Natural reinforcement of bent wooden elements

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INTRODUCTION

The building industry is one of the most conservative of all industrial branches. It is characterized by unwillingness to introduce new, untested in a long-term use materials and design solutions. When comes to repair of existing engineering structures, the most common reinforcement technique used is a simple replacement of overload element for a new one, which is made of steel or concrete. But because of conservational restrictions the replacement method often cannot be allowed to use in historical structures.

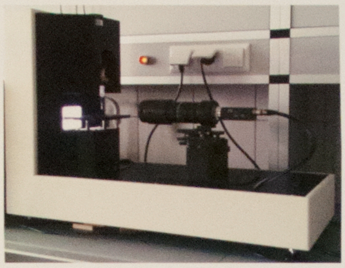
One method which can be successfully used in historical structures is a technique consisting in the introduction the reinforcing material inside the cross section of reinforced element. Significant advantage of this solution is the possibility to hide the reinforcement, which allows to keep the original aesthetic qualities. It is especially important for example in case of polychrome decorated ceiling beams.

Developed repair engineering method involves the use of LLBC – Layered Laminate Bamboo Composite. LLBC provides many possibilities for designers, constructors and builders because of its low specific gravity and high strength parameters, as well as lack of difficulties with processing and gluing.

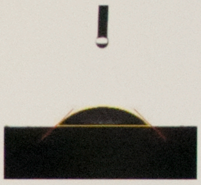
Mechanical properties of LLBC

Property*	LLBC
Density (kg/m^3)	900
Young's modulus (GPa)	16.9
Tensile strength (MPa)	260

*Verma et.al 2012: Tensile Strength Analysis of bamboo and Layered Laminate Bamboo Composites. In: IJERA 2



Phoenix 300 goniometer device



Determination of contact angle for LLBC

* Contact angle 40°
* Surface energy 65mJ/m^2

MATERIALS AND METHODS

Tests were carried out using pine samples (Pinus sylvestris L.) as the most common species used in construction works in Poland.
Samples with dimensions of 20x40x800mm were divided into 4 groups:
a) sound wood, without any wood defects,
b) sound wood, weakened with a single opening with diameter of 10mm (simulation of the knot),
c) wood reinforced with a LLBC plate 1.2mm thick,
d) Wood reinforced with a LLBC plate 4.0mm thick.

Shape of reinforcement

Semi-technical scale of samples was used in aim to determine the parameters of testing procedures for further research. Because of semi-technical scale, less variation of strength parameters was provided, in comparison to full-scale structural lumber. Additionally, since the samples were free of natural defects, determination of reinforcement influence on wood strength parameters was possible.

Strengthening technique assumed local application of D-shape reinforcement in form of LLBC plate. Reinforcement was placed inside previously made grooves and glued with Havel Composites G60 epoxy glue. The D-shape of reinforcement was resulted from the technologically easiest shaping of the slot, that could be made using circular saw. Reinforcement procedure assumed strengthening the tension area of bended beams. Thus the height of the D-shape reinforcement was set at 20mm, while the length was resulted from the diameter of the saw used (250mm). Samples were tested in three point bending.

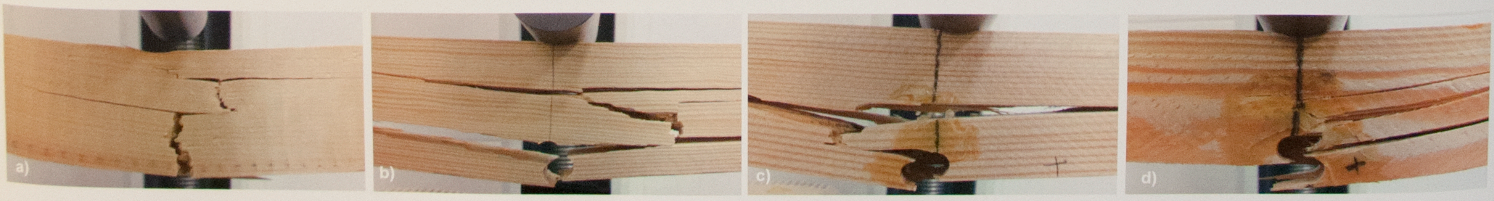
Preparation of material

RESULTS

On the basis of load and displacement values obtained during testing, modulus of rupture (MOR) and modulus of deformation (EI) for each group of samples were determined.

MOR and EI values obtained during testing

Group	MOR* [N/mm^2]	Standard dev. [N/mm^2]	EI [N·m^2]	Standard dev. [N·m^2]
A	80.2	9.0	3164.4	248.5
B	49.6	7.1	2799.0	349.6
C	53.3	6.0	2714.4	296.5
D	57.5	6.1	2715.5	242.6



Failure modes observed in (a) group A, (b) group B, (c) group C, and (d) group D

Samples weakened with an opening showed 38% reduction in MOR and 12% drop of EI in comparison to sound samples of A-group. In case of D-group testing showed statistically significant gain in MOR value (16%) in comparison to samples of B-group. Thickness of C-series reinforcement was not sufficient to provide a significant increase in MOR. Reinforcement (C-group , D-group) did not bring significant gain of EI.

CONCLUSIONS

Based on the studies it was confirmed that local LLBC D-shape reinforcement is reasonable in structural timber. The LLBC, because of its rough surface, low contact angle and high surface energy is good for gluing. The bond itself and the wood-adhesive-LLBC contact area is not prone to cracking. Additionally, the LLBC reinforcement provides desirable, uniform stress distribution within the bond, which does not exceed critical values. Described reinforcement technique could be used especially in historical structures, where the issue of aesthetics is crucial. There is still a need to further analysis of the developed reinforcement technique in aim to optimize it both in terms of the shape, as well as the length of local reinforcement.

ACKNOWLEDGMENTS

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