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Effect of microwave-assisted curing on bamboo glue strength: Bonded by thermosetting phenolic resin

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HIGHLIGHTS

- Microwave is employed to cure thermosetting phenolic resin.
- Bamboo samples cured by microwave have much higher shear strength.
- Microwave can reduce defects on the interface between bamboo and resin.

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ABSTRACT

In this study, bamboo strips was glued by thermosetting phenolic resin which was cured by microwave, and the effect of microwave-assisted curing on bamboo glue strength was also researched. Fourier transform infrared spectroscopy (FT-IR) was used to evaluate curing degree of phenolic resin and bamboo bonding strength was characterized by compression shear test. Scanning Electron Microscopy (SEM) and Atomic Force Microscope (AFM) were employed to observe the morphology of cured phenolic resin and glued bamboo. Curing degree results showed that microwave was a fast and efficient curing method, which could reduce curing time by 50%. Bamboo compression shear strength results indicated that the sample cured at 100 °C for 10 min would reach its optimum mechanical performance. Higher curing temperature (110 °C) caused carbonization in bamboo, which would weaken mechanical strength of bamboos. The SEM image indicated that fast curing by microwave would cause expansion of phenolic resin, which would cause rough surface and increase the bonding strength of bamboo and phenolic resin. Furthermore, during the rapid curing process, phenolic resin embedded in the pores on bamboo surface, which would reduce defects on the interface between bamboo and resin. Thus shear strength of microwave cured bamboo was much higher than that of bamboo cured by thermal.

1. Introduction

Bamboo is an indigenous plant in many Asian countries. In recent years, as a kind of renewable material, bamboo has caused people's extensive concern. Because of its rapid growing speed, high strength and high toughness, bamboo has been expected to be a sustainable alternative for traditional construction materials, such as wood, concrete, steel and timber [1–5]. In its applications, the bamboo elements, like bamboo strips, bamboo beams etcetera, are usually cemented by resin [6–8].

Thermosetting phenolic resin is a kind of ancient adhesive, which has been produced and used for nearly one hundred years [9–12]. Because of its good bonding strength and excellent weather resistance property, phenolic resin is widely applied as a binder for wood and bamboo productions [9,11,13–16]. Curing of thermosetting phenolic resins is usually carried out by conventional thermo curing method, which usually takes long time to obtain cured product. Hence, it is important to develop a fast curing method for practical application of phenolic resin.

Microwave is a kind of high-frequency electromagnetic wave, whose wavelength is between one millimeter to one meter, intermediate between infrared and short-wave radio wavelengths. In recent years, microwave has been considered as an alternative energy source for curing process [17,18]. Some previous studies have indicated that microwave is effective for reducing curing time of resin [19–22]. Furthermore, studies have showed that microwave curing technique can greatly affect the mechanical properties of composites [23–27].

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In this work, bamboo strips (Moso bamboo (*Ph. heterocycla var. Pubescens*), four years old) were cemented by thermosetting phenolic resin and microwave was employed as the curing method. Furthermore, the effect of microwave on bonding strength of bamboo strips was also discussed in this research.

2. Experiments

Thermosetting phenolic resin (PF, Taier Chemical company, Beijing), whose molecular weights was about 2000–3000, was employed as adhesive in this study. Both microwave curing process and thermo curing process were researched. Firstly, 0.5 g phenolic resin was dropped evenly on a piece of microscope slides as the curing sample. Then the curing samples were divided into two groups: one group was cured by microwave oven (XH-200A, Xianghu Technology Development Co., Ltd., using IR temperature measurement technology), and the other group was cured by thermal oven.

Bamboo strips, which were 20 mm × 30 mm × 10 mm, were glued by phenolic resin as which was shown in Fig. 1. Firstly, bamboo strips were dipped in phenolic resin for 5 h and then they were dried in air for 12 h. Secondly, the completely dried bamboo strips were pre-compressed at 25 MPa for 10 min. Lastly, the bamboo samples were cured by microwave oven and thermal oven respectively. According to the research of curing of phenolic resin, thermal curing is at 120 °C for 30 min. In order to study the influence from curing temperature and curing time, one series of microwave cured bamboo samples are prepared at 80 °C, 90 °C, 100 °C and 110 °C respectively for 15 min, and the other series of bamboo samples are cured at 100 °C for 5 min, 7.5 min, 10 min, 15 min and 20 min respectively.

In addition bamboo was natural gradient materials; the properties of bamboo green skin (outside) and bamboo yellow endothecium (inside) were quite different. In order to avoid the effect from bamboo surface, all the samples was bonded by yellow-side to yellow-side.

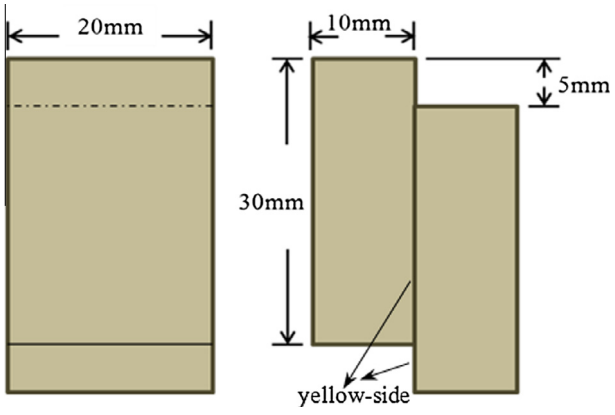

Fig. 1. Schematic of glued bamboo strips sample.

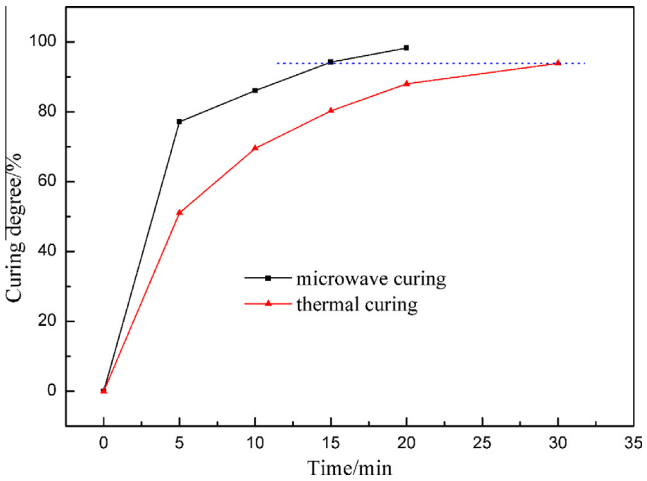

Fig. 2. Curing degree results of phenolic resin cured for different time (all the resin samples were cured at 120 °C).

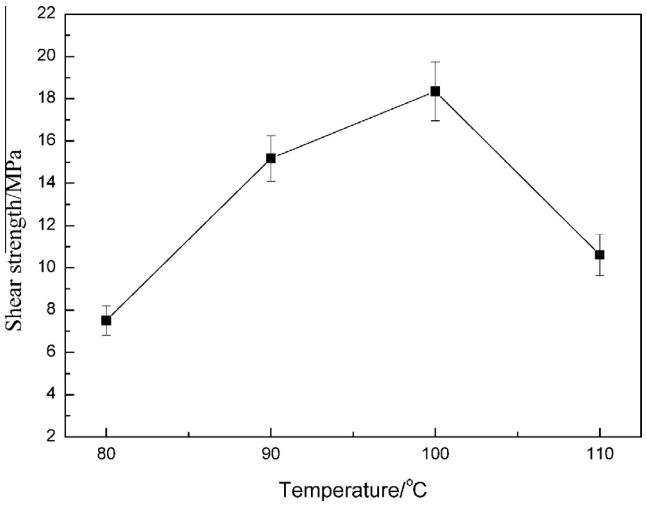

Fig. 3. Glue shear strength of bamboo samples cured by microwave at different temperature (all the resin bamboo samples were cured for 15 min).

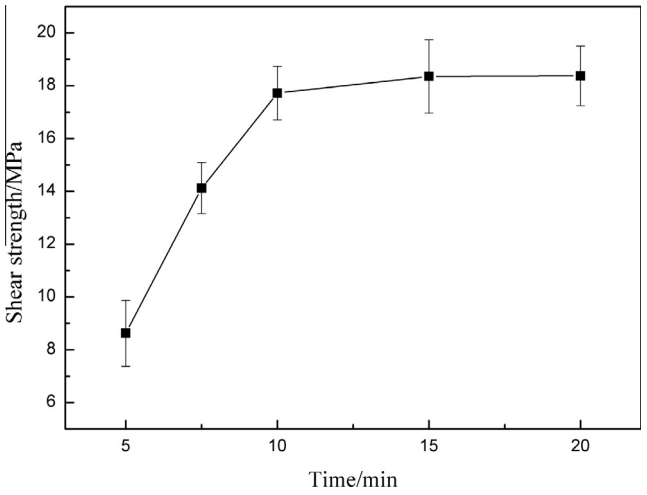

Fig. 4. Glue shear strength of bamboo samples cured by microwave for different time (all the bamboo samples were cured at 100 °C).

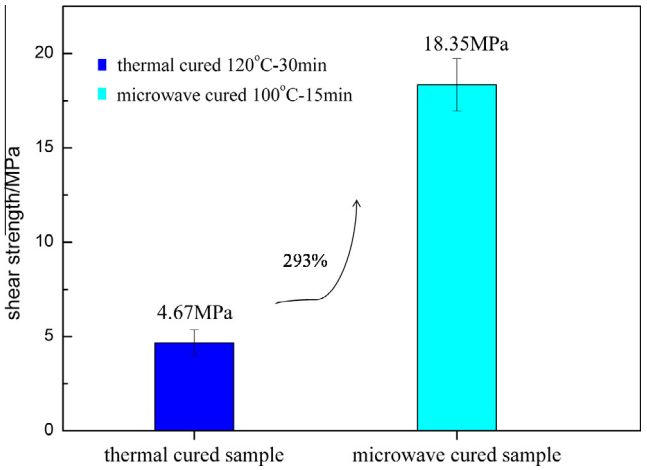

Fig. 5. Glue shear strength of bamboo sample cured by different methods.