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IMPROVING OF THE MECHANICAL PROPERTIES OF WOOD BEAMS REINFORCED WITH CFRP COMPOSITES PLATES

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Abstract: The main objective of this study was to investigate the flexural performance of wood beams reinforced by using carbon fiber reinforced plastic (CFRP) composite plates. The one-point bending test was used to determine the load–displacement relationships of wood beams. The performance of the CFRP plates adhered to the tensile side of several wood beams was investigated. Observations of the experimental load–displacement relationships show that flexural strength increased and middle vertical displacement decreased for wood beams reinforced with CFRP composite plates, compared to those without CFRP plates.

1. INTRODUCTION

Wood is a very efficient material. Its notable resistance under both compressive and tension loads must be considered as being nearly unique when compared with its limited weight density. However, due to its characteristics, this material has never been known for its durability. Wood elements such as beams, used to bear bending loads in the past, have been usually subjected either to replacement or reinforcement with classic techniques involving the use of common building materials such as concrete or steel.

In recent years, FRP composites have been increasingly used in highway bridge decks. Specifically, the use of composite materials as a reinforcement for wood elements under bending loads requires paying particular attention to several aspects of the problem. First, it is very important to carefully plan the kind of intervention to be realized. In fact, there are many techniques of reinforcing a wood element using different layouts of the FRP elements and each choice could potentially lead to different results. When the choice has been made, the next step is the selection of the most adequate FRP elements. The wide range of products and the mechanical properties of FRP elements currently available can lead to difficulty in choosing for the designer who approaches this reinforcement technique. For this reason, selection of the reinforcement layout and material should be guided by an accurate analysis of the characteristics of the element to be reinforced in order to avoid ineffective interventions. However, significant architectural and structural issues remain to be resolved.

2. THE ANALYSIS OF CFRP—WOOD COMPOSITE BEAM

By using composite materials in constructions is expected growth flexural strength and shearing, and confinement elements tablets (increased concrete and wood resistance). It is also done the raising of ductility areas of plastic joint and meets the requirements of exploitation (decrease arrows and status cracking). Among the composites used in constructions it's included: glass fiber, cellulose fiber, Kevlar fiber, carbon fiber and graphite, etc.

The method of consolidation with composite materials offers advantages over conventional methods, because the composite materials show:

- very high resistance to traction, several times greater than steel;
- small weight (¼ of the weight of steel), flexibility and availability in various lengths, suitable for quick and easy application;
- Increased resistance and ductility constructions without changing the geometry or stiffness;
- resistance to the corrosive environment and long life;

- costs of intervention extremely competitive.

The evaluation of the flexural strength of reinforced and non-reinforced glue-laminated (glulam) timber beam was the main thrust of this study. Straight beams can be designed and manufactured with horizontal laminations (load applied perpendicular to the wide face of laminations) or vertical laminations (load applied parallel to wide face of laminations). Glulam is normally manufactured using lumber with the moisture content in the range 10–16%. It generally comes with camber or upward deflection.

Laminating allows control over the location of material of different quality within the member cross-section. By placing the strongest material in the regions of greatest stresses (near the top and bottom in the case of a flexural member), member performance can be improved. Laminating also allows the dispersion of lumber defects throughout the length of the member. Glulam is commonly used as a replacement for sawn lumber when higher-sized lumber is unavailable. Allowable strength properties of glulam are generally superior to those of sawn lumber. Reinforced glulam beam costs less because the use of reinforcement will reduce the need of a top grade laminate on the extreme tension face (less high

grade material can be used); moreover the volume of wood is reduced. Reinforced glulam beams have lower product variability, they are not affected by natural growth characteristics, and the manufacture of reinforcement is consistent, controlled. Moreover, reinforced glulam beams provide for a ductile failure, excessive deflection occurs before failure.

Material used in the experimental work is Fagus sylvatica (beech). The matrix was a standard epoxy resin Sikadur 330, with a density of 1,31 kg/dm^3, from Sika-Romania. The type of the plates used were Sika CarboDur S 512 (black) ,with rectangular section 1,2 x 50 x 500 mm density of 1,6 kg/dm^3 and E=165.000 N/mm^2.

The total number of specimens manufactured was 23. Twenty two of them were reinforced, and one was un-reinforced. The wood part of all beams was formed by laminating two or three wood beams which size were equal to 25 x 10 x 500 mm. The un-reinforced beam (one beam) which was formed only from wood had a finished dimension equal to 25 x 50 x 500 mm.

The cross-sectional dimensions of solid wood structural beams and composite wooden beam usually have established sizes, depending upon the manufacturing process and intended use. The total beam length shall also include an overhang or extension beyond each reaction support so that the beam can accommodate the bearing plates and rollers and will not slip off the reactions during the test.

The un-reinforced beam is a bar with rectangular section 25 x 50 x 500mm, from dry beech (fig.1). The bending test results for the un-reinforced beam are shown in table 1 (σ_r = 90 MPa).

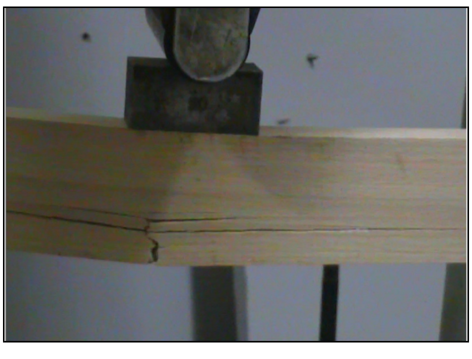

Fig.1 Tension failure of an un-reinforced wood beam

Results for un-reinforced beam *Table 1*

Force (daN)	0,2	0,4	0,6	0,8	1,0	1,2	1,4	1,6	1,8	2,0	2,2
Deflection f (mm)	2,5	3,9	5	6,7	8,5	11,1	13	17	-	-	-

Another type of reinforcement is a wood beam with rectangular section $25\times 50\times 500$mm, reinforced with composite plates with rectangular section of 1,2 x 50 x 500 mm (fig.2).
The bending test results for the reinforced beam with one CFRP plate are shown in table 2 (σ_r =209 MPa)

Fig.2 Tension failure of a reinforced wood beam with one CFRP plate

Results for reinforced beam with one CFRP plate *Table 2*

Force (daN)	0,2	0,4	0,6	0,8	1,0	1,2	1,4	1,6	1,8	2,0	2,2
Deflection f (mm)	1	1,9	2,5	3,5	4,5	5,5	7,2	9,5	15	-	-

Other type of reinforcement is a wood beam with rectangular section $25\times 50\times 500$mm, down reinforced with one composite plate with rectangular section of 1,2 x 50 x 500 mm, glued by the reference sample with epoxy resin, and by the composite plate glued, with epoxy resin, a slide of beech wood of $25\times 10\times 500$mm (3). The bending test results for the reinforced beam with one CFRP plate and a slide of wood are shown in table 3 (σ_r =125 MPa).

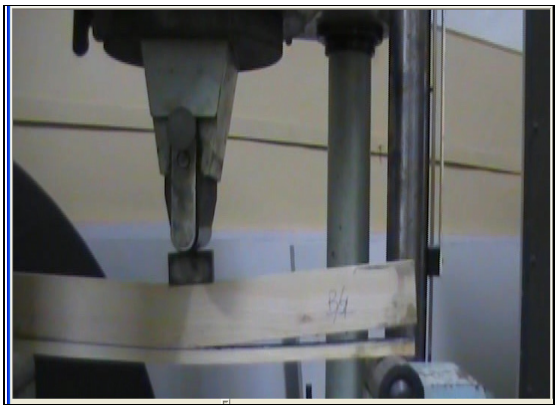

Fig.3 Tension failure of a reinforced wood beam with one CFRP plate and a slide of wood

Results for reinforced beam with one CFRP plate and a slide of wood *Table 3*

Force (daN)	0,2	0,4	0,6	0,8	1,0	1,2	1,4	1,6	1,8	2,0	2,2
Deflection f (mm)	0,5	1,4	2	3	3,8	4,6	6	7,5	-	-	-

The other type of reinforcement is a wood beam with rectangular section $25\times 50\times 500$mm, up and down reinforced with two composite plates with rectangular section of 1,2 x 50 x 500 mm , glued by the reference sample with epoxy resin, and then two slides of beech wood of $25\times 10\times 500$mm glued by the composite plate with epoxy resin (4). The bending test results for the reinforced beam with two CFRP plate and two slide of wood are shown in table 4 (σ_r =136 MPa).

Fig.4 Tension failure of a reinforced wood beam with two CFRP plates and two slides of wood

Results for reinforced beam with two CFRP plates and two slides of wood *Table 4*

Force (daN)	0,2	0,4	0,6	0,8	1,0	1,2	1,4	1,6	1,8	2,0	2,2
Deflection f (mm)	1,5	2	2,5	3	4	5	5,5	6	7	8	9,5

Other type of reinforcement is a wood beam with rectangular section $25\times 50\times 500$mm, glued with epoxy resin by another wood beam with rectangular section $25\times 50\times 500$mm (5). The bending test results for the reinforced beam with epoxy resin are shown in table 5 (σ_r =110 MPa).

Fig.5 Tension failure of a wood beam reinforced with epoxy resin

Results for reinforced beam with *epoxy resin* *Table 5*

Force (daN)	0,2	0,4	0,6	0,8	1,0	1,2	1,4	1,6	1,8	2,0	2,2
Deflection f (mm)	1	2	2,5	3,3	4	5	5,5	6,5	7,5	9	-

After we study those examples we observe that the reinforced wood beam with one CFRP plate (fig.2) is the most resistant and has a good elasticity breaking into a 15 mm deflection. Also, the reinforced wood beam with two CFRP plates and two slides of wood (fig.4) has a good resistant to bending. A good bending resistant and a good elasticity has the wood beam reinforced with epoxy resin (fig.5).

5. CONCLUSION

Reinforced glulam beam costs less because the use of reinforcement will reduce the need of a top grade laminate on the extreme tension face (less high grade material can be used); moreover the volume of wood is reduced. Reinforced glulam beams have lower product variability, they are not affected by natural growth characteristics, and the manufacture of reinforcement is consistent, controlled. Moreover, reinforced glulam beams provide for a ductile failure, excessive deflection occurs before failure. The strengthening of wood structural elements through innovative techniques presents numerous interesting aspects. The results of the experiments carried out, although varying according to the tests performed, have highlighted the limitations as well as the advantages of the various techniques. The use of CFRP can be applied as a strengthening technique without necessitating the removal of the overhanging portion of the structure. The technique used proved to be easy and fast to execute, even when on in situ parts. In particular, it demonstrated to be very promising in many cases of reinforcement of old, historical structural wood parts.

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