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THE POTENTIAL OF NATURALLY GROWN BENT BAMBOO STRUCTURES: QUANTIFYING THE EFFECT OF THERMAL BENDING ON THEIR TENSILE STRENGTH

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ABSTRACT

This work investigates the effect of thermal bending on the tensile strength of bamboo canes. Two different bending-radii as well as the inner, outer and neutral fibre of bent bamboo canes are mechanically tested with a hydraulic testing machine. The results show a loss of tensile strength of up to 54% compared to a non-bent bamboo cane. In a current research project (Technical Product Harvesting) the growth of bamboo is directly manipulated into certain bending angles, with the goal to avoid additional manufacturing steps and energy input required for the thermal bending. The results allow the prospect that due to superior tensile strength compared to thermal bending it is furthermore worth mechanically to manipulate the bamboo's growth next its positive effect on the CO_2-footprint.

Keywords: bamboo structures, biomechanics, technical product harvesting.

INTRODUCTION

The demand for ecologically produced and sustainably operable products is constantly growing. This leads to ongoing research for material scientists, engineers and architects to explore new sustainable processes and materials. Exploiting the potential of natural materials by manipulating organisms during their growth period with external moulds is one of the approaches being investigated. By harvesting semi-finished products, manufacturing steps, including energetic as well as monetary input, can potentially be saved. It is further expected that naturally grown structures have fully unscathed cells and therefore show stronger properties than structures that have been treated and bent after their growth period.

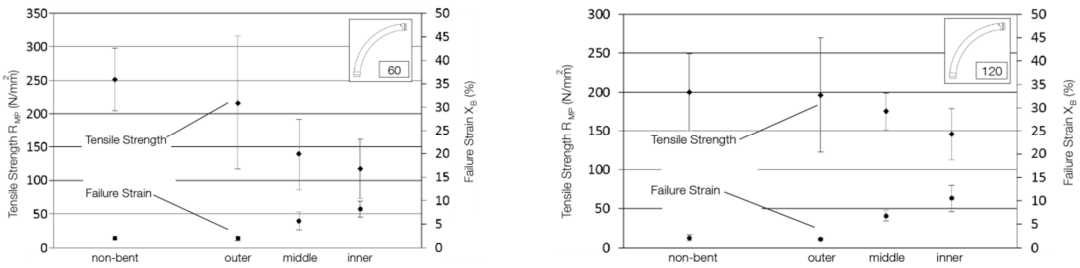
This work quantifies the potential of the described procedure for the example of bent bamboo canes by investigating the loss of tensile strength resulting from the thermal bending process. Tensile strength of bamboo depends on the species and age of the specimen, since the lignification process takes up to 5 years after the growth is finished. Furthermore, the moisture content of the structure is relevant. As a result the range for the tensile strength referring to literature varies from 54 N/mm² to 335 N/mm², also depending on the species, age and diameter which are often not particularly specified (Arce-Villalobos, 1993; Atrops, 1969).

Two different species of bamboo, *Phyllostachys bissetii* (*P. bissetii*, age: three and seven years after harvesting) and *Phyllostachys vivax*, (*P. vivax*, age: three years after harvesting) that were grown in Aachen, Germany with inner bending radii of 60 and 120 mm are

investigated. The results of material samples, extracted from the inner, outer and neutral fibre of the bent section are compared to tensile specimen of non-bent bamboo canes. The tests are executed using a hydraulic testing machine according to DIN EN ISO 6892-1. For each scenario six specimens are tested and interpreted by means of a 3^3-factorial design of experiment considering species including age, bending radius and origin of specimen.

RESULTS AND CONCLUSIONS

The results from the tensile strength tests for a 3-year-old *P. bissetii*, thermally bent with a 60 mm inner radius and for a 3-year-old *P. vivax*, thermally bent with a 120 mm inner radius are exemplarily shown in Fig. 1. For all tests the tensile strength is highest for the non-bent structure, lower for to the outer, even lower for the neutral fibre and lowest for the inner fibre. The tensile strength for the small bending radius of 60 mm of a 3-year-old *P. bissetii* goes down by 54% to 117 N/mm² compared to the non-bent structure that can withstand 251 N/mm² (Fig. 1, left). The loss of the tensile strength for a 3-year-old *P. vivax* for bigger bending radii of 120 mm is lower with 26% (Fig. 1, right), The tensile strength of the non-bent structure of the *P. vivax* starts with only 80% compared to *P. bissetii*.



(a) (b)

Fig. 1 - Analysis of tensile strength:
(a) 3-year-old *P. bissetii*, radius 60 mm; (b) 3-year-old *P. vivax*, radius 120 mm

This study shows that there is a loss of tensile strength of up to 54% if bamboo is bent thermally after the growth has terminated. The impact of the loss is in particular dependent on the bending radius and rises with decreasing radii. It is expected that bamboo grown into a certain angle by means of an external mould in order to achieve similar bending radii will feature better tensile strength compared to thermally-bent bamboo. Tests of already harvested and currently lignifying bamboo that was manipulated to grow into a 90° angle will be executed soon to verify the hypothesis. Furthermore microscopical cell-analysis of both thermally-bent and growth-manipulated bamboo canes will be executed to allow inferences to be drawn about the mechanical behaviour and the conditions of the cell structure.

ACKNOWLEDGMENTS

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