Introduction

The application of cross laminated Timber (CLT), typically as two-dimensional elements like ceilings and walls, has been very common in modern timber engineering structures. CLT-elements represent multi-layer plate structures consisting of a sequence of alternating orthogonal oriented board layers. Usually built up symmetrically with respect to the plate mid-plane. The boards of each single layer are usually arranged side by side glued or unglued on the narrow face. CLT-elements are available 3- to 9-layered. Commonly 3- and 5-layered elements are used for walls, 5- and 7-layered ones for ceilings and 9-layered ones for special high-bearing purposes. The thickness of each layer lies in between 6 and 45 mm.

Modules

The software tool CLTdesigner is organised in modules. For the verification of CLT-elements under loads out of plane there are two modules implemented. The first module “ContinuousBeam” verifies CLT-plates according to EN 1995-1-1, as a continuous beam up to 7 spans with or without cantilevers. The CLT-plates show an almost self-supporting load, wind and wind load. The ultimate limit state design (ULS) is provided in respect of bending and shear stresses as well as compression stresses perpendicular to grain for combinations of actions for permanent or transient and accidental (fire) design situations. The serviceability limit state design (SLS) is made in respect of deformations and vibrations. The second module “CSVerification” provides the cross-sectional verification of CLT-elements depending on given internal forces and moments as well as a stability verification tool based on the model column method.

Principles of design verification and scope

Because of geometric relations within the CLT-element and geometric boundary conditions nowadays produced CLT-plates show a main load carrying direction. Therefore 1D-beam theory sufficiently represents the bearing behavior of CLT-plates for practical applications and is applied for calculating stresses and deformations. Nevertheless, compared to uni-axial layered products like glue laminated timber (GLT), due to low rolling shear modulus of cross layers, CLT-elements show remarkable deformations. Therefore shear deformation shall be taken into account in SLS-design. A comparison of the different design methods for cross-layered plates with an exact solution, reflects that all of them provide suitable solutions for practically relevant length to depth ratios L/H > 15. Beside that it is strongly recommended that the chosen method for the design of CLT-plates is congruent with the evaluation of strength and stiffness in testing procedures. The implemented method in the CLTdesigner is based on the Timoshenko beam theory.

Stiffness of a layered cross section

When calculating stiffness values of a CLT cross section the orthotropic behaviour of timber in orthogonal layering have to be taken into account.

Due to the influence of the transversal shear flexible cross layers, the shear correction coefficient ψ of a CLT-element is in the current product range nearly constant and about 0.25 (compared to uni-axial 0.83).

Ultimate Limit States (ULS)

Deflections

Due to low rolling shear modulus of cross layers the shear deformation shall be taken into account when calculating deflections at time t = 0. For long time effects the deformation factor k_s shall be considered. The proposed and implemented values are 0.85 for service class 1 and 1.10 for service class 2.

Vibrations

According to EN 1995-1-1, four criteria have to be verified for judging vibration behaviour of a CLT plate: eigenfrequency, stiffness criterion (deflection caused by a concentrated static force of 1kN), vibration velocity and vibration acceleration. The damping factor, which is very important for this calculation, lies between 2.5% and 4.0% depending on the ceiling construction.

Serviceability Limit States (SLS)

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Structural fire design

The implemented structural fire design is based on the method of reduced cross section according to EN 1995-1-1-2. Therefore, the information about charring depth d_char over the time is decisive. The charring depth on the charring rate, the type of adhesive applied and on the availability of fire protection. The depth will also be reduced by k_i d_char, which considers the zone of thermal modified material parameters.

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