ANNALS of the ORADEA UNIVERSITY.
Fascicle of Management and Technological Engineering, Volume XI (XXI), 2012, NR2

THEORETICAL AND PRACTICAL CONSIDERATIONS ON THE CARBON FIBER-EPOXY MATRIX COMPOSITES

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Keywords: fiber-matrix interface, strength fibers, constitutive equations.

Abstract: In recent years, use of polymer composites increased due to easy application and high performance of these materials. Mechanical properties and especially their linear elastic behavior to failure gave rise to various questions about their effectiveness in strengthening structural elements subjected to mechanical loads. The composites materials optimize the technical design of various structures, primarily based on high diversity of combinations that can be implemented. It must be added the possibility to predict a composite properties by suitable choice of nature, form and presentation of the weight of its constituents, or through application of appropriate technological steps.

1. INTRODUCTION

In this paper is presented a deepening macro mechanical study of composite materials in the sense that it develops the idea of composite and its constituents, namely the matrix material and reinforcing material for. It proposes a summary of the fundamental principles of analysis of composite materials and the design and use. Study consolidation of composites revealed that they are made by bonding fibrous material impregnated with resin on the surface of various elements, to restore or increase the load carrying capacity (bending, cutting, compression and / or torque) without significant damage of their rigidity [1, 2]. Fibers used in building applications can be fiberglass, aramid or carbon. Items that can be strengthened are concrete, brick, wood, steel and stone, and in terms of structural beams, walls, columns and floors, applying lately and beam-column nodes. Composite materials are carried out in a metallic or nonmetallic matrix that is reinforced by the dispersion of particles, fiber or gas. Those achieved in a non-matrix, more precisely epoxy are strengthened by the dispersion of fiber glass, aramid, boron, carbon. Fibers are able to withstand elastic applications but to resist and other requests for compression, cutting, bending. Examples of composites are: CFRP (carbon fiber reinforced plastic), GFRP (glass fiber reinforced plastic), AFRP (aramid fiber reinforced plastic), etc. Unions, they must be combined with a matrix to form a compound. Matrix serves only a number of functions, most of which are: ensuring a support for fiber, stabilizing the fibers against the forces of disruption and cutting, from the resins system used epoxy resins offer a practical and versatile field of properties including adhesion and volatility negligible during the treatment also have good mechanical properties in the form of resin treated.

2. THEORETICAL CONSIDERATIONS

It was found that if a composite material consisting of matrix (M) parallel fibers embedded (f) is applied along the uniaxial tensile strength fibers Fc, which produces elastic deformation of composite materials and its components, its behavior can be described as: composite specific deformations (elongation) matrix and fibers on direction of force application are equal. If E_M, E_F and E_C are the longitudinal elastic modules of matrix, fiber and composite and σ_M, σ_f, σ_c are the normal stresses (in the direction of the force Fc) generated by mechanical stress in the matrix, fiber and composite it can apply Hooke's law and follows the relationship (1):

$$\varepsilon_M = \frac{\sigma_M}{E_M} \quad \varepsilon_f = \frac{\sigma_f}{E_f} \quad \varepsilon_C = \frac{\sigma_C}{E_C} \tag{1}$$

Also, the normal stress (on Fc force direction of application) generated by σ_M σ_f and σ_c are equal. If the assumption is made that the effects of these applications on wood samples overlap without mutual influence may be inferred that the total values of the three components of specific strains will be calculated depending on the components of the state of global tension, with the following relationship (2):

$$\begin{cases} \varepsilon_x = \frac{\sigma_x}{E_x} - \nu_{yx}\frac{\sigma_y}{E_y} + \eta_{sx}\frac{\tau_{xy}}{G_{xy}} \\ \varepsilon_y = -\nu_{xy}\frac{\sigma_x}{E_x} + \frac{\sigma_y}{E_y} + \eta_{sy}\frac{\tau_{xy}}{G_{xy}} \\ \gamma_{xy} = \eta_{xs}\frac{\sigma_x}{E_x} + \eta_{yx}\frac{\sigma_y}{E_y} + \frac{\tau_{xy}}{G_{xy}} \end{cases} \tag{2}$$

As we seen, this expression connects the parameters of a state of tension with the flat plane strain state. We reach to offset the constitutive equations of a given material. Description of this type of response can only be achieved by introducing additional constant challenge to the material, making tests be more complex than for isotropic materials. Constitutive equations are corresponding to the generalized Hooke's law, which is studied in the concepts of elasticity theory, with reference to homogeneous and isotropic materials. Looking closely, we find that these relations may be written in the format matrix as (3):

$$\begin{Bmatrix} \varepsilon_x \\ \varepsilon_y \\ \gamma_{xy} \end{Bmatrix} = \begin{Bmatrix} \frac{1}{E_x} & -\frac{\nu_{yx}}{E_y} & \frac{\eta_{sx}}{G_{xy}} \\ -\frac{\nu_{xy}}{E_x} & \frac{1}{E_y} & \frac{\eta_{sy}}{G_{xy}} \\ \frac{\eta_{xs}}{E_x} & \frac{\eta_{ys}}{E_y} & \frac{1}{G_{xy}} \end{Bmatrix} \times \begin{Bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{Bmatrix} \tag{3}$$

The constitutive relations can be written, for example, in a similar way as above, with components denoted by $\{\varepsilon_i\}$, specific strains denoted by $\{\varepsilon\}_i = \{S_{ij}\}\{\sigma\}_j$, where $\{S_{ij}\}$ is the flexibility matrix of the material. Moreover, the same constituent relations can be written $\{\sigma\}_i = \{C_{ij}\}\{\varepsilon\}_j$, where {Cij} is called rigidities material matrix [5].

As a conclusion, considering expressions result that the matrices $\{S_{ij}\}$ and $\{C_{ij}\}$ contain the coefficients of stress state parameters and the deformation for constitutive relations are written.

3. PRACTICAL CONSIDERATIONS

It brings in discussion the material that will be strengthened, namely wood [3]. During this paper we work with two wood species namely Abies (fir) and Fagus sylvatica (beech). Composite material used to strengthen wood samples is the type of carbon fiber sheet (Megawrap-200) and carbon fiber plates (Megaplate), supplied by Building Consult S.R.L from Sika S.A Romania [4, 5].

This paper describes an experimental study which was designed to evaluate the effect of layers number of composite material on the stiffness of the wood beams. The type of reinforcement used on the beams is the carbon fiber reinforced polymer (CFRP) plates or sheet and an epoxy resin for bonding all the elements. Structural epoxy resins remain the primary choice of adhesive to form the bond to fiber-reinforced plastics and are the generally accepted adhesives in bonded CFRP–wood connections. In addition, it is clear that the most pronounced differences will be between the longitudinal characteristics values and transverse respectively [7].

To control with high precision disposition, share and their percentage volume, were made in the laboratory several types of laminated products, namely:

-Beech beams, with dimensions of 25mm x 50mm x 500mm, reinforced with carbon fiber sheet and carbon fiber plates and an epoxy resin;

-Fir beams, with dimensions of 50mm x 50mm x 500mm, reinforced with carbon fiber sheet and carbon fiber plates and an epoxy resin.

The beams were reinforced with 500 mm carbon fiber sheet length, 1 mm thick, glued with an epoxy resin EPOMAX-PL, or carbon fiber plates, 500 mm length, 1,2 mm thick, glued in the same way with the same epoxy resin.

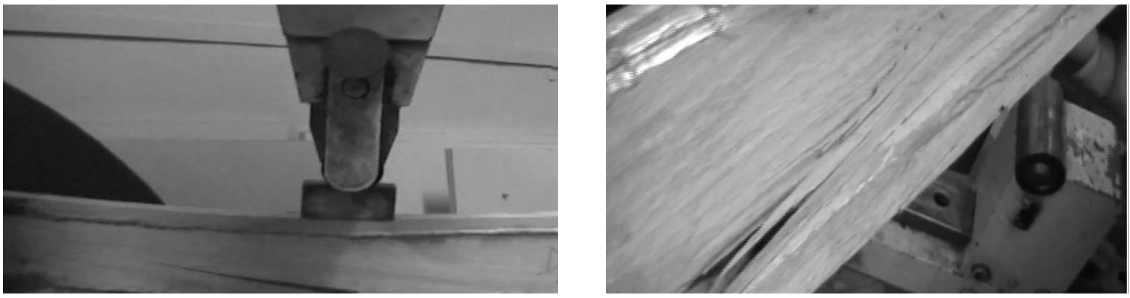

Figure 1 Tension failure of a reinforced beam with carbon fiber sheet [3,4]

Figure 2 Tension failure of a reinforced beam with carbon fiber plates [3,4]

The main purpose is to analyze bending phenomenon due to fracture at the wood-composite samples. To achieve the objective proposed in this paper was presented a particular computer program, Presa.txt, for experimental determination of bending strength for the samples. This was done with Spider 8 data acquisition equipment connected to fixtures and fittings of the samples tested on the universal testing machine. Work equipment and instrumentations used in this case are: universal machine for mechanical tests [6], data acquisition system Spider 8, 12 bit resolution linear WA300 race inductive transducer, force transducer S9 50kN, signal conditioning NEXUS 2692 - A-014, 4391 type piezoelectric accelerometer, IBM ThinkPad R51 notebook. Parameters recorded after the bending tests are: F (kN)-compressive strength of hydraulic press, Ft (kN -transverse compressive strength, CRS (mm)-race piston, Acc (m/s2) -acceleration of beam vibration (sensor break). The beam is leaning against the head and driven across to the breaking strength recorded maximum cross and displacement (no longer measured axial tensioning force).

Functional dependency graphs are represented in Excel in the figures 3 and 4 from below.

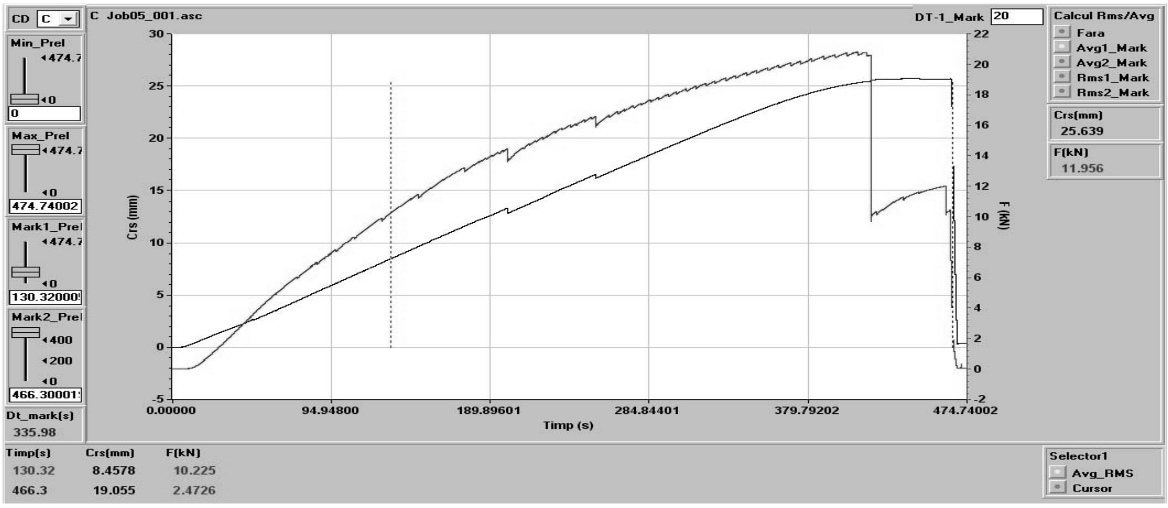

Figure 3 Determined characteristics for a Ft = 25 kN force [3,4]

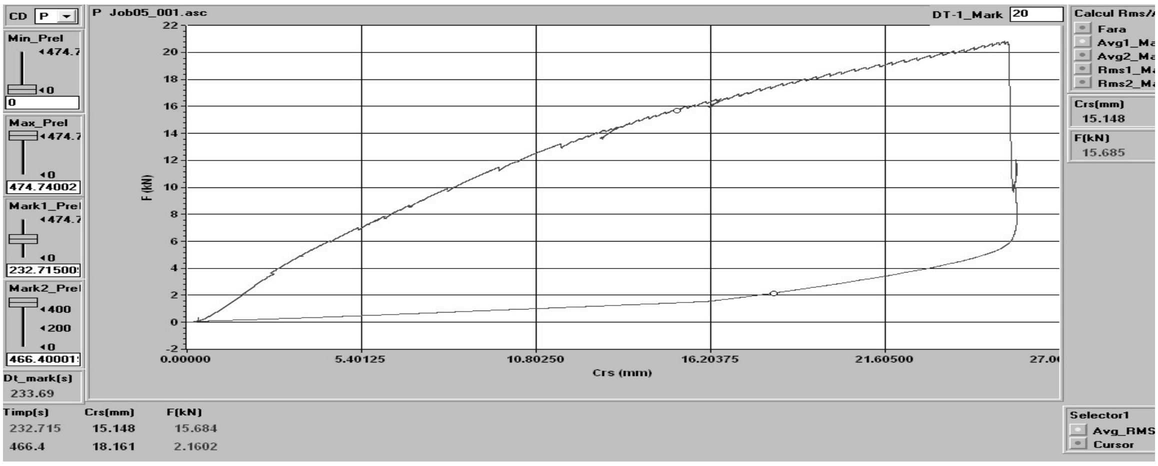

Figure 4 The histeretic curve for a Ft = 25 kN force [3,4]

Observations of the experimental load–displacement relationships show that bending strength increased and middle vertical displacement decreased for wood beams reinforced with carbon fiber plates, compared to those reinforced with carbon fiber sheet.

4. CONCLUSIONS

Following conclusions can highlight: wood is a material with a certain degree of heterogeneity, which makes its mechanical properties vary in a range too wide, so it is especially necessary to improve resistance with composite reinforcement; the wood properties are depending on wood fibers that showing heterogeneity so in experiments it is required a large number of samples to make a statistical analysis and to determine safe levels of resistance and rigidity; it is necessary to work with very good quality samples, no prospective concentrators power to distort test results; beech wood subjected to bending tests gave better results than fir; beech relative humidity was around 12% which improved mechanical resistance to bending of consolidated beams. Composite materials used must have a very good quality, a proper matrix being crucial; where the resin impregnated sheet was used directly on the sample did not lead to expected increases in composite strength due to poor quality product so that testing can provide conclusive data, the phenomenon resulting in a hysteretic curve.

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