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"Contributions to mechanical properties study and applications of some composite materials"
(Abstract)

In the current global energy crisis are needed, in industry, new material resources which do not require high operating costs and processing and that is also environmentally friendly and biodegradable. Thus, there should be on the market and be as accessible material ever better performance and lower density too (to allow the manufacture of parts characterized by small forces of gravity, friction and inertia), the conditions of production and operating costs acceptable. In this way, in this paper I have highlighted the advantages of using composite materials to improve the mechanical strength of structural elements of buildings, to use conventional materials that require much higher consumption and costs.

The thesis is a study on the properties of composite materials and their applications put to work building elements such as bending and shearing. It proposes a summary of the fundamental principles of analysis of composite materials and the design

Conventional materials used in their natural state can not simultaneously achieve a satisfactory level of complex requirements so that recourse to the completion of their combinations, generically called composite materials. They optimize the technical design of various structures, primarily based on high diversity, practically inexhaustible, of combinations that can be implemented. It must be added the possibility (if no use ordinary materials) to predict and even to "steer" a composite properties by suitable choice of nature, form and presentation of the weight of its constituents, or through application of appropriate technological steps.

Thus, it presents the main reasons for the past 30 years shows continued expansion of the use of composite materials and the research conducted on them, worldwide. On this basis the progress has been achieved, which would once have been unthinkable in the development of composites with outstanding performance and features and which are designed in accordance with specific application domain and the desired use. Important and fruitful research on this broad class of materials is conducted in our country over three decades, too.

It can say that this work falls in this framework. It proposes a summary of the fundamental principles of analysis of composite materials and the design and use. In this way, in Chapter 1, is a study of the emergence and development of composite materials in industry, from its origins to the present. 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. Fibers used in building applications can be fiberglass, aramid or carbon. Items can be strengthened concrete, brick, wood, steel and stone, and in terms of structural beams, walls, columns and floors, applying lately and beam-column nodes.

In Chapter 1 a comparison between conventional and composite materials is done and shows the extraordinary advances in composite materials that have made possible in technical engineering but also in many other aspects of human activities. It is also done the general classification of composite materials presenting their properties and application fields. Also, in Chapter 1, is expressed motivation research in this thesis. Because they are easy to apply, have very low weight and allow strengthening the elements to which access is difficult, is why I have studied and used these carbon fibers (in the form of blades or blade) to strengthen beams, of wood construction, with spans of up to 10-15 m.

In Chapter 2 is a deepening macromecanic 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 brings in discussion the material that will be strengthened, namely timber, with its properties.

During Chapter 2 is a selective review of the literature on composite materials in general and the wood-type carbon fibers in particular. This analysis highlights some considerations with theoretical, technological, and economic practice which are summarized below. Several studies on composite materials are made by worldwide researchers. As a general conclusion it can be said wooden damaged repair elements is an attractive option than replace them with concrete or steel elements, which is not

profitable. This involves wood elements strengthening with carbon fiber plates or carbon fiber sheet and an epoxy resin. The end result is a composite material with superior properties, which resist at the mechanical stress. The use of bonded Carbon Fibers Reinforced Plastic (CFRP), which is already widely used in high performance applications, has led to a variety of rehabilitation and strengthening of building

Fig.7.26 Carbon fiber plates strengthening on a wooden beam

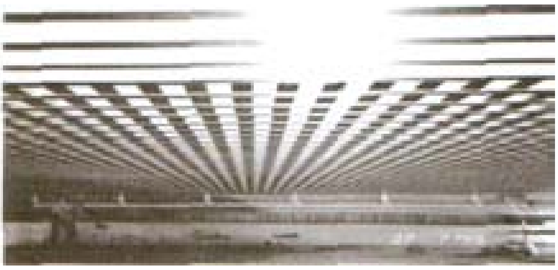


Fig.7.27 Carbon fiber plates strengthening a concrete floor

structures.
Chapter 3 refers to the thesis objectives. The essential aim of the thesis is to determine the critical force value at which is initiated the crack propagation inside the timber and the amount of maximum force that is tearing the specimen timber. In literature there are many works that propose different models/specimens for analytical determination of numerical or experimental fracture strength for composites reinforced with various types of mineral fibers (glass, carbon, etc.).. Just a few authors have focused attention to study fracture behavior on wood samples. Careful analysis of the literature shows that the study of fracture problems can be made using basic mechanics breaks principles, where the initial crack is considered a material defect or a discontinuity. Due to the large number of parameters and variables involved in breaking problems, we achieved an idealization of actual models. Developed mathematical models based on these assumptions, will be solved analytically or numerically, and finally verified by experimental testing. The main purpose of this paper is to analyze bending phenomenon fracture at the wood-composite samples. To achieve the objective proposed in this thesis, two devices were made to study the breaking beams phenomenon, carbon fibers reinforced, due to bending forces imposed on them (Fig. 3.1 and Fig. 3.2).

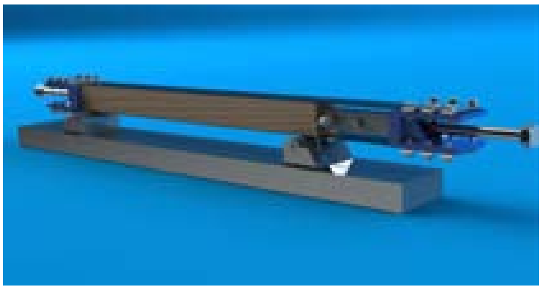


Fig. 3.5 Type I device

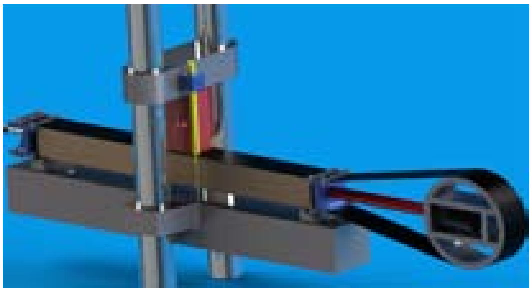


Fig. 3.6 Type II device

Along with the main objective of the thesis was intended achieving a particular computer program, Presa.txt for experimental determination of bending strength for the four representative samples. This was done with Spider 8 data acquisition equipment connected to fixtures and fittings of the samples on the machine table. Also, using FEM (finite element method) provides important information about tasks and movements located corresponding to the first failure of beams using the theory of maximum stress, and comparing the results with those obtained from experimental processing.

Chapter 4 is an analysis of the calculation and design of composite materials. It seeks to determine the constitutive relations which can be estimated using physical and mechanical characteristics of a composite material. To arrive at these constituents relations in final form, are considered three separate cases:

A. composite material has a matrix structure consisting of fibers parallel embedded which is drive along the axial fiber required;

B. composite material has a matrix structure consisting of fibers parallel embedded which is drive along the axial fiber required in a perpendicular direction from the arrangement of fibers direction;
C. the material is a composite aggregate applied uniaxial tensile.
It was found that if a composite material consisting of a 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, as shown in the diagram in figure 4.8, 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:

$$\varepsilon_M = \frac{\sigma_M}{E_M} \quad \varepsilon_f = \frac{\sigma_f}{E_f} \quad \varepsilon_C = \frac{\sigma_C}{E_C} \tag{4.15}$$

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 relationships:

$$\begin{cases} \varepsilon_x = \frac{\sigma_x}{E_x} - \nu_{yx}\frac{\sigma_y}{E_y} + \eta_{sx}\frac{\tau_{xy}}{G_{xy}} \\ \varepsilon_y = -\nu_{xy}\frac{\sigma_x}{E_x} + \frac{\sigma_y}{E_y} + \eta_{sy}\frac{\tau_{xy}}{G_{xy}} \\ \gamma_{xy} = \eta_{xs}\frac{\sigma_x}{E_x} + \eta_{yx}\frac{\sigma_y}{E_y} + \frac{\tau_{xy}}{G_{xy}} \end{cases} \tag{4.8}$$

Looking closely, we find that these relations may be written in the format matrix as:

$$\begin{Bmatrix} \varepsilon_x \\ \varepsilon_y \\ \gamma_{xy} \end{Bmatrix} = \begin{Bmatrix} \frac{1}{E_x} & -\frac{\nu_{yx}}{E_y} & \frac{\eta_{sx}}{G_{xy}} \\ -\frac{\nu_{xy}}{E_x} & \frac{1}{E_y} & \frac{\eta_{sy}}{G_{xy}} \\ \frac{\eta_{xs}}{E_x} & \frac{\eta_{ys}}{E_y} & \frac{1}{G_{xy}} \end{Bmatrix} \times \begin{Bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{Bmatrix} \tag{4.9}$$

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. The constitutive relations can be written, for example, in a similar way as above, with components denoted by $\{\varepsilon_i\}$, specific strains denoted by $\{\varepsilon\}_i = \{S_{ij}\}\{\sigma\}_j$ (4.10), where $\{S_{ij}\}$ is the flexibility matrix of the material. Moreover, the same constituent relations can be written $\{\sigma\}_i = \{C_{ij}\}\{\varepsilon\}_j$ (4.11), where {Cij} is called rigidities material matrix.

As a conclusion to Chapter 4, considering expressions (4.9) - (4.11) result that the matrices $\{S_{ij}\}$ and $\{C_{ij}\}$ contain the coefficients of stress state parameters and the deformation for constitutive relations are written. Also, the highest degree of anisotropy is recorded for long continuous fiber reinforced composites, especially if reinforcement is unidirectional. In addition, it is clear that the most pronounced differences will be between the longitudinal characteristics values and transverse respectively.

Chapter 5 deals with the degradation and rupture phenomena occur in composite materials. A fracture mechanism of composites includes all mechanical processes that generate the appearance of cracks at the microscopic and macroscopic level. This phenomenon has two phases: crack initiation and propagation of cracks.

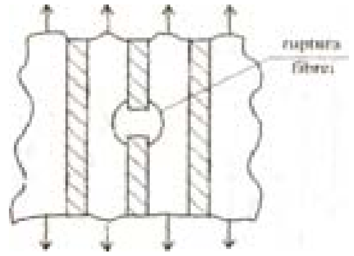


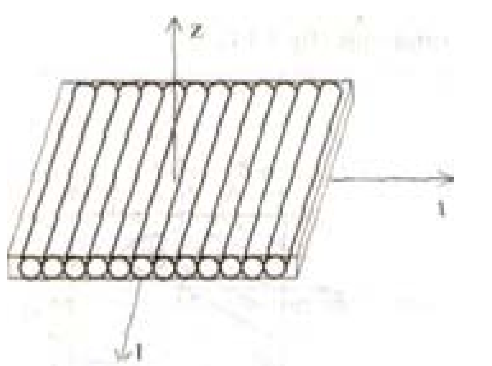
Fig.5.1 Unidirectional material breaking

The creation of micro-crack initiation at the microscopic level, and crack propagation is the result of the generation of macroscopic surface rupture, which has microscopic starting point. Rupture of unidirectional composite is the result of accumulation of various elementary mechanisms: fiber reinforced fracture, transverse and longitudinal rupture of the matrix, fiber-matrix interface rupture. In a unidirectional material fiber breakage occurs when normal tensile exceeds the fiber breakage tensile. Fiber breakage (fig.5.1) creates the appearance of a concentrator in the vicinity of the rupture area. Experience has shown that the tensile strength of high performance composites is determined by the strength properties of fibers and composites. The practical results showed that the maximum average tensile is a parameter that can be done to assess fracture strength of a composite. It is necessary therefore to adjust the properties of the matrix of fibers. When a fracture is initiated in a composite, its propagation depending on the nature of fiber-matrix interface. During this chapter is a study of fracture composites theories. Breaking tension difference that appears depends on the direction and requests it in a very large value. In complex applications, when tensions tensor has several components different to zero, it is necessary to use criteria which take into account both burst size of each part and tensions related to their effect. Need to introduce these resistance criteria, results for the following remarks:

a) Material ortotrop main stress directions do not coincide in general with ortotropie directions as in isotropic materials;

b) Uniaxial test is not sufficient to determine all terms of the constitutive equation, because the behavior (and elastic constants) change the direction of application;

Fig. 5.12 Main directions for tension in an orthotrope material



c) Fiber-resin composites, elastic limit corresponds to the breaking limit, but breaking strength is different for different application purposes (meaning long–l or cross-long t) and the type of application (traction-compression). Criteria to be taken into account when considering the damage and breakage of a composite are:

- Criterion requires that the maximum tensile stress is within a range of values $\left(\sigma_{ij}^{-}\right)_r \leq \sigma_{ij} \leq \left(\sigma_{ij}^{+}\right)r,$ (5.1), where: $\left(\sigma_{ij}^{-}\right)_r si\left(\sigma_{ij}^{+}\right)_r$ is a request tensions breaking at σ_{ij} negative, positive respectively. This criterion has the disadvantage that, in terms of breakage, requires the independence between stress tensor components. Therefore this criterion overestimates the qualities of strength of materials, which is an inconvenience for sizing.

- The criterion of maximum strains, formally speaking, is maximum tension criterion identical, but refers to deformations. Mathematical expression of the criterion of maximum deformation is:

$$(\varepsilon_{ij}^{-})_r \leq \varepsilon_{ij} \leq (\varepsilon_{ij}^{+})_r \tag{5.5}$$

The two criteria are different because the principal directions of stress do not coincide with the principal directions of strain.

- Tsai-WU criterion which proposes a polynomial form for the study of fracture and, in practice, keep only first and two terms order. For example, if the flat state of tension, Tsai-Wung criterion assumes the form:

$$F_{11}(\sigma_{11})^2 + 2F_{12}\sigma_1\sigma_2 + F_{22}(\sigma_{22})^2 + F_{66}(\sigma_6)^2 + F_1\sigma_1 + F_2\sigma_2 = 1 \tag{5.7}$$

- Hill criterion is a Tsai-Wu special case criterion and has following mathematical expression:

$$\sum_{i=1}^{6}\sum_{j=1}^{6} F_{ij}\sigma_i\sigma_j = 1 \qquad (5.13)$$

Due to the symmetry of stress tensor, resulting equality $F_{ij} = F_{ji}$.This criterion is used mainly for plane stress states which assumes the form:

$$-2F_{12}\sigma_1^2 + 2F_{12}\sigma_1\sigma_2 - (F_{12} + F_{23})\sigma_1^2 + F_{66}\sigma_6^2 = 1 \qquad (5.15)$$

It was found experimentally that this criterion considers the maximum tension better than the state of stress at which rupture occurs. The conclusion that emerges at the end of Chapter 5 is that the four criteria used to study fracture of composites, fracture Tsai-Wu criterion is relatively easy to use and adapted automated calculations.

Chapter 6 of the thesis contains the design and calculation of composite consolidations. Composite reinforcements are effective techniques that can be applied to large-scale structures made of different materials. In this chapter are discussed several issues related to strengthening of reinforced concrete elements. Were taken into account some basic applications: bending, cutting and axial compression. Calculations were conducted by two international normative account prevailing normative view that are representative: report of 14 fib TG 9.3 - "externally Bonded FRP reinforcement for RC Structures" (2001) and ACI 440.2R-report 02 - "Guide for the Design and Construction of externally Bonded FRP Strengthening Systems for Concrete Structures" (2002). Recommendations of calculation which makes fib TG 9.3 normative take account of ultimate limit state verification (SLU) of the composite. This may be idealized with a linear response, defined as:

$$\sigma_f = E_{fu}\varepsilon_f \le f_{fd} \;,\quad E_{fu} = f_{fk} / \varepsilon_{fuk} \qquad (6.1)$$

where: E_{fu} is elasticity modulus based on characteristic values of tensile strength and ultimate specific strain of the composite. If in the ultimate limit state calculations (SLU) failure way is by crushing the concrete or composite detachment, then it limits the maximum specified deflection it can occur in composite. Criterion is verifying the bending of concrete-composite type structure. This check is done in three states: the initial situation, the ultimate limit state (SLU) and the limit state of normal operation (SLEN). The calculation is considering a linear-elastic behavior of elements and materials. Also, take into account the effect of initial loading before strengthening. Based on elasticity theory and having the initial service moment M_0 acting on the element during the consolidation, one can evaluate the distribution of specific strains of the item. As a rule, M_0 is higher than cracking moment $M_{cr,}$, calculations are based on a cracked section.

Failure modes of these types of consolidations are classified according to the contribution of such composite: composite material operating at full capacity of, losing the contribution of the composite, a detachment (peeling off), and a failure in the concrete shear force at the end of the composite. Account recommendations of ACI 440.2R-02 norm take account of the characteristics of the composite discount factor. Calculation is made in two limit concrete-composite structure states, namely: calculating the ultimate limit state (SLU) and calculating the limit state of normal operation (SLEN). Such conditions shall limit the efforts that can occur in steel reinforcement in normal operating condition. As conclusion of this chapter, it should be noted that since the execution of a construction project involves combining various aspects of structures and building systems are different, the designer must have experience in designing structural consolidation.

Chapter 7 contains the procedures for implementing the consolidation of composite materials and experimental means by which I studied these consolidations. It exposes the main objectives that are pursued through experimental research. Solutions are combining samples with carbon fiber materials such as hardness is as high beam and to achieve the lowest costs. From this point of view, bring into question the work schedules of the two devices to help carry out experimental research and presented models of specimens reinforced composite materials, which will be explored throughout the thesis.

Chapter 8 includes experimental studies conducted to determine the mechanical strength of wood reinforced composite materials with carbon fiber plates. So one of the ideas pursued in the thesis was to obtain enhanced structures with low prices and cheap materials, easy to process. Traditional building material, wood, became the target of the study. It was also noted that major stressed construction unit is beam. Predominant application of a beam is bending. Therefore they relied on classical solution addition of quality materials in highly stressed areas such as lift beam increases correspondingly. Very simple solution design highlight quantitative improve lift costs and experimental effort being reduced. The only practical difficulty is finding a solution and solidarity means for low resistance material (wood) of attaching it to the composite paltes. By means of solidarity depends on the degree of increase bearing capacity, so the use of added

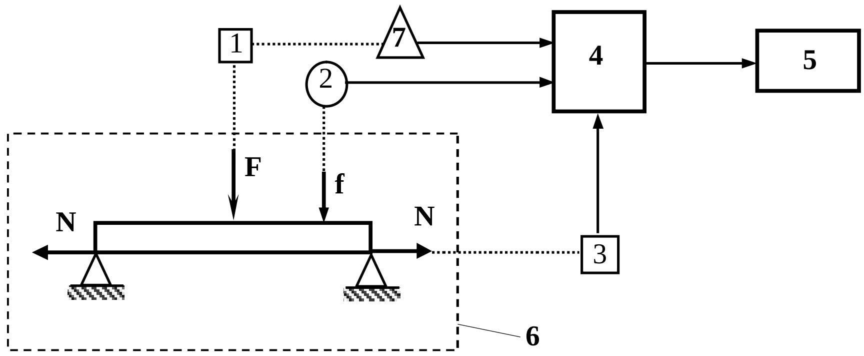


Fig. 7.4. Experimental system scheme

material strength. It should be emphasized that the two sides of the beam (wood and composite) must be deformed together, the contact surface producing real glissade longitudinal force large enough.

Most conclusive parameter to assess lift and synthetic experimental element (beam) is mechanical tension σ that occurs in cross section. Area of interest is the contact wood-composite one, but currently there is no solution for measuring the mechanical stresses within the required bodies. Therefore we renounced to measure tensions but track the arrow (strain) beam denoted f. The experimental scheme is in fig. 8.4. Experimental physical module 6 is composed of a material test machine that allows controlled application requests. The two forces are measured with transducer (1) car belonging, and a dynamometer test of 5 kN (noted 3 on the scheme) deflection (displacement) f is measured with a displacement transducer 2.

A universal test machine material is given in fig. 8.5. Test specimens were used in two ways: directly placed onto the roller machine (specialized bending test) or placed in an axial tensioning device for composite plates. Tensioning device is shown schematically in fig. 8.7. In essence, the operation of tension solution is based on two composite plates that are fixed in stands 1; on one set of brackets is a nut that allows axial strain of beam 3, the force of tension is measured with transducer 4. Technical feasibility of the tensioning device is given in images of fig. 8.8. Test procedure has the following phases:
- Calibration of the measuring system,
- Positioning beam on the test machine,
- Mechanical loading beam,
- Tracking and recording parameters,
- Noting the details of the test (material behavior, anomalies, etc.).

a b

c d

Fig. 7.8 Tensioning device

a - view, b – device placed on the machine, c - right detail, d – left detail

Fig. 7.5 Universal machine for mechanical tests of material (Amsler type)

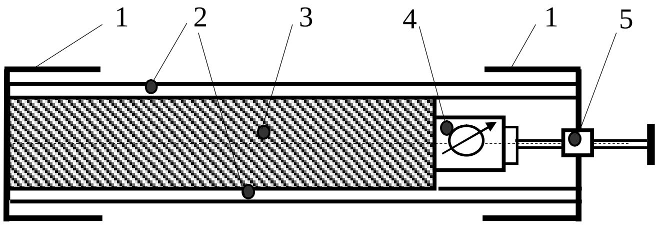


Fig. 7.7. Axial tensioning device

1,2-stands, 2-composite material, 3-wood beam, 4-force transducer, 5-screw-nut system for axial tension

Experimental cases are:

Case 1: reinforced composite beam:

-1.a: softwood with Megaplate reinforced composite plates,

-1.b: beech with Megaplate reinforced composite plates,

-1.c: metal beam (INP type 100) with Megaplate reinforced composite plates.

In **1.a** case the beam is reinforced bottom up high strength plates composite material. Composite plates axially tensioned on the beams with a screw and are leaning against the head and driven by transverse fracture occurring transverse force, axial force (the tension), maximum displacement.

Work equipment and instrumentation used in this case are: universal machine for mechanical tests, 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).

For each test was flown the following sequence of operations:

-Complete installation-experimental;

-Setting an initial force of cross-pretension;

-Setting characteristics and test-launch data acquisition;

-Increasing the pressing force gradually, maintaining manual compression force on a high cross;

-Pressing force-download;

-Stopping data-acquisition system and backup data file.

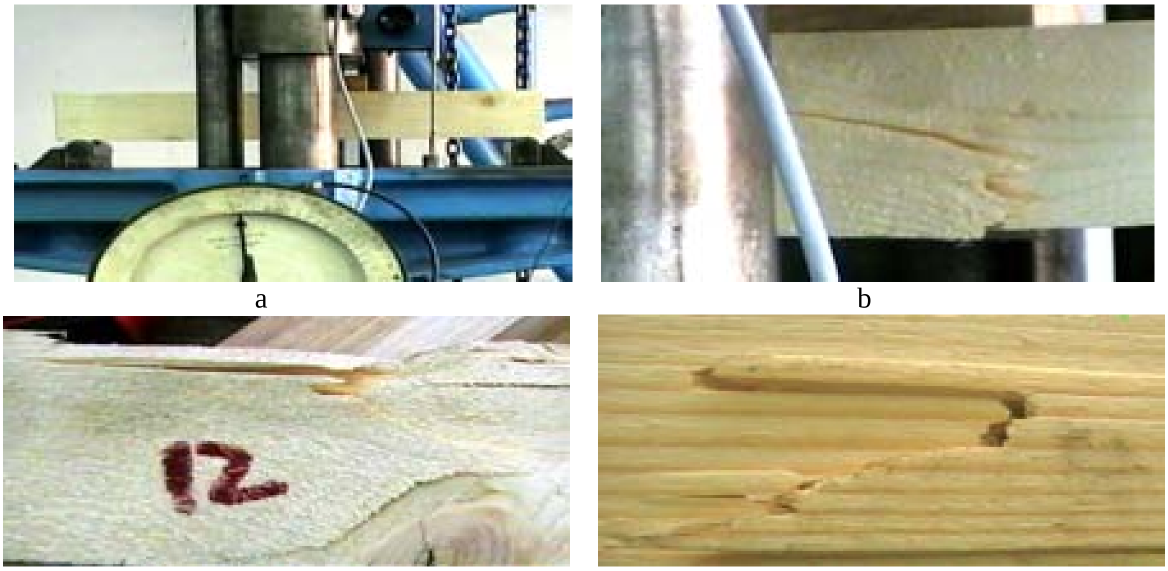


Fig. 8.21.1 Reference beam 1.a Case
a-test image to reference beam, b- breaking part of the reference beam, c- final breaking of reference beam, d- breaking depth of beam reinforced with tensioned composite
b-

Experimental data processing was being used "Presa.tst” program. The experimental data were visualizated and using cursor Mark1 were selected moments of time separated within 5 ... 10 seconds, in terms of stability for action force and cross-pretension force. For each point was recorded the average value of the parameters, on a 40 samples sequence centered on the cursor. We used a graphic with two sliders, with the possibility of reading the instantaneous values displayed in the inner and suggestive names associated with the color slider and pulled. Maximum displacement is the same car moving frame, denoted Crs (mm) is black and is reported in the left ordinate. Press Force developed denoted F (kN), is red and is reported in ordinate on the right. The average values calculated on a total of 40 samples centered on Mark1 mouse are displayed and transmitted to the right and are stored in the data file by typing selector Selector1. Acquired data were presented as tables. A conclusive interpretation of experimental results was obtained by comparing the results of beams reinforced with the reference beam (non-composite beams). In fig. 8.21.1 a reference beam is shown; the break way when there was no strengthening of the composite material is shown in fig. 8.21.1.b and c; the break way when the beam is enhanced, the image shown in fig. 8.21.1.d.

Functional dependency graphs are represented in Excel. Analysing of vibration acceleration can be observed moments of failure of the first beam of wood fibers, resulting in gradual reduction of prestressing force. This decrease has required manual intervention through the screw-nut system to increase the tensioning force, resulting in graphic form. In an 8.23 graphic example are all dependencies forces – displacements.

In **1.b** case we have beech beam strengthened up and down with high strength composite material, composite strips into the modified axially tensioned where tensioning screw is replaced with a special hydraulic device (as fig.8.31.a) ; beam is leaning against the head and driven across to the breaking strength recorded maximum cross and displacement (no longer measured axial tensioning force). In **1.c** case we have rolled steel beam (rolling type INP100), reinforced high strength composite material below, composite plate bottom attached with straps and screws (as detailed in fig. 8.31.b).

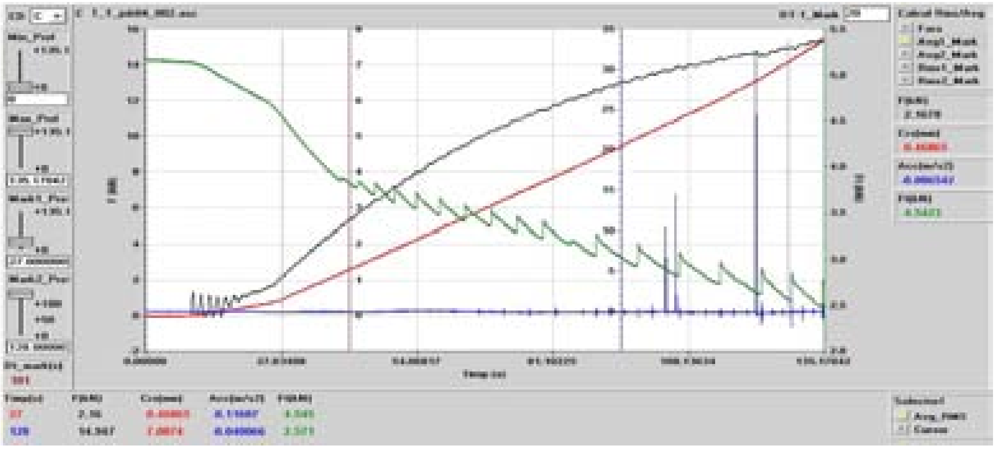
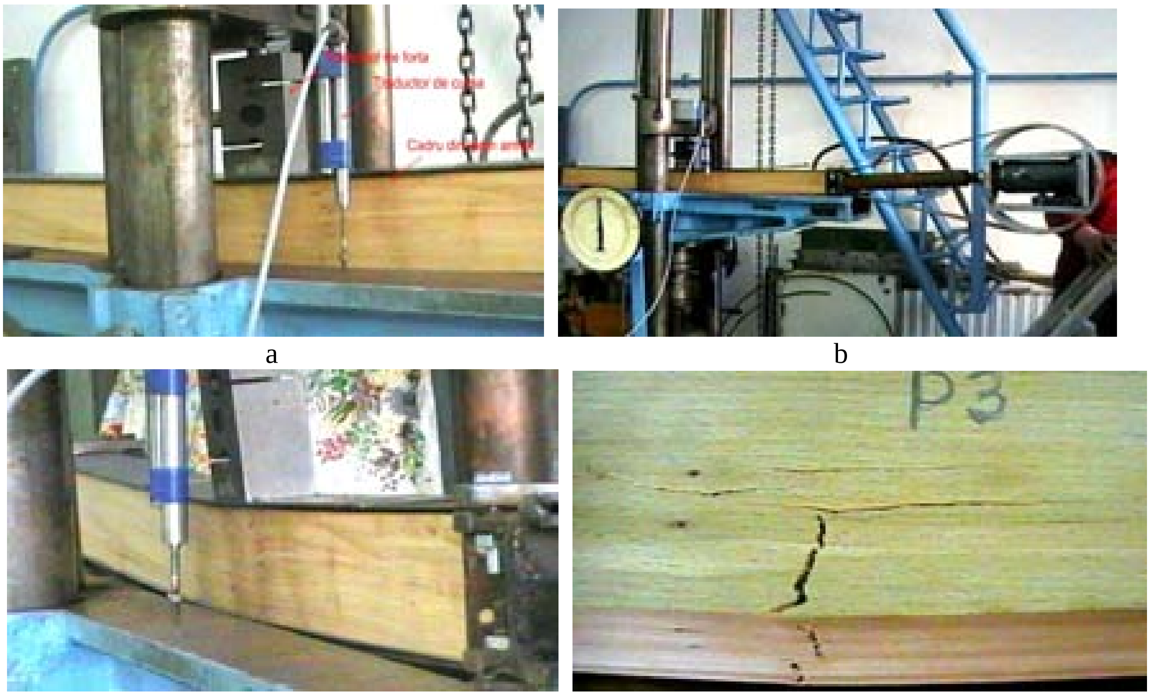


Fig. 8.23 Determined characteristics for a Ft = 5 kN force

Work equipment and instrumentation used in the two cases are similar to case **1.a** namely: universal machine for mechanical tests, data acquisition system Spider 8, 12 bit resolution linear WA300, race inductive transducer, force transducer S9 50kN , IBM ThinkPad R51 notebook.

Parameters recorded after bending tests are: F (kN) - force hydraulic press, Crs (mm) - Race car linear framework, equal to the maximum displacement of the beam. In Fig. 8.31 is presented the experimental assembly for wooden beams strengthened detail tensioning device. In Fig. 8.32 is presented the experimental assembly for metal beam INP 100 and in Fig. 8.33 is presented the experimental assembly for wooden beams unarmed.



a b

c d

Fig. 8.31 Experimental assembly for 1.b Case
a-reinforced wood-pretensioned composite beam, b-pretensioned specialized device,
c-reinforced distorted beam, d- breaking beam depth

a b

Fig. 8.32 Experimentaly assembly 1.c Case
a-steel beam transverse applied, b-assembly depth

a b c

Fig. 8.33 Experimental Assembly for the reference beams (Case 1.b and 1.c)
a- wood beam (reference for 1.b Case), b-steel beam (reference for 1.c Case),
c-wood beam (reference for 1.b Case), applied and distorted.
c-

For each test was flown the following sequence of operations:

- Complete installation experimental;
- Setting up and launch the test characteristics of data acquisition;
- Increase cross-loading progressive force;
- Downloading of force;
- Stopping the data acquisition system and the backup data file.

Experimental data processing was used the same program "Presa.tst. Visualization was achieved using experimental data and cursor Mark1 selected moments of time separated within 5 ... 10 seconds, under conditions of stability for the force actuator. For each point the average value was recorded, a sequence of 40 samples centered on the cursor. We used the same graphics with two sliders, with the possibility of reading the instantaneous values displays positioned in the inner and suggestive names associated with the color slider and pulled. Maximum displacement, the same car moving frame, denoted Crs (mm) is black and is reported in the left ordinate. Press force developed denoted F (kN), is red and is reported in ordinate on the right. Average values calculated on a total of 40 samples centered Mark1 mouse displays are transmitted to the right and are stored in the data file by typing selector Selector1. Acquired data were presented in tables. Figure 8.34 b is representing temporal variation of applicated force by the displacement. In Figure 8.34 is presented the variation in time of the force by the displacement. Analyzing the characteristics represented in polar coordinates is apparent hysteresis courve resulting in a loading-unloading cycle framework. The area covered by the hysteresis courve is a measure of energy dissipated in the beam.

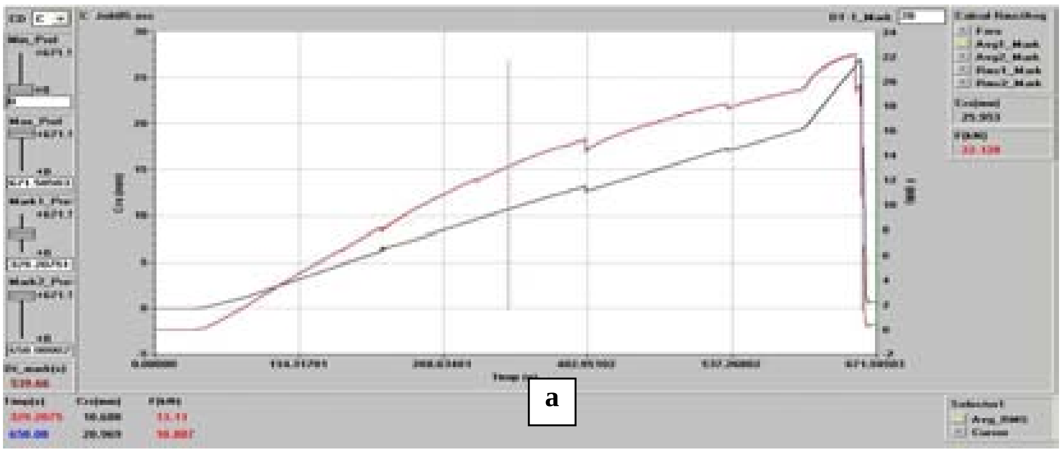


Fig. 8.34a. Temporal variation of loading force by the displacement on a wooden beam reinforced

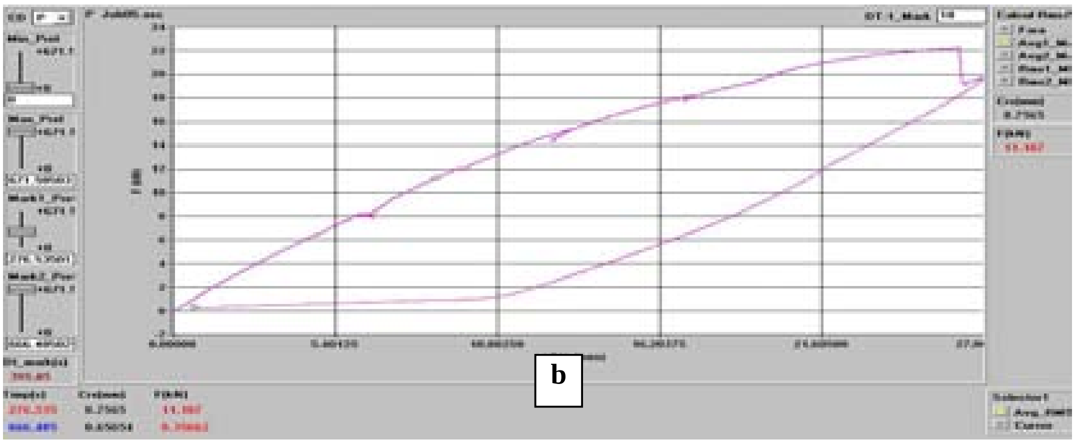
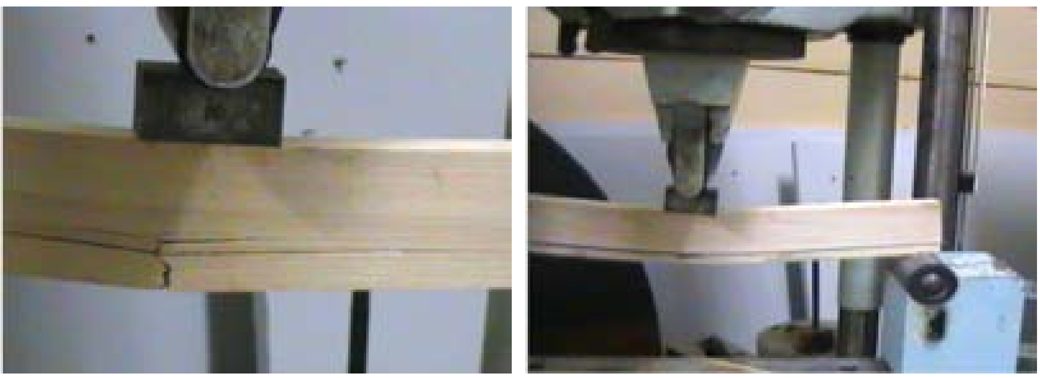


Fig. 8.34b. Temporal variation of demand force by the displacement on a wooden beam reinforced

In Chapter 9, I studied **Case 2**: beams reinforced with Megawrap-200 sheet bonded with epoxy resin Epomax-PL type. In **Case 2** are carried out experimental studies on more bending beech beams constructive solutions. It was stick pieces of wood of various sizes, with an epoxy resin. It was studied samples containing reinforcements with carbon fiber sheet Megawrap-200. The reinforcements were made with an epoxy resin (Epomax-PL) which solidarized carbon fiber of wood pieces cut down in size initially size.



a b

Fig. 9.1.5 Experimental Assembly for Case 2

a – wood reference beam, b- reinforced beam with wood plates and distorted after the test.

Variations resulting samples were tested in bending on the universal testing machine. Results were put in tables and graphs. It was found that beams reinforced with sheet results are not so good as the reinforced beams plates results.

In Chapter 10 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 pine; beech relative humidity improved mechanical resistance to bending of both consolidated and unconsolidated beams.
- Strengthening the composite material are more effective if they are away from the section neutral axis; variants with reinforcements placed in the middle section of the beam did not increase strength in some cases even having negative effect;
- Composite material used must be of 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;
- Using high stiffness composite don't lead to good results since it produces relatively fast detachment of wood; in this situation requires the composite plate pretensions and its mechanical solidarity with wood beams with the two devices specifically designed for this type of test.
- Metallic material used (profile INP 100) was subjected to successive loading and unloading without exceeding the elastic so that testing can provide conclusive data, the phenomenon has resulted in a hysteresis curve.

Finally, in Chapter 10, are highlighting the personal contributions to the study of mechanical properties and applications of composite materials, methods of study this new type of materials in industrial and experimental side which led to the completion of these studies. So we can say, as a general conclusion of the thesis that compared to current materials used as concrete, metals, plastics, etc., composite materials possess remarkable physical and mechanical properties. Experimental determination of fracture strength of composite materials has been the subject of numerous studies, whose results led to the development of a variety of testing methods, particularly conventional composite reinforced with carbon fiber or glass fiber.

Currently, bonding with adhesives or resins, is the basic process used to connect structural elements. Quality of bonding is influenced by many factors depending on the nature of wood raw material (wood or other natural fibers), resin, bonding process and the conditions under which products are used.

The experimental study aimed to quantify the objective to improve the mechanical strength of a structure made of a cheap material (wood) by adding composite reinforcements.We were chosen beams with concentrated bending required force. We have analyzed several types and ways of achieving constructive assembly between the two materials (wood or metal base material, and composite reinforcement). Solutions that were experienced: mechanical connection to the ends of the beam, multiple mechanical connections distributed throughout the length of the beam (metal), continuous connection. The parameters chosen to quantify the strength of the beam were displacement for a given loading force, maximum force (tear), the maximum breaking displacement. By measuring and recording the force time variation and corresponding displacement (produced by force) could show an increase lift at each solution. The key is reference beam.

A first difficulty encountered was the inhomogeneity of the basic material (wood), established by fairly large changes in mechanical strength (from a sample to another). This has required the use of a large number of tests for the same material.

Also, the wood having very low mechanical strength, has sought an additional way to increase lift experimental model. Thus was conceived a device for applying a tensioning force to the composite plate placed at the bottom of beam (in the tensile are).

There have been attempts by various forces pretensioners finding optimal combination between wood strength and these forces. Ascertaining loading deficiencies at the mechanical device we replaced the axial screw with a special hydraulic device used in practice for rehabilitation of reinforced concrete beams. Also, the wood having very low mechanical strength, has sought an additional way to increase lift experimental model. Thus was conceived a device for applying a tensioning force to the composite plate placed at the bottom of beam (in the tensile are). Ascertaining loading deficiencies at the mechanical device we replaced the axial screw with a special hydraulic device used in practice for rehabilitation of reinforced concrete beams.

The results were basically improved. It was found that if you increase the tensioning force as the increase request (to compensate for subsidence) port beam rise proportionately much smaller amounts, so this is not a way to improve the lift; at small pretension forces lift improvement is modest; pretensions not change, in general, elastic behavior (the strain) because of the limitations that occur in wood mechanical assembly facility; only if material is high quality and strong pretensioned, the lift was significantly increased.

In experiments with beams of high quality wood (beech) and pretension composites plates reinforced in the improved device (Type II), conclusions can be drawn:

- The results have much improved repeatability rate and experimental values have a smaller scattering;
- Maximum lift compared to softwood beams is about four times higher (equivalent beams), thus showing that it can not be compensated a very low resistance of wood with reinforced composite;

For the steel beams the experiments are not conclusive because the number of tests is too small. Solution proved viable achieving a 14% increase lift and an increase in stiffness by 27%. Charges were made in the elastic area existing possibility of conducting repeated charge and discharge cycles; it is demonstrated the repeatability of results.

Reinforcing steel beams experiments showed a potential to improve the lift for less than wood but more research must be done, considering that it can find viable solutions growing rigidity.

Experiments have shown sustainability of the method for wood construction reinforced with composite materials. The solution is easy to implement and costs are low.

Effectiveness of using composite reinforcements is still modest, requiring further and deeper studies and trying new methods and design alternatives for the tested samples.

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