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The influence of humidity on mechanical properties of bamboo for bicycles

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HIGHLIGHTS

- Mechanical properties of two different bamboos in dry (environmental) and wet condition.
- The change of moisture content in specimens is min 0,39% and max. 0,73%.
- Both bamboos have lower values of mechanical properties after 3 weeks in wet chamber.

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ABSTRACT

Bamboo as an eco-friendly material has potential as construction material and proves his suitability in use as an alternative for more traditional materials such as steel, aluminium and composite. This work presents the influence of humidity on mechanical properties of two different bamboos, *Pseudosasa amabilis* (or Tonkin Cane) and *Pleioblastus amarus* (or Ku Zhu) which are used for bicycle frames. A large number of tensile, compression and bending tests were carried out in two conditions, dry (in terms of the environment) and wet (after 3 weeks in wet chamber). It is shown that both, Tonkin Cane and Ku Zhu, in spite of low change in weight after 3 weeks in wet chamber have lower values of mechanical properties. The results show that the tensile, compressive and bending strength of bamboo significantly decreased after bamboo samples were kept in an environment with humidity level of 60%. The reduction of strength in the wet state for both types of bamboo is statistically proven by two sample comparisons of their arithmetic means at significance level $\alpha = 0.05$. The results of this study indicate that the minimum change of moisture in samples decreases bending, tensile and compression strength of bamboo. Potential application of the results of this research is in the design and production of bicycle frameworks.

1. Introduction

Bamboo is natural construction composite material and there are over 1250 different botanical types of bamboo in the world. It grows very fast and it can be harvested after 3 years, depending on the species [1]. Therefore, global interest and research of its use are growing in many different applications in engineering and in civil construction [2–4]. Most of the research is focused on bamboo fiber–reinforced composites [5,6] or for constructional purpose [1,3]. Bamboo as an eco-friendly material has been used for fabrication of bicycles [7,8] as a cheap alternative to traditional materials like steel or aluminium alloys. It has high strength to weight ratio [8] which is very important for the structural design.

There is a lot of research on the mechanical properties of bamboo [9–19]. The mechanical properties of bamboo are determined by properties of fibers and matrixes and fibre density [6,11,19]. Some studies have researched the fracture and toughening mechanisms in bamboo structures [20,21] and the effects of microstructure on the micro mechanisms of crack growth [11]. These studies have shown that bamboo is susceptible to inter-laminar fracture, but the influence of outside moisture on crack behaviour has not been quantified. Some of them, like work by Askarinejad et al. [22] have investigated the effects of humidity on shear behaviour of bamboo. In this work it is shown that the specimens kept in environment with humidity levels between 60% and 80% had the highest shear modulus and drop after it. The results show that bamboo exhibits more ductility under torsion as the humidity of the samples increases. The results of this study provide significant information on the role of water on the optimal shear strength of

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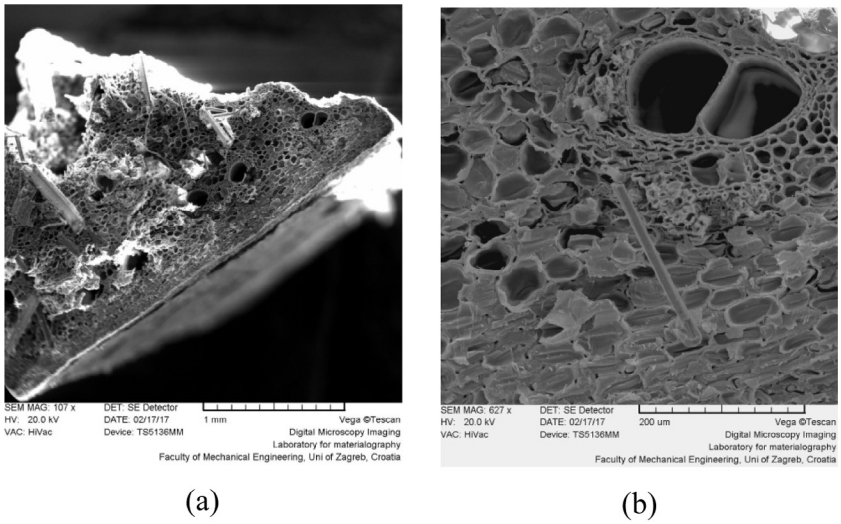

Fig. 1. Scanning electron microscope images of Tonkin Cane bamboo. (a) cross-section of Tonkin cane bamboo. (b) vascular bundles of fibers.

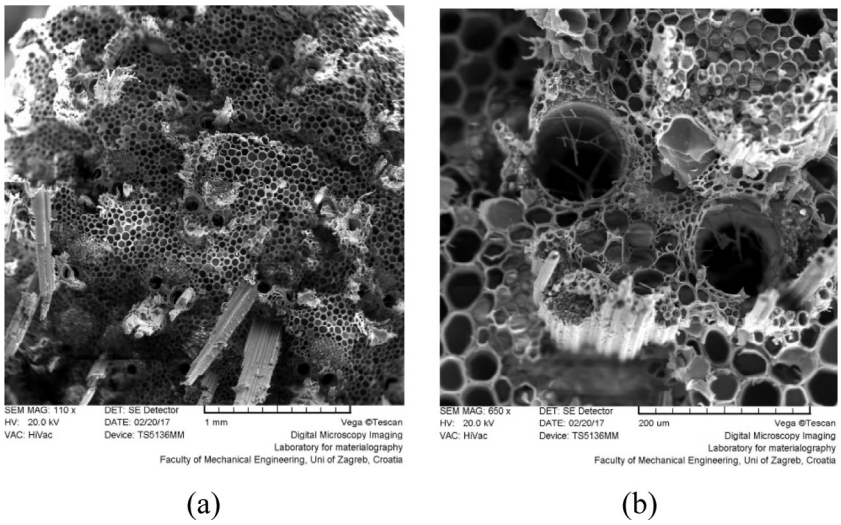

Fig. 2. Scanning electron microscope images of Ku Zhu bamboo. (a) cross-section of Ku Zhu. (b) vascular bundles of fibers.

Table 1
Samples testing plan.

Types of bamboo	Number of samples			
	Tonkin Cane		Ku Zhu	
Tests/Condition	Dry	Wet	Dry	Wet
Tension test	5	6	5	5
Compression test	5	5	5	5
Bending test	5	5	5	5

bamboo and its influence on mechanical properties of bamboo fibre and matrix.

There have been some prior studies of mechanical behaviour of round form (culm) specimens [13,18]. These studies have shown that chosen types of bamboos are acceptable construction materials with excellent mechanical properties. Mechanical properties of *Bambusa Pervariabilis* (or Kao Jue) and *Phyllostachy Pubescens* (or Mao Jue) which are used in bamboo scaffoldings have been studied in [18] in terms of compression and bending strength in both dry and wet condition. The specimens in wet tests were immersed in water over different time periods and tests showed that mechanical properties decreased in bamboo exposed to high humidity.

Some of the primary properties that are affected by moisture content include: dimension, weight, strength (tension, compression, bending), etc. This paper presents the findings on influence of humidity on mechanical properties (tension, compression and bending) of two bamboo species, *Pseudosasa amabilis* (hereinafter, Tonkin Cane) and *Pleioblastus amarus* (hereinafter, Ku Zhu) that are used for bamboo bicycle frames. The first part of paper investigates the mechanical properties of two types of bamboos in dry (environmental) condition and the second part the mechanical properties after 3 weeks in wet chamber.

2. Materials and methods

Both bamboo (Tonkin Cane and Ku Zhu) materials were obtained from China. Every pole was cut from a bamboo culm of over 3 years of age (Tonkin cane was cut in 2012 and Ku Zhu in 2013). After harvest they were dried for six months in a warehouse with 30% humidity without any chemical treatment and then following laboratory conditions, they were stored in ventilated warehouse for at least a year.