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INCREASING THE LOAD BEARING CAPACITY OF TIMBER BEAMS BY USE OF INTERPOSED FIBRE REINFORCED POLYMER LAMMELAE

BY

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Abstract. Fibre Reinforced Polymeric (FRP) **s**trengthening techniques are of great interest in the scientific research all over the world, due to FRP reduced weight and increased strengths. The association of wood and Glass Fibre Reinforced Polymer (GFRP) is a promising procedure to overcome the low mechanical properties of wood because of the compatibility which exists between these materials, presenting similar moduli of elasticity and material`s structure. The objective of the study is to develop an effective method to repair totally or partially broken timber structural members. A step-by-step procedure will be presented and a preliminary finite element analysis is conducted for the proposed system.

Key words: timber structures; composite materials; structural strengthening.

1. Introduction

For the case of large openings or increased loads of timber structures, some of the structural elements must support high stresses that many times overcome the mechanical properties of wood.

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It was found that a possibility of increasing the load bearing capacity of a timber member may be the hybridation of member cross section by interposing between the wood planks of GFRP lammelae, which posess physico-chemical properties similar to wood and complementary mechanical properties.

The paper presents a method of increasing the load bearing capacity of timber members, by alternatively associating prefabricated GFRP strips, of different thicknesses, with timber elements (planks or boards), by bonding them with polyester resin applied in two layers: first as a primer on the wood element and the second as gluing agent for fixing together the lammela and the wood element.

2. Strengthening Technique with Wood–GFRP Hybrid Cross-Section

The described above method, concerning load bearing increasing of timber members, associates a performant GFRP composite material in form of strips obtained by succesively impregnating the glass thread with polyester resin with reinforcement ratio of 50% at environment temperature of more than 15^{o}C. The wood planks are also impregnated with the same type of resin and then successively glued to the GFRP strips, until the number of strips resulted from the design computations are reached.

The procedure of obtaining such a hybrid cross section follows some steps presented forward (Fig. 1)

a) wood surface preparation by clearing away dirt or defibrated zones resulted from the cutting off process, ensuring a healthy surface (Fig. 1.1);

b) impregnation of wood surface with polyester resin (Fig. 1.2), which constitutes the primer, and the start of gel formation;

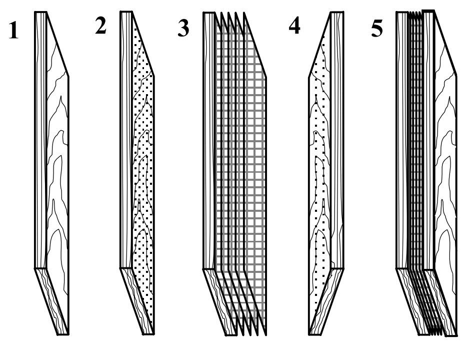

Fig. 1 – Sequence stages for achieving the hybrid cross section.

c) application of the second layer of resin and of succesively impregnated glass thread strips (Fig. 1.3), untill the desired thickness of GFRP strip is reached;

d) positioning the second timber element (Fig. 1.4), previously prepared as the first one;

e) finally, the whole packet is pressed (Fig. 1.5), for obtaining the optimal contact between materials.

This packet forms a module with different strength properties, superior to wood. For a certain structural element this module will repeat untill reaching the necessary strength, without extremely increasing of cross-section`s dimensions.

The advantages of the presented above method are the following:

a) increase of load bearing capacity of the timber member;

b) the relative ease of application the technology, without the need of special engineering equipments;

c) decrease of wood consumption;

d) rapidly introducing in exploitation process the structural element thus obtained;

e) high productivity.

3. Case Study

The described above method was used for the design of a 10.90 m timber beam and with loading scheme as in Fig. 2.

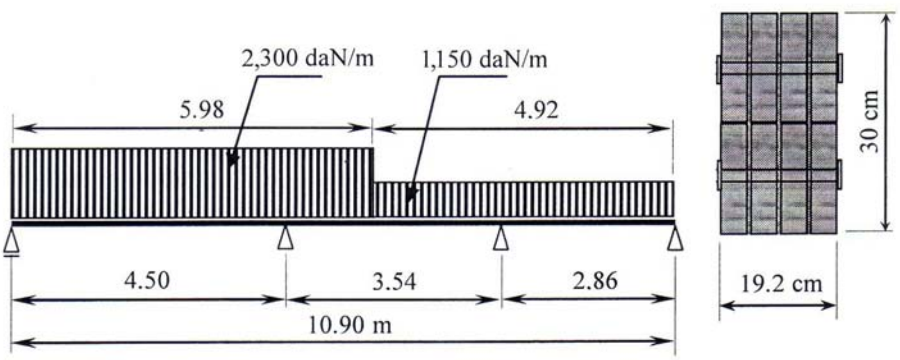

Fig. 2 – Loading scheme of the timber beam.

The beam was effectively constructed with 4.5 × 15.0 cm wood planks, the cross-section being composed of superposed and bonded wood elements, as presented in the previous section.

From technical and safety reasons the packet was fastened with 12.0 mm diameter bolts disposed on two rows with 50.0 cm shift one over the other, every 100.0 cm on the beam`s length. Thus constructed, the beam was mounted in the structure and, presently, is still functional.

4. 3-D Finite Element Analysis of the Beam

The finite element analysis was performed using 7,560 brick type finite elements, using the COSMOS finite element software. The static scheme is presented in Fig. 3. The thickness of the GFRP strips was of 4 mm each, and in the computations were considered three such lammelae.

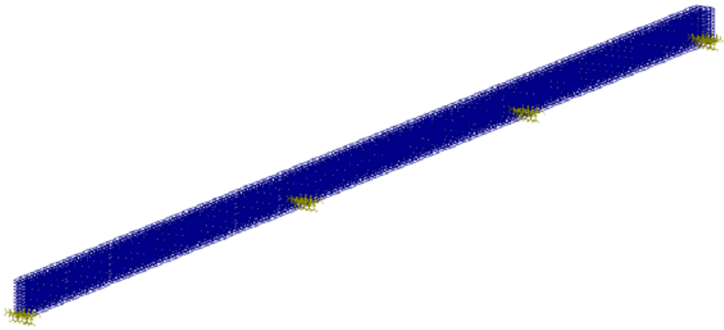

Fig. 3 – Static scheme used in analysis.

Table 1
Mechanical Properties of the Wood and GFRP

Mechanical property	Wood	GFRP strip
Modulus of elasticity, [N/mm^2]	11,300	16,000
Poisson's ratio	0.3	0.3
Compression strength*, [N/mm^2]	12.0	210.0
Tension strength*, [N/mm^2]	8.6	160.0

*For wood, the strengths are considered for the direction paralel to the grains.

The presented below results are showing the development of stresses and displacements in the structural element in form of maps (see Figs. 4,...,8).

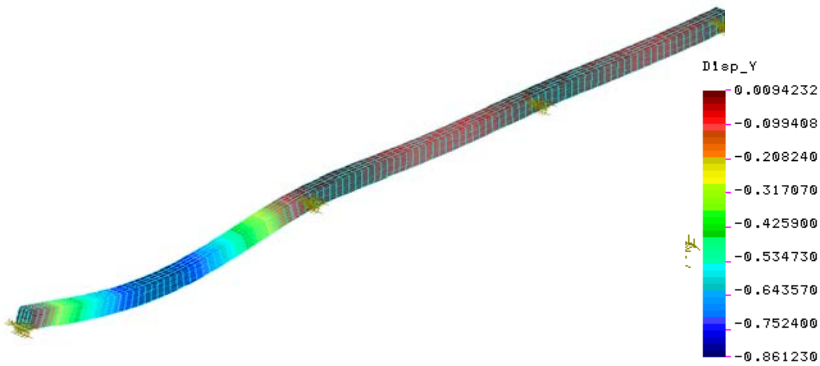

Fig. 4 – Displacements, [cm].

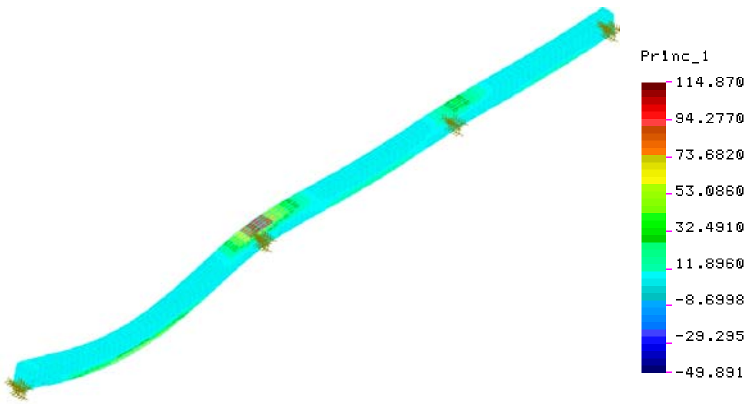

Fig. 5 – Maximum principal stresses *P*1, [daN/cm^2].

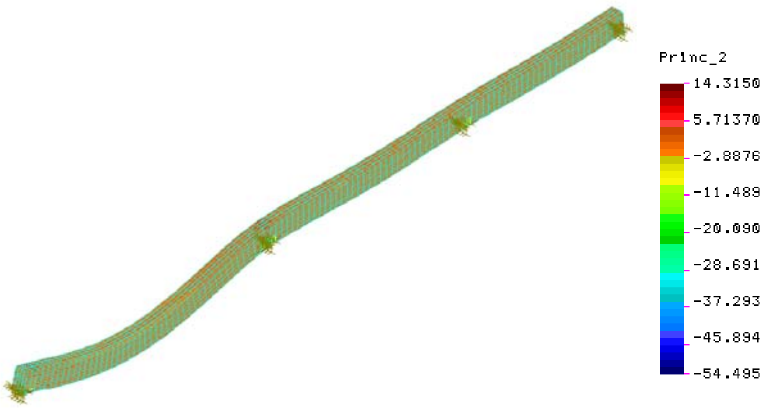

Fig. 6 – Principal stresses *P*2, [daN/cm^2].

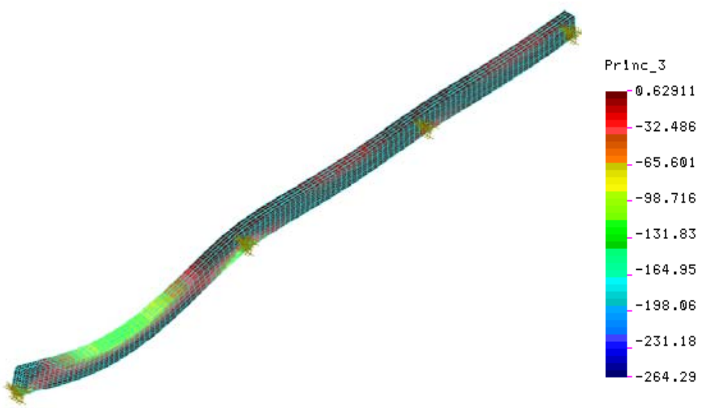

Fig. 7 – Minimum principal stresses *P*3, [daN/cm^2].

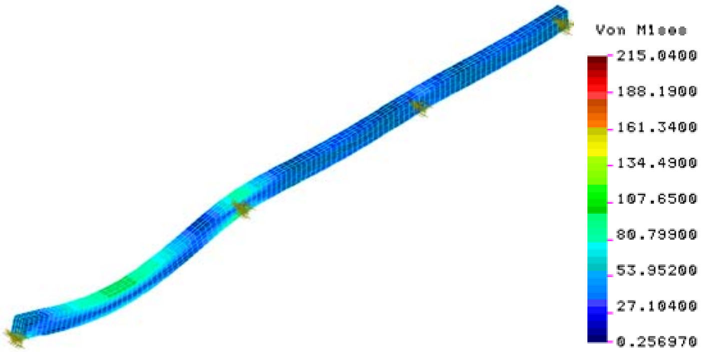

Fig. 8 – Von Mises stresses, [daN/cm^2].

In Fig. 9 the stresses for the most loaded section are showed, to see how the three strips of composite material influence the overall behavior of the element. It may be seen that the strips are able to overtake more stresses than wood, even though the moduli of elasticity are similar.

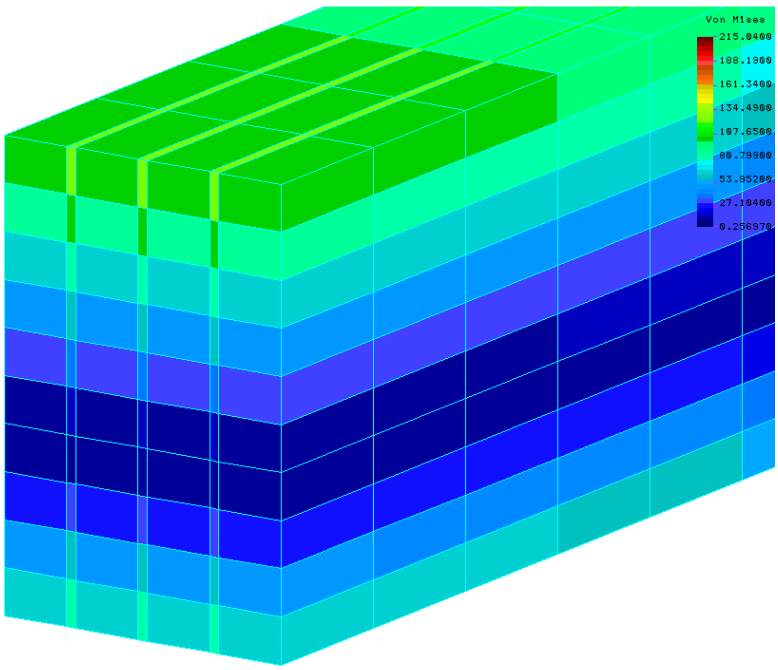

Fig. 9 – Cross section detail and von Mises stresses, [daN/cm^2].

5. Conclusions

The trend towards lighter constructions may be considered as one of the main features of modern technology development. Inherently, the objectives of strengthening impose new technologies of joining different materials and structures for buildings and to find ways of improving the strengths computing methodologies.

This study openes new perspectives for construction industry. One of them referes to applying this type of timber elements when high bearing capacities are needed.

Application of modern GFRP systems, with relatively simple execution techniques, lead to the possibility of being used on large scale, bringing added value to timber structural elements, both from structural and architectural points of view.

Increased productivity, relatively little running time, are the main factors of achieving cheaper constructions and obtain economical benefits.

As a conclusion remark, the association of these two materials, wood and GFRP, led to good results in terms of strength and stability requirements. On this topic further research should be performed in order to find out in which conditions the method could be applied, the behavior of the interface between wood plank and the FRP lamella and to establish the tests to be carried out in order to gain more reliable information.

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CREŞTEREA CAPACITĂŢII PORTANTE A SECŢIUNII BARELOR DIN LEMN

(Rezumat)

Metodele de creştere a capacităţii portante a elementelor structurale prin utilizarea sistemelor compozite prezintă interes crescut în lumea ştiinţifică, datorită raportului optim greutate/rezistenţă. Hibridizarea secţiunii din lemn prin interpunerea lamelelor din poliesteri armaţi cu fibre de sticlă (PAS) este o procedură capabilă să îmbunătăţească proprietăţile mecanice slabe ale lemnului, cunoscută fiind compatibilitatea dintre aceste două materiale care prezintă moduli de elasticitate şi structuri asemănătoare. Obiectivul lucrării este de a propune o metodă de reparare a elementelor structurale din lemn rupte (parţial sau total). În scopul stabilirii eficienţei metodei descrise s-a realizat analiza cu elemente finite a starii de tensiuni şi deformaţii într-un element structural cu deschidere mare şi solicitări crescute, ce constituie studiul de caz prezentat în lucrare.