



# Wettability of oil heat-treated bamboo and bonding strength of laminated bamboo board



Tao Li<sup>a,b,\*</sup>, Da-li Cheng<sup>a</sup>, Magnus E.P. Wålinder<sup>b</sup>, Ding-guo Zhou<sup>a</sup>

<sup>a</sup> College of Materials Science and Engineering, Nanjing Forestry University, Nanjing 210037, China

<sup>b</sup> Division of Building Materials, Department of Civil and Architectural Engineering, KTH Royal Institute of Technology, SE-10044 Stockholm, Sweden

## ARTICLE INFO

### Article history:

Received 29 November 2014

Received in revised form 30 January 2015

Accepted 4 February 2015

Available online 16 February 2015

### Keywords:

Bamboo

Oil heat treatment

Wettability

Laminated bamboo board

Bonding strength

## ABSTRACT

In order to improve the interface properties of bamboo in laminated board applications for severe outdoor environment, bamboo sheets were heat treated in soybean oil and post oil extracted in this paper. Following oil heat treatment at 180 °C for 2 h, bamboo specimens were either removed from the oil immediately or left in the oil until they were cooled to room temperature. Contact angle measurements before and after oil heat treatment showed a significant increase in the hydrophobicity of bamboo, and these changes differed based on the process parameters. Results from scanning electron microscopy and Fourier transform infrared spectroscopy indicated that these phenomena may be due to the combination effect of the change of chemical composition and the surplus oil on the surface of modified bamboo. Then, the ethanol extraction process was subsequently applied to remove the surplus oil. Finally, the results of bonding strength tests on laminated bamboo boards prepared from oil heat-treated samples which thereafter had been subjected to ethanol extraction showed acceptable interface properties, although lower than the reference.

© 2015 Elsevier B.V. All rights reserved.

## 1. Introduction

Because of bamboo's abundance and excellent mechanical properties, it is viewed as an attractive natural material in terms of cost and strength (Van der Lugt et al., 2006). During the past 30 years, bamboo scientists and the bamboo processing industry in China have successfully developed bamboo products including bamboo flooring, bamboo building templates, bamboo wood composite flooring, and laminated bamboo. In order to more effectively utilize bamboo in a variety of applications, an important step involves flattening the bamboo to crack-free bamboo sheets. This is because the formation of crack-free bamboo sheets can reduce the amount of adhesive needed in subsequent manufacturing processes. Common products made from bamboo sheets include bamboo craft decorative products, kitchenware, and bamboo furniture; as these products are considered to be environmentally friendly, they have been well received by consumers. However, as is common with other bio-based materials, bamboo products are susceptible to deformation and degradation by the growth of mold.

Heat treatment, also known as thermal modification, has been shown to be an effective way to improve the performance of wood and wood products (Yildiz et al., 2006; Bak and Németh, 2012; Kwon et al., 2014). Currently used commercial thermal modification methods include the Plato process, which uses high pressure and high-temperature water, the rectification process, which uses nitrogen gas, and the thermowood process, which uses superheated vapor. Although resulting in improved dimensional stability and biological durability, the main drawback of these methods is the poor mechanical performance of final wood product. Oil heat treatment process, in which vegetable oil is used for both heat transfer and protection, is also an industrial thermal modification process. The mechanical properties of oil heat treated wood has been found to be better than that of above mentioned heat treatment methods, and sometimes even better than non treated samples. (Rapp and Sailer, 2001; Hill, 2006). As previous research has pointed out, the oxygen-free conditions when using the vegetable oil medium and the certain level of oil uptake for the modified wood seem to be the key factors for the improvement of wood properties. (Stamm, 1956; Cheng et al., 2014). In order to improve the performance of bamboo, Cheng et al. (2013) also successfully increased the mold resistance of bamboo using a two-step heat treatment method.

The interface properties of bio-based materials play an important role in the coating of wood products and in the manufacturing of wood/bamboo-based composites. While numerous studies have

\* Corresponding author at: College of Materials Science and Engineering, Nanjing Forestry University, Nanjing 210037, China. Tel.: +86 13675142571.

E-mail address: [litao@njfu.edu.cn](mailto:litao@njfu.edu.cn) (T. Li).

investigated the wettability of wood and bamboo (Wälinder and Ström, 2001; Wälinder et al., 2013; Li et al., 2004), other studies have looked more specifically at changes in the wettability of wood during heat treatment. For example, Bryne and Wälinder (2010) studied the interface properties of thermally modified spruce wood, and predicted its interactions with different adhesives. Hakkou et al. (2005) found that the hydrophobicity of beech wood increased during heat treatment at temperatures from 130–160 °C. Pétrissans et al. (2003) also pointed out the decrease in wettability and the corresponding increase in the hydrophobicity of spruce, poplar, beech, and pine due to heat treatment. For wood subjected to heat treatment using oil, the presence of residual oil on the wood surface has been shown to have an adverse effect on subsequent gluing or painting processes (Tjeerdsma et al., 2005). Sulaiman et al. (2006) studied the shear strength of laminated bamboo that was made from bamboo sheets heat treated using palm oil, and found that the oil heat treatment affected the surface structure of the bamboo and reduced the shear strength of the glue line of laminated bamboo.

Therefore, with a goal of enlarging the application of bamboo to the field of outdoor building and construction, more attention should be emphasized on the interface properties of oil heat-treated bamboo, a new kind of modified bamboo semi-product. The idea of ethanol extraction on the oil heat treated wood was derived from the vegetable oil industry, in which solvent extraction has been the primary means of extracting vegetable oil from oleaginous materials. The possibility and other information about the ethanol extraction on oily wood have been presented in the coauthor's previous published paper (Cheng et al., 2014). The objective of this paper was to apply oil extraction with ethanol, based on the above coauthor's research on oil heat-treated wood (Cheng et al., 2014), to improve the oily bamboo surface and thereby improve the interface properties of oil heat-treated bamboo. Following extraction, the wettability of the bamboo skin and bamboo pith surfaces, measured by the contact angle of distilled water, was quantitatively compared for untreated bamboo, oil heat-treated bamboo, and oil heat-treated bamboo extracted with ethanol. Finally, the bonding strength of laminated bamboo boards prepared with different bamboo specimens was evaluated and compared.

## 2. Material and methods

### 2.1. Bamboo samples

Moso bamboo (*Phyllostachys pubescens*) is an important forest resource with great potential in China. Flattened Moso bamboo sheets were obtained from a bamboo product plant in Anji, Zhejiang

province, China. The sheets, which were 1000 mm long and 5 mm thick, had a hard outer surface (bamboo skin) and a soft inside surface (bamboo pith). The flattened bamboo sheets were processed to a width of 135 mm and a length of approximately 260 mm. Before the oil heat treatment, the moisture content of all specimens was conditioned to ca. 10–12% in a conditioning chamber at 25 °C and a relative humidity of 65%.

### 2.2. Oil heat treatment

The specimens were divided into two groups (I and II). All bamboo sheets were first oil heat treated in hot soybean oil at 180 °C for 2 h. The specimens in I were immediately removed from the hot oil, while the specimens in II were removed after the oil had cooled to room temperature. Residual oil on the surface of all specimens was manually wiped away. Some specimens from I and II were set aside for testing, and some were further treated with the extraction method described in the following section.

### 2.3. Oil extraction and determination of oil uptake

The oil heat-treated bamboo sheets were first pre-pressed at a pressure of 2.0 MPa for 10 min in order to partially remove the surplus oil. The specimens were then exposed to vacuum at 0.01 MPa, and finally immersed in 100% ethanol (laboratory reagent) to extract the residual oil in the modified bamboo. The final low-oil content specimen III was obtained from I, and the low-oil content specimen IV was obtained from II. The determination of oil uptake percentage was done by Soxhlet extraction using absolute ethanol (analytical reagent) according to the method described by Cheng et al. (2014).

### 2.4. Measurement of wettability of specimens

The contact angle was measured using distilled water with the sessile drop technique. These experiments were performed on bamboo sheet samples with dimensions 50 × 50 × 5 mm at a temperature of 20 °C. The samples were sanded with 120-grit sandpaper before measurement. For each of the four modified bamboo groups (I–IV) and the reference group (not undergone above mentioned oil heat treatment or/and oil extraction steps), the measurements were performed on the bamboo skin and the bamboo pith portions separately. There were five samples in each group, with six testing points (three for bamboo skin, and three for bamboo pith) on each sample. On each testing point, the contact angle was recorded 10 s after application both on the left side and on the right side of the droplet, and the mean contact angle was calculated.

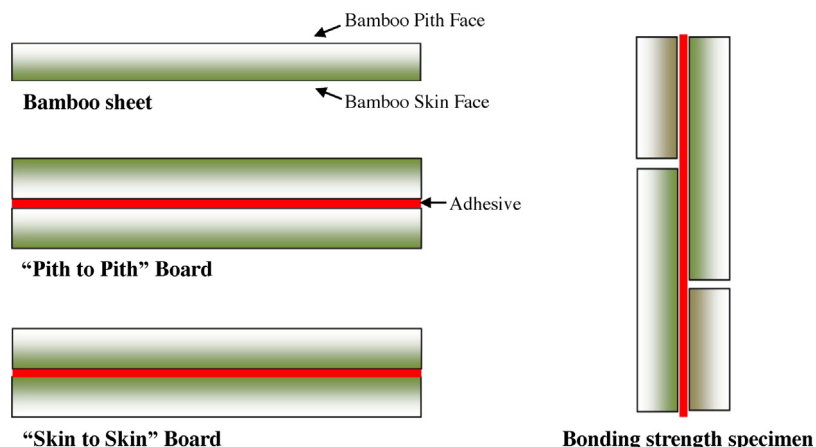


Fig. 1. Bamboo sheet, laminated bamboo board, and bonding strength specimen.

Download English Version:

<https://daneshyari.com/en/article/4512975>

Download Persian Version:

<https://daneshyari.com/article/4512975>

[Daneshyari.com](https://daneshyari.com)