Structural reinforcement of timber beams along the line of principal stresses

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Abstract

This research revisits an idea by the German engineer Otto Hetzer [1] to enable the construction of timber structures with low-quality wood by reinforcing them with higher-quality wood, an idea he patented in 1905. By carefully gluing a board along a parabolic cut in a timber beam, the idea was intended to improve the beam's structural behavior by enabling a material with high tensile strength to be positioned at the location of constant tension. However, the production of his invention was discontinued because of the complexity encountered in manufacturing the parabolic cut [2].

Nowadays, digital tools have made it much easier to build complex shapes [3], making the idea applicable to modern timber construction. Combining low-quality wood for the bulk of the structure with a material that can withstand high tensile stress for reinforcement could lower the costs and the environmental impact of timber structures while reducing the pressure on forests for straight, high-quality, and defect-free lumber. Borrowing from Hetzer's idea, this project explores the possibility of reinforcing timber beams along the line of principal stresses.

This research investigates the structural efficiency of different materials and material placement as a reinforcement for low structural grade timber. The paper will discuss the results of the numerical and physical investigations. Preliminary results show that a reinforcement along the line principal stress increases the stiffness by about 10% when compared with standard reinforcement methods. Together with the use of less desired wood grades, this research has the potential to increase forest resources utilization, while possibly offering high-performing structural elements with reduced cost and reduced environmental impact.

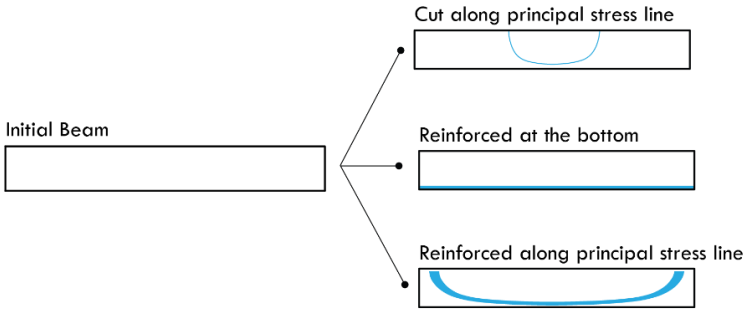

Fig. 1: Comparison of reinforcement options. The physical investigation confirms the theory of principal stress lines: the beam separated along a line of principal tensile stress performs identically as the initial beam. The beam reinforced along the line of principal stresses is 10% stiffer than the beam reinforced at its bottom edge.

References

[1] O. Hetzer, "Verfahren zur Herstellung eines Verstärkten Holzbalkens," Austria Patent #23744.
[2] C. Müller, *Holzleimbau*. Birkhauser-Publishers for Architecture, 2000.
[3] C. Beorkrem, *Material Strategies in Digital Fabrication*. Routledge, 2013.