Natural materials used as a reinforcement of lumber

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Designing with biobased building materials – Challenges and opportunities

24-25 February 2016, Madrid, Spain

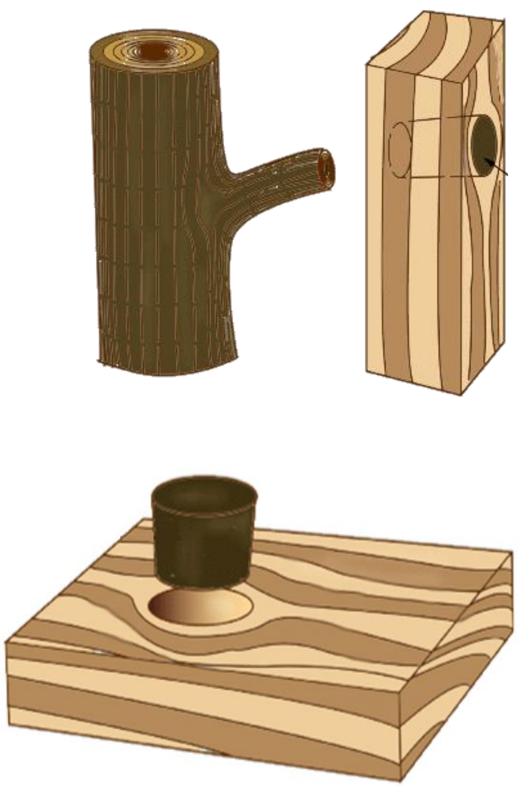
COST FP1303
Performance of bio-based building materials

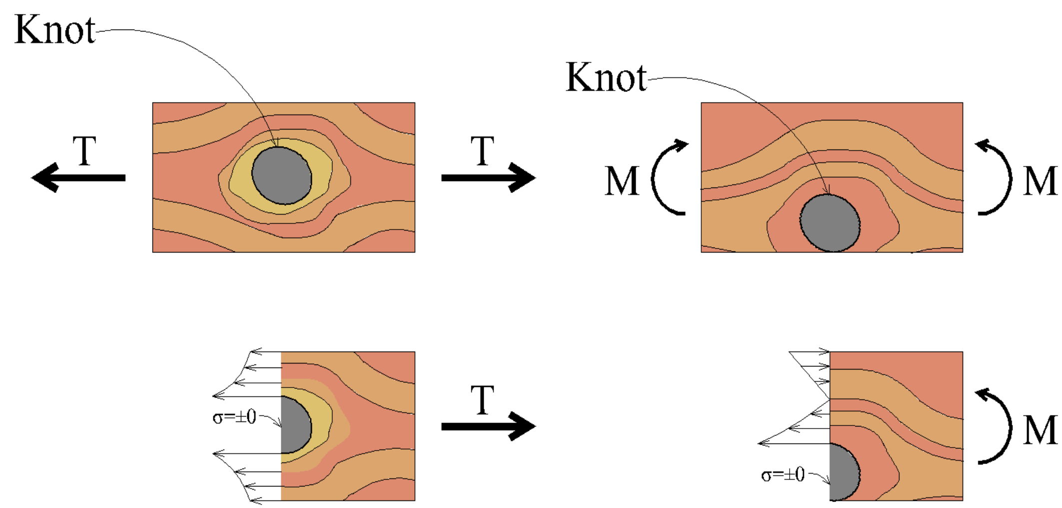
COST

- **high safety** enforcement, **high quality** materials, availability of stock conforming to **standard requirements**,

- **negative impact** of structural defects on material properties,

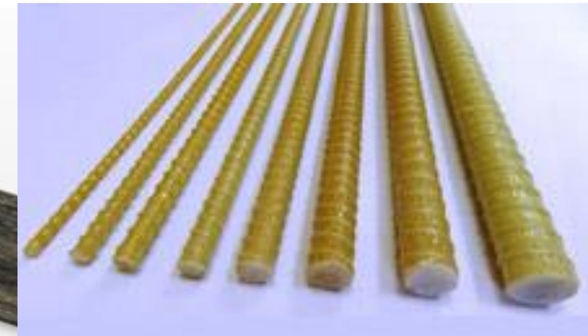
- **knots** placed in the tension zone of bent beam can be simulated as a simple **hole**,

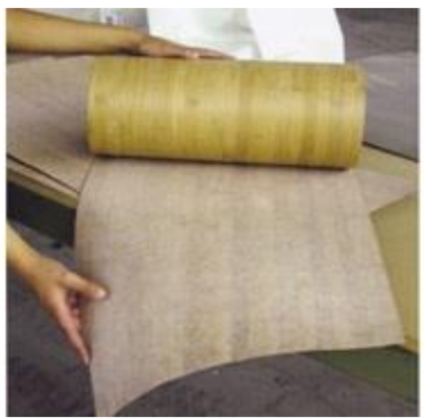




Any material can be used as a **reinforcement**, on condition it has higher strength or stiffness in comparison to the initial, unreinforced material.





The aim of work was to determine the possibility of using **natural, lignocellulosic** materials as a **local reinforcement** of timber beams.

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INTRODUCTION

It is estimated that in a typical pine log, **only 15%** of the volume can turn into **high-quality,** knotless lumber. The remaining 85% of the volume is loaded with various structural defects, which decrease the strength lumber.

The necessity of **reinforcing** wooden structural members may apply for both **new structures**, at the stage of material preparation, as well as **existing ones**, requiring some repair. Many strengthening techniques have been developed. Usually, reinforcement is applied to the whole length of the strengthened member, which solves problems related to depth of anchorage, sufficient to withstand the assumed load. However, techniques involving **local reinforcement**, placed at limited parts of the member, are gradually becoming more common. Such techniques significantly limit the total cost of reinforcement as well as interference with the original structures, which is important from a conservational point of view (especially in historical structures).

REINFORCEMENT MATERIALS

Any material can be used as a reinforcement, on condition it has higher strength or stiffness in comparison to the initial, unreinforced material.

Recently, new, **eco-friendly materials** of low production cost become the research objective. Table 1 presents the value of global production of selected natural fibres. On the basis of its analysis it can be stated that it is possible to ensure the stability of fibres supply for reinforcement purposes.

As a reinforcement layered **laminate bamboo composite** (LLBC) can be used. It is characterized by **high bending** and **tensile strength** (table 3), resulting from specific structure of bamboo fibre. The fibre contains relatively high proportion of cellulose and lignin. Additionally the angle between microfibrils is relatively low (table 2). Other bamboo advantage is a short renewability period.

Recently **flax** and **hemp fibres** become more popular. This phenomenon can be explained by the increasing ecological awareness, manifested in the seeking of renewable, cheap in production, biodegradable materials. Over the last three decades many research programs involved the search for a substitute for synthetic fibres. Widely used synthetic glass fibres can successfully be replaced by the flax fibres, because of its suitable mechanical properties (table. 3). The use of flax as a reinforcement of composite materials requires a careful selection of fibres. It is common that some structural defects of fibres may occur. The most often defect of fibres are nodes, which initiate crack under loading.

World production of hemp fibres is almost four times smaller in relation to the flax fibre production. However, it is predicted that in the future hemp fibres become the basis of European industrial crops. Hemp fibres can be a substitute for a **synthetic glass fibres** when light, rigid composite is needed (figure 1).

Table 1. World production of fibres [Faruk et al. 2012]

The origin of the fibres	Bamboo	Jute	Kenaf	Flax	Hemp	Coconut	Grass
World production [10^3 tons]	30 000	2 300	970	830	214	100	700

Table 2. The chemical composition of selected natural fibres [Jain et al. 1992:]

The type of the fibres	Density [kg/m^3]	Angle between the microfibrils [°]	Cellulose [%]	Lignin [%]
Coconut	1150	30 - 49	43	45
Banana	1350	11	65	5
Sisal	1450	20 – 25	70	12
Jute	1450	8.1	63	11.7
Bamboo	600 - 800	2 - 10	60.8	32.2

Table 3. Mechanical parameters of selected natural materials [Lilholt and Lawther 2000]

Parameter	LLBC	Flax	Hemp
Density [kg/m^3]	900	1540	1590
Young's modulus [GPa]	9.5	12 - 85	30 - 60
Tensile strength [MPa]	110	600 - 2000	350 - 800

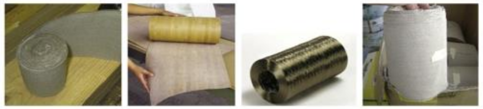

Figure 1. Mats used for timber reinforcement: flax, bamboo, basalt hemp [Borri et al. 2013]

METHODS AND RESULTS

Initial tests (according to EN 408 standard) were carried out using pine samples (*Pinus sylvestris* L.) as the most common species used in construction works in Poland. For the reinforcement technique, **LLBC plate** was selected. It was shaped in flat horizontal shape as well as into shape of D-letter.

Samples with dimensions of 50 x 100 x 2200 mm were divided into 3 groups (figure 2):
A - sound wood, weakened with a single opening with diameter of 18mm (simulation of the knot),
B - wood reinforced with a LLBC plate 4.0 mm thick,
C - wood reinforced with a LLBC D-shaped plate 4.0 mm thick.

Strengthening effectiveness was determined by the modulus of rupture (MOR) and Young's modulus (MOE) values.

In both cases it was not possible to obtain significant increase in MOE (due to very limited length of reinforcement). However, strengthening with LLBC plate increased the MOR by 50% in comparison to control (group A) samples and by 49% in case of C – group of samples.

Figure 2. LLBC reinforcement of pine wood, flat shape (on the left) and D-shape (on the right) [Burawska et al. 2015]

CONCLUSIONS

The potential benefit of using natural composites instead of steel is increased **resistance to fire** as a result of lower conductivity (in case of reinforcement located inside the reinforced cross section). The research carried out under the supervision of Martin [5] shows that hiding the reinforcement material inside the reinforced cross section has a beneficial effect on the load-bearing capacity during a short-term fire. Additionally, when the bond between reinforcement and reinforced material is made of phenolic resin, very small amount of harmful substances is emitted in case of fire.

Literature

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