# Improving the Performance of Timber Beams with Prestressed Laminates

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## Summary

Deflection criteria for the serviceability limit state (SLS) often govern the design of timber structures; the resistance at ultimate limit state (ULS) can rarely be exploited. Timber as a natural material exhibits large scatter in bending resistance and stiffness with accordingly low design values. Some improvement in the SLS performance can be achieved by applying glued laminated timber (glulam) sections; the stiffness, however, is usually still too low to achieve ULS design to be governing. This lack of stiffness gave the idea for a new type of composite structure: glulam of lowest quality timber is reinforced with prestressed carbon-fiber reinforced polymer (CFRP) laminates. The paper reports on the results from full-scale tests in a preliminary, mainly experimental study, analyzes the structural behavior of these composite elements at SLS and ULS, and gives recommendations for future research on such glulam-CFRP composite structures.

**Keywords:** Glulam, carbon-fiber reinforced polymers (CFRP), prestressing, composite action, full-scale tests, serviceability limit state, ultimate limit state, bending, anchorage.

## 1. Introduction

### 1.1 Design criteria and material characteristics for timber structures

In general, timber structures are supposed to perform elastically [1]. Due to this material behavior, timber structures are sensitive to imposed displacements, which are creating additional stresses in the structure that have to be considered in design. Taking the usual erection procedures for timber structures additionally into consideration, this explains why timber structures are often planned as statically determinate structures.

The design of statically determinate timber structures is often governed by deflections in the serviceability limit state (SLS), due to the rather low elastic modulus. Some improvement in SLS performance can be achieved by applying glued laminated timber (glulam); regrettably, this also means applying methods with an increased energy demand, due to the cutting, finger jointing and gluing of the timber lamellas.

However, the bending stiffness is usually not increased sufficiently, even when applying glulam sections, to achieve the design at ultimate limit state (ULS) to be governing the overall design of statically determinate timber structures; the ultimate resistance can thus rarely be exploited.

This lack of bending stiffness of timber structures gave the idea for a new type of composite structural element currently under development at the University of Applied Sciences Fribourg, Switzerland: glulam sections of lowest quality timber lamellas [2] are prestressed with carbon-fiber reinforced polymer (CFRP) laminates, in order to improve the SLS performance.

If the ULS resistance of the material can be exploited due to the enhanced SLS behavior, the governing sections may be reduced. Hence, this approach would reduce the exploitation of natural resources and increases the economic vitality, leading to more sustainable timber structures.

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