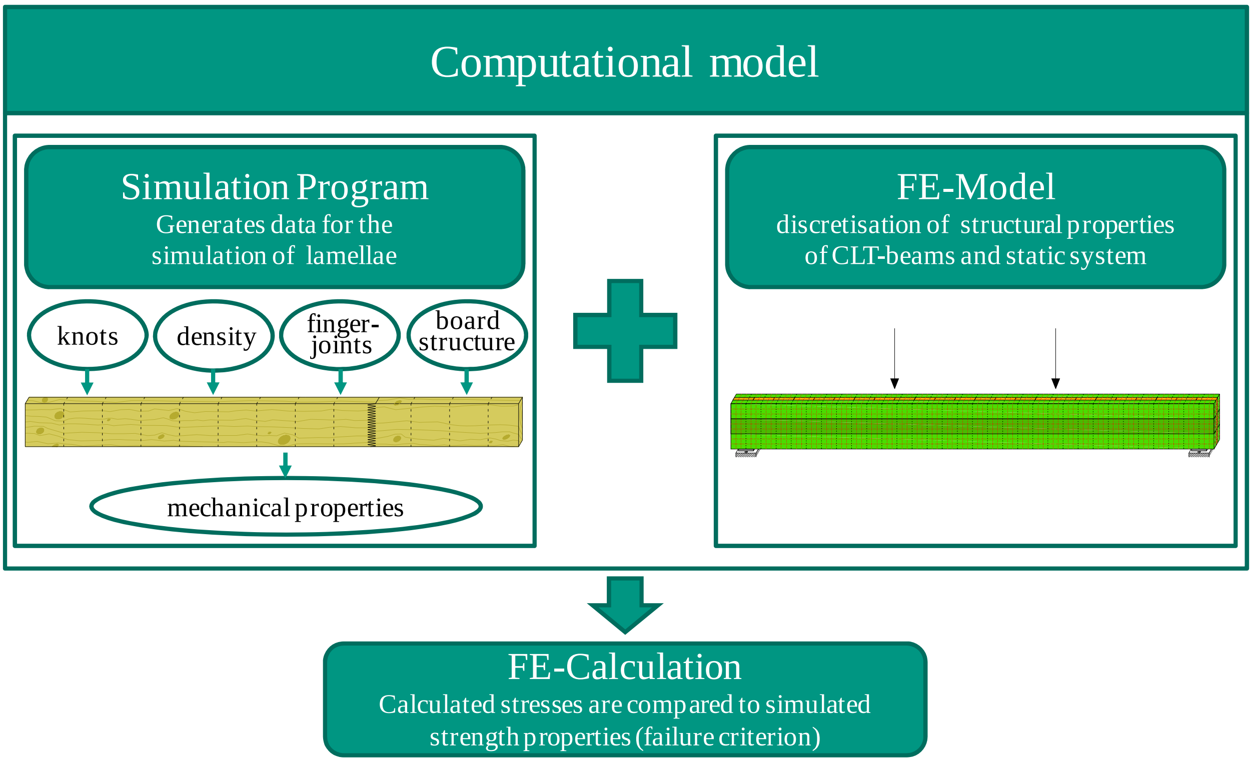

Fig. 4: Scheme of the computational model used for the simulation of bending strength of cross-laminated timber members

For the calculation of the strength and stiffness properties of CLT-beams the existing data given by the glulam model have to be prepared and supplemented with a couple of characteristics that are required in addition. For a number of variables, such as the bending strength of softwood, published frequency distributions and regression equations are available [4]. Due to a lack of relevant data, frequency distributions of other material properties, such as the edgewise bending strength of finger-joints and the rolling shear strength, have to be determined by tests.

2.2 CLT-beams with notches or holes and tapered CLT-beams

To determine the load-bearing capacity of CLT-beams which are subject to tensile stresses perpendicular to the grain tests have been carried out. In particular, test series involving load components perpendicular to the grain in connections, beams with notches, and beams with holes and tapered beams have been conducted. The test results shall serve as a basis for deriving design approaches for the beam types under investigation.

References

[1] CUAP "Solid wood slab element to be used as a structural element in buildings", ETA request No 03.04/06

[2] Bejtka I.; "Cross (CLT) and diagonal (DLT) laminated timber as innovative material for beam elements", Karlsruher Berichte zum Ingenieurholzbau, Band 17, 2011

[3] Colling F., "Tragfähigkeit von Biegeträgern aus Brettschichtholz in Abhängigkeit von den festigkeitsrelevanten Einflussgrößen", Berichte der Versuchsanstalt für Stahl, Holz und Steine der Universität Fridericiana in Karlsruhe, 4. Folge, Heft 22, 1990

[4] Isaksson T., "Modelling the Variability of bending strength in structural timber", Report TVBK-1015, Lund Institute of Technology, 1999