REINFORCING TECHNIQUES OF WOODEN BEAMS

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ABSTRACT: *Composite materials are different from macroscopic and homogeneous materials that are obtained by embedding - continue or not - of a durable material (reinforcing) in another material called matrix and whose mechanical characteristics are significantly lower than the first. The matrix preserve the geometric arrangement of armature to which it sends the stresses at it is subjected the sample.*

KEY WORDS: composite, reinforcement materials, wood, carbon fiber

1. INTRODUCTION

The increasing demand for higher performance of products and materials led to further developments in the field of composites. Reinforcing materials advanced, such as special fibers (carbon or aramid) or resins (such as epoxy) and the cores (such as PVC foam or the structure of the honeycomb) have been developed and used for building materials and products have excellent mechanical properties, considered "exotic" a few decades ago. These advanced composite materials are used in many industries such as aerospace, automotive, energy, sports/ recreation facilities in all applications where low weight and other special properties are required [1]. There are two main categories of constituent materials: matrix and reinforcement. At least one portion of each type is required. The matrix material surrounds and supports the reinforcement materials by maintaining their relative positions [2]. The reinforcements impart their special mechanical and physical properties to enhance the matrix properties. A synergism produces material properties unavailable from the individual constituent materials, while the wide variety of matrix and strengthening materials allows the designer of the product or structure to choose an optimum combination. Typically, most common polymer-based composite materials, including fiberglass, carbon fiber, and Kevlar, include at least two parts, the substrate and the resin. Epoxy resin is almost totally transparent when cured. In the aerospace industry, epoxy is used as a structural matrix material or as structural glue. Reinforcement usually adds rigidity and greatly impedes crack propagation. Thin fibers can have very high strength, and provided they are mechanically well attached to the matrix they can greatly improve the composite's overall properties. Fiber-reinforced composite materials can be divided into two main categories normally referred to as short fiber-reinforced materials and continuous fiber-reinforced materials. Continuous reinforced materials will often constitute a layered or laminated structure. The woven and continuous fiber styles are typically available in a variety of forms, being pre-impregnated with the given matrix (resin), dry, uni-directional tapes of various widths, plain weave and harness satins, braided, and stitched. The short and long fibers are typically employed in compression moulding and sheet moulding operations. These come in the form of flakes, chips, and random mate (which can also be made from a continuous fiber laid in random fashion until the desired thickness of the ply/laminate is achieved). Common fibers used for reinforcement include glass fibers, carbon fibers, cellulose (wood/paper fiber and straw) and high strength polymers for example aramid.

2. EXPERIMENTAL STUDY

The properties of composite materials are generally not isotropic in nature, but rather are typically anisotropic (different depending on the direction of the applied force or load). For instance, the stiffness of a composite panel will often depend upon the orientation of the applied forces and/or moments. Panel stiffness is also dependent on the design of the panel. For instance, the fiber reinforcement and matrix used the method of panel build, thermo set versus thermoplastic, type of weave, and orientation of fiber axis to the primary force. In contrast, isotropic materials (for example, aluminum or steel), in standard wrought forms, typically have the same stiffness regardless of the directional orientation of the applied forces and/or moments. The relationship between forces/moments and strains/curvatures for an isotropic material can be described with the following material properties: Young's modulus, the shear modulus and the Poisson's ratio, in relatively simple mathematical relationships. For the anisotropic material, it requires the mathematics of a second order tensor and up to 21 material property constants. For the special case of orthogonal isotropy, there are three different material property constants for each of Young's Modulus, Shear Modulus and Poisson's ratio- a total of 9 constants to describe the relationship between forces/moments and strains/curvatures. Techniques that take advantage of the anisotropic properties of the materials include mortise and tenon joints (in natural composites such as wood) and Pi Joints in synthetic composites [3].

A wood beam, generally, can withstand a relatively small concentrated bending force because the maximum bending strength that can handle the material is also small. If in the great strength area of the beam is added composite with greater strength than wood (fig.1) then the wood beam can withstand a bigger force because the maximum strength is bigger too [4]. Initially the load–deflection is shown to be linear elastic up to local failures induced by the presence of defects (knots, etc.). Wood yield produced a non-linear response terminated by a sudden drop of the load as a result of wood rupture. Wood rupture was immediately followed by CFRP fracture in the tension zone, resulting in collapse of the beams (fig.2). The wood beams reinforced with CFRP plates and sheets revealed more ductile behavior with respect to un-reinforced beams. One of the principal focuses of this investigation was on the damage of the composite material under the load deformation applied to the wood beams [4,5].

Fig. 1. Down reinforcement and up and down reinforcement application for two plates of composite material

Table 1. Results for reinforced beam with one CFRP plate [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)	2	2,2	2,5	3,2	4,1	5,6	6,9	11,7	14	-	-

Table 2. Results for un-reinforced beam

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)	1,8	4,2	6,1	7,3	8,7	12,2	14,2	16,6	19,1	-	-

One 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 [4]. The bending test results for the reinforced beam with one CFRP plate and a slide of wood are shown in table 1. The presence of carbon plates and sheets causes an interesting increase in stiffness varying from 22.5% to 30.3%, when compared to that of the same wood beams before reinforcement.

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. Experimental tests were performed on twelve beech beams un-reinforced and reinforced with CFRP composite plates (fig.1) and sheets (fig. 2 and fig. 3). The first sample was the reference beam without reinforcement. The results for the un-reinforced beams are reported solely for the purpose of quantitatively evaluating the effectiveness of the interventions through a comparison with the results for strengthened beams.

Fig. 2. Middle reinforcement application: one sheet of composite material [4]

Fig. 3. Up and down reinforcement application: two sheets of composite material [4]

The wood beam samples were reinforced with composite plates and carbon fiber sheets and bending subjected. All beams were surveyed for both their geometric dimensions and wood defects. The CFRP materials were conditioned in an environment of 65±5% relative humidity and temperature of 20±2°C as this is the service environment in which CFRP reinforced beams are expected to be used [6,7]. The observed mode of failure was due to cracking of the beams and the CFRP reinforcements.

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 .

3. CONCLUSION

Observations of the experimental load–displacement relationships show that bending strength increased and middle vertical displacement decreased for wood beams reinforced with CFRP composite plates and sheets, compared to those without CFRP plates.

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;
- weight small (¼ of the weight of steel), flexibility and availability in various lengths, suitable for quick and easy application;
- increased resistance and ductility construction without changing the geometry or stiffness;
- consolidation and reinforcement for different materials such as: concrete, wood, steel;

If the main force that action on the wood beam is bigger than a maximum value of the allowed force for wood material then the wood beam will be fracture by this force. Wood rupture was immediately followed by CFRP fracture in the tension zone, resulting in collapse of the beams. Breaking the composite material will occur, but at a much larger displacement, almost double than in the case of an unreinforced beams. The main conclusion of the tests is that the tensioning forces allow beam taking a maximum load for a while, something that is particularly useful when we consider a real construction, so in case of excess lift beam, we have time to take strengthening measures and when is about a catastrophic request (earthquake) the construction remain partially functional.

In conclusion, the most critical task is the determination of the allowable flexural strength for commercial uses [8]. Only when a clear understanding of the actual flexural strength values for full-scale beams is known and the actual behavior is understood, will the refinement of the flexural safety factor be possible.

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