HIGH-TECH TIMBER BEAM® – A HIGH-PERFORMANCE HYBRID BEAM SYSTEM MADE OF COMPOSITES AND TIMBER

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ABSTRACT

Wood in Europe, especially in Germany, is a good available raw material. It has a high load capacity and stiffness in comparison to the low death weight. Timber is traditionally used for bending beams and columns with low processing. Since it is a natural material, there are variations in properties and quality. There is a demand for homogenisation for using in modern engineering and for the exploitation of the good properties of timber. Therefore, the timber is sliced, sorted and remounted as glued laminated timber or even as veneer lumber, to eliminate defects, knots or cracks. For increased requirements in terms of load-carrying capacity and long spans, a hybrid composite beam made of glulam and high-performance materials was developed at the Bauhaus University Weimar in cooperation with a local SME.

The main material of the developed High-Tech Timber Beam is still glulam with more than 90 % of the girders volume. Replacing one or two lamellas at the bottom side of the glulam by laminated veneer lumber (LVL) allows a significant homogenization of the timber beams properties.

For upgrading the compression zone of the bending beam, the upper lamella of the glulam is replaced by a decking of polymer concrete (PC). This is made of a mineral mixture with a special grain-size distribution and a binder on base a of 2-component epoxy resin. The PC has a high compression strength and also a high stiffness because of its high rate of filling with mineral grits.

The tension zone at the bottom is strengthened either with Fibre Reinforced Plastics (FRP)- or steel-reinforced lamellas made of LVL. Four versions of reinforcement have been developed and optimized with the help of numerical simulation and verified with prototypes in experimental examinations. The bracing materials are Carbon-FRP with a high stiffness (E = 210 000 MPa) and very high tension strength (f_t,k = 2 500 MPa) as lamellas with a thickness of 1.4 mm and a width of 25 mm or 50 mm (S&P reinforcement), reinforcement bars of Glass-FRP (f_t,k = 580 MPa, E_mean = 60 000 MPa) with a diameter of 16 mm (Schöck Combar®) and reinforcement steel (f_y,k = 500 MPa) with a diameter of 16 mm. The Lamellas are mounted to the surface or into pre cut saw grooves with glue made of the epoxy resin and a filling of sand and mineral flour. The GFRP and steel bars are casted into trenches in an additional board of LVL.

The types of HTB are (Figure 1):

- HTB-1 with four 50 mm CFRP lamellas, flat mounted beneath LVL
- HTB-2 with eight 25 mm CFRP lamellas, upright mounted into saw grooves in a second layer of LVL
- HTB-3 with eight reinforcing steel bars, casted in pre-cut trenches in a second layer of LVL
- HTB-4 with five prestressed GFRP bars, casted in pre-cut trenches in a second layer of LVL

Further reinforcing elements increase the shear resistance or improve the transverse load-carrying capacity at the bearings. An epoxy based polymer concrete (PC) in matched formulations was used for the mounting of all reinforcement elements. Therefore, all connections are rigid connections.
Short term bending tests at the four prototypes were arranged to determine the behaviour of load bearing, deformation performance and the failure of the hybrid beams (Figure 3). The dimensions of the specimen were $W \times H \times L = 40 \times 60 \times 800$ cm. Thus, the span width was 7.80 m. The tests were carried out as 6-point-bending tests partly according to DIN EN 408 (Figure 2). The load set-up approximates the distribution of shear forces and bending moments like under linear load in usual service. During the tests the load, the deflection, the deformation and the strain at several points of the beam and at every component were recorded. Areas of advanced interest were monitored by close-range-photogrammetry (CRP) additional to the traditional measurement with inductive displacement transducers (IDTs) and strain gauge. The test results of the HTB’s were compared with theoretical values for stiffness and load capacity of a normal glulam beam with the same dimension (cross section of 40 x 60 cm) to characterise the reinforcement effects. Figure 4 shows the load-deflection curves of the four variations of HTB up to the maximum load. In reference to the unreinforced glulam beam (100 \%) an enhancement of stiffness, compared at the middle deflection, was denoted to about 130 \% (HTB 1, -2 and -4) and 144 \% (HTB 3), respectively. The investigations on hybrid timber beams show good results regarding the enhanced load capacity and stiffness at reduced construction height by reinforcements with modern high-performance materials.

![Figure 3: Bending test of HTB-1](image)

![Figure 4: Load-deflection curves and ultimate loads for the HTB prototypes and calculated behaviour of an unreinforced GL24h-glulam beam](image)

**REFERENCES**
