Structural Design Approach and Novel Applications for Folded Shell Structures made of Single-curved CLT – Tower Urbach, Remstal Gartenschau 2019

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Abstract

The introduction of curved cross-laminated timber (CLT) in architecture opens up a vast range of novel applications for timber as slender single-curved shells. These shells can be composed of cylindrical surfaces which form a folded structural system by their interpenetration with linear or rotational compositions in plan and in horizontal or vertical alignment. Such surface-active structural typologies provide advantageous structural behaviour through a combination of arch -, plate -, and slab action [1]. Thus, they allow for efficient and lightweight structures that simultaneously determine the envelope and space of the building. Moreover, the high degree of prefabrication and a construction material made from renewable resources makes curved CLT an ecological and economic solution for the construction of shell structures with expressive shapes. However, these complex geometries result in curved line joints with various angles and require digital design tools, customized connection strategies and robotic fabrication.

This paper presents a holistic structural design approach and technical development of a folded single-curved shell structure made of curved CLT. The construction system is evaluated through an architectural demonstrator, a 14m high tower that serves as a landmark and hiking shelter for the Remstal Gartenschau 2019. The structure is composed of twelve vertically orientated cylindrical CLT components of 2.4m radius that interpenetrate each other and form a polygonal cantilever. The research focuses on the global structural performance of the expressive CLT structure, as well as on the geometrically complex detailing to join the curved CLT components. A customised computational workflow enables the simulation with finite element analysis of the complex geometry, CLT material build-up with fibre orientations and varying stiffnesses of the connections. Further, integrated post-processing into the interface allows for an optimisation of the structure regarding its deformation and stress state and its connections. As the angles of the joints vary along the curved connection line between the CLT components, a connection strategy adaptable to a continuous range of angles is demanded. A Crossing screw connection offers a suitable solution and its rather novel application in CLT builds upon research carried out by Blaß [2] and Li [3]. The varying joint stiffnesses – dependent from the enclosed screw angle and screw length – are computed and modelled using linear spring elements in the structural simulation.

Further, the structural potential of other possible applications of curved CLT for folded single-curved shell structures are investigated. The structural design focuses on the correlation of fibre orientation, curvature and structural performance in regards to other application scenarios, e.g. roof structures. The research displays how advances in curved CLT production and in structural design tools can enable lightweight structures that expand the architectural possibilities in timber construction.

References

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