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ScienceDirect

Procedia Engineering 210 (2017) 18–23

Procedia Engineering

www.elsevier.com/locate/procedia

6th International Workshop on Performance, Protection & Strengthening of Structures under Extreme Loading, PROTECT2017, 11-12 December 2017, Guangzhou (Canton), China

Axial compression performance of steel/bamboo composite column

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Abstract

A new type of thin-walled steel tube/bamboo plywood hollow composite column with binding bars (SBCCB) that used transverse binding bars to reinforce the composite column was developed. The compression performance of 4 specimens with larger slenderness ratio was tested to examine the failure mode of the SBCCBs. The results indicated that the compression failure modes are mainly crushing failure of the bamboo plywood material, partial debonding failure of the adhesion interface and buckling instability failure; the ultimate bearing capacity of the specimens is not only related to net cross-sectional area and slenderness ratio, but also greatly affected due to binding bars. Transverse binding bars can ensure the integrity of the composite column, effectively reduce the debonding failure of the adhesion interface and significantly improve the load-bearing capacity of the SBCCBs.

Peer-review under responsibility of the scientific committee of the 6th International Workshop on Performance, Protection & Strengthening of Structures under Extreme Loading

Keywords: Bamboo-plywood; thin-walled steel-tube; composite column; axial compression; bearing capacity

1. Introduction

Bamboo-laminated composite engineering materials are one of the most feasible applications for utilizing bamboo resources [1]. However, applications of bamboo-laminated materials in engineering have focused on concrete-based construction; research on using bamboo-laminated materials as an engineered structural material has only been conducted recently [2-3]. Professor Xiao proposed that bamboo has not been widely used in modern engineering structures primarily because of the lack of effective theoretical validation from solid mechanics,

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Peer-review under responsibility of the scientific committee of the 6th International Workshop on Performance, Protection & Strengthening of Structures under Extreme Loading.
10.1016/j.proeng.2017.11.043

materials science, structural design, and experimental technology [4]. In recent years, significant progress has been made in the studies and applications of bamboo composite materials and bamboo-laminated materials [3-6], including steel/bamboo-laminated composite structural columns [7-12]. With the increasing shortage of engineered wood and the promotion of sustainable green construction materials, research into steel/bamboo composites has received significant attention worldwide. Liu et al. developed a steel/bamboo (curtain plywood) box composite column [10], and Li Y. et al. explored a bamboo composite column reinforced by steel rebar [11]. Li Y.S. et al developed a series of steel/bamboo plywood composite elements [8-9], and Xie et al. explored a similar column application with cold-formed thin-walled C-section steel and a bamboo-wood composite plate [11]. Zhao et al. developed a thin-walled steel tube/bamboo plywood hollow composite column [7]. The thin-walled steel tube in the column served as the skeleton, making the composite suitable for industrial assembly. The thin-walled steel tube also increased the cross-sectional are of the composite columns, thereby reducing the slenderness ratio and effectively improving the instability and failure performance of the columns under pressure. Few international reports have described the studies on the steel tube/bamboo-laminated composites used as structural bearing elements.

Drawing on research on the compressive properties of thin-walled steel tube/bamboo plywood hollow composite column (SBCC) [7], a new type of thin-walled steel tube/bamboo plywood composite column with binding bars (SBCCBs) were developed to address the loss of effectiveness due to debonding failure and the low ultimate strength of regular SBCCs. The compression performance of SBCCB specimens with small slenderness ratio had been tested to examine the failure mode and the ultimate bearing capacity of the SBCCBs [13]. In this paper, based on axial compression studies of 4 specimens with larger slenderness ratio, the compression failure mode of SBCCBs is examined.

2. specimens design

2.1. Materials and specimens design

Four axial compression test specimens were designed; the parameters are listed in Table 1, and the cross-section and finished specimens are illustrated in Fig. 1. The bamboo plywood for the specimens was cut into a plate belt from the same batch of raw bamboo plywood according to the specimen requirements. The water content of the plywood was 9%; the transverse and longitudinal elastic modulus was 7.4 GPa and 8.3 GPa, respectively; and the longitudinal compressive strength was 24 MPa. The galvanized seamless square steel tube Q235 was selected for the steel tube with the thickness of 2 mm; its elastic modulus was 205 GPa, the yielding strength was 260 MPa, and the ultimate strength was 340 MPa. The binding bar was composed of a full thread screw rod with a diameter of 6 mm and yield strength of 260 MPa. Because the elastic modulus of steel is much larger than that of bamboo, to prevent the steel tube from taking on load during the loading process and suffering buckling damage, the steel tube was shorter than the bamboo plywood by 15–20 mm from each end so that it would provide only inner support. This design generated a hooping effect with the horizontal binding bar. The interface adhesive was the modified epoxy resin with a shrinkage rate of less than 1% and shear strength of greater than 12 MPa. After completing the construction of the specimens, the composite column was assembled by fixture fastening and cured for seven to ten days in dry ventilated conditions to ensure that the full binding strength was achieved.

2.2. Test method

A multi-channel electro-hydraulic servo loading system was employed for the axial compression test; Fig. 2 shows the test equipment and measurement point layout. Both ends of the test specimen were pressed by unidirectional knife hinges, and a cushion was placed between the column ends and the knife hinge plate to exert uniform pressure on the contact surfaces. Six displacement sensors for measuring lateral deflection, 12 axial strain gauges and 12 transverse strain gauges were placed near the upper, middle, and lower binding bars. The axial compressive load, displacement, and strain data were collected by the measurement system. Loading was applied using continuous low-speed uniform displacement loading. The test terminated when the specimen incurred large cracking damage or a distinct unloading phenomenon was observed; the maximum load was assumed to be the ultimate axial load of the specimen.