Experimental study on laminated bamboo lumber column

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Abstract: This paper presents and discusses the experimental study on the mechanical properties of LBL column both under axial and eccentric compression. The results shows that the ultimate load for the eccentric compression specimens with the eccentricity values of 30 mm and 110 mm are 95.2 kN and 31.8 kN respectively. Eccentricity is one of the main influencing factors for the ultimate bearing capacity of the LBL columns. Because of the vulnerability of the mechanical connections or natural nodes to tensile stress and secondly, laminated bamboo is vulnerable to defects that has more detrimental influence on the tensile resistance of the material. The variation in strain for the laminated bamboo lumber column sections is linear throughout the loading process, following standard normal section bending theory which is similar as that for the beam.

1 Introduction

As a sustainable green building material, bamboo has attracted more and more researchers' attention [1-28]. Original bamboo culm has low rigidity and limited diameter. In order to solve these problems, industrial bamboo materials appeared in different forms such as parallel bamboo strand lumber (PBSL) [5-10], laminated bamboo lumber (LBL) [11-28] and so on. Laminated bamboo lumber (LBL) is made by laminating the thin flat bamboo strips together with adhesive under a certain treatment and the structural size could be controlled in the factory.

In order to apply laminated bamboo lumber to engineering area, many scientists [11-28] have done a lot of research on manufacturing technology and mechanical properties. Correal et al. [12] studied the adhesive bond performance in glue line shear and bending for glued laminated guadua bamboo. Verma et al. [13-14] have investigated the stiffness and strength of four layered laminate bamboo composite at macroscopic scale. Lee et al. [15] have studied the properties of laboratory-made laminated-bamboo lumber. Yeh et al. [16] has investigated finger joint performance of structural laminated bamboo member. Varela et al. [17] have investigated cyclic performance of glued laminated guadua bamboo-sheathed shear walls. Taheri et al. [18] have studied buckling response of glue-laminated columns reinforced with fiber-reinforced plastic sheets. Li et al. [19-21] have studied the flexural performance of laminated bamboo lumber beam and the ultimate load calculation formula for the LBL beams were proposed. Axial compression performance of LBL has been studied by Li et al. [22-24] and Su et al. [25]. Li et al. [26-28] also investigated the eccentric compression performance of LBL columns. Even though some researchers have studied the mechanical properties of laminated bamboo lumber column, the study for it is limit. There is still no standard for LBL columns under compression. More work needs to be done to investigate the mechanical performance for LBL columns.

This paper mainly studies mechanical properties for LBL columns based on the former research. In order to know the compression behaviour of LBL columns, the study will examine in detail the behaviour of structural members constructed from laminated bamboo lumber with a design dimension of 76 mm × 76 mm × 800 mm.

2 Materials Information and Test

Moso bamboo, harvested at the age of 3-4 years, was chosen for manufacturing laminated bamboo lumber columns. Phenol glue was used to manufacture the column specimens. Single layers were made first, and then they were pressed together to form the blocks (Figure 1). The pressing temperature was 140±5ºC and the transverse compression was 1.82MPa for both the sheets and the blocks, and a confining pressure of 4.74MPa was used when manufacturing the sheets. Considering axial compression and eccentric compression with two

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eccentricities of 30 mm, 110 mm, 5 column specimens (three for axial compression) were constructed with the cross-section of 76 mm× 76 mm and the length of 800 mm. The eccentric direction is tangential eccentric direction.

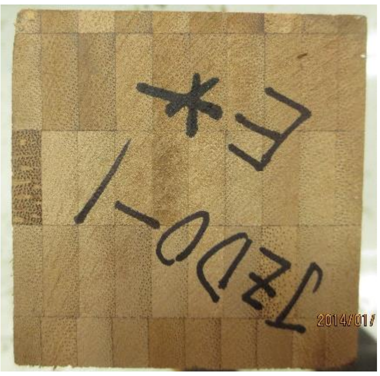


Figure 1 Laminated bamboo lumber (LBL) Figure 2 Axial compression test Figure 3 Eccentric compression test

Axial compression test photo and eccentric compression test photo can be seen from Figure 2 and Figure 3 respectively. Both the axial and lateral displacements were measured by Laser Displacement Sensors for all columns. Two main strain gauges along lateral and longitudinal directions were placed at the mid-height of specimens for axial compression tests. While for the columns under eccentric compression, besides two strain gauges were placed at the mid-height of four side surfaces, four more strain gauges were used on one side surface as can be seen from Figure 3. The loads were applied using a microcomputer-controlled electro-hydraulic servo universal testing machine with a capacity of 1000 kN with a TDS-530 Data Acquisition System.

The load was applied initially through load control in the elastic stage, and then was changed to displacement control before the proportional limit. The total loading time was controlled between 8-12 minutes. The test was continued at a certain displacement rate until the load reduced by 15% of the ultimate load and the specimen had sustained significant damage.

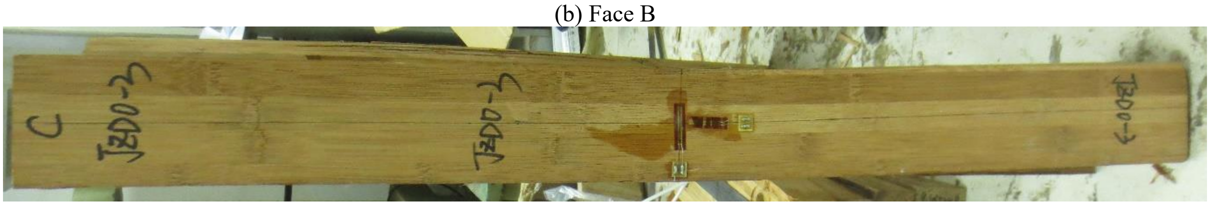
3 Test results and analysis

As for the columns under axial compression, the specimens behaved elastically at beginning and then buckling failure happened to them. The specimens bent to one direction suddenly. With the increasing of load and obvious deflection, cracks appeared. Finally the specimens crushed and the load values decreased. Typical final photos for the specimens under axial compression can be seen from Figure 4 and the ultimate load for three specimens are 274.7 kN, 270.2 kN, 275.0 kN respectively.

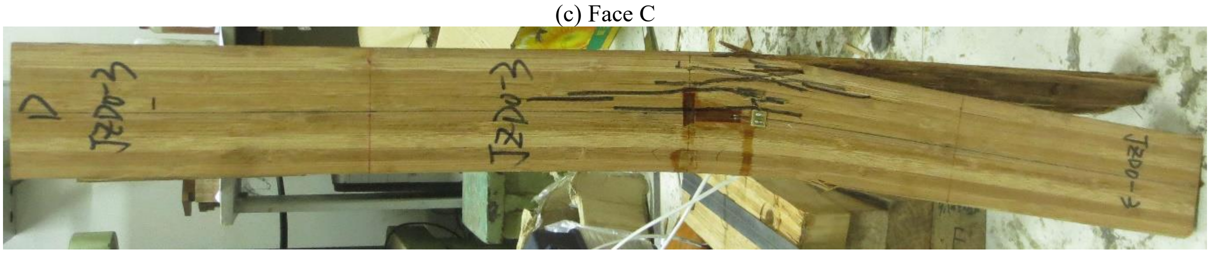
As for the specimens under eccentric compression, similar to the specimens under axial compression, the column specimens behaved elastically at beginning then followed by some plastic deformation with increasing load. The stiffness decreased in the plastic-elastic stage. With the increasing of load and obvious deflection, cracks (accompanied by a slight noise) appeared on the tensile surface D. The load application was stopped when the load was reduced by 15% of the ultimate load and the specimen sustained significant damage. Except for the compression surface B, cracks were visible on other three side surfaces. It was obvious that failure was triggered due to bending for all the two column specimens under eccentric compression. Typical final failure photo can be seen from Figure 5. The ultimate load for the eccentric compression specimens with the eccentricity values of 30 mm and 110 mm are 95.2 kN and 31.8 kN respectively. Compared with the axial compression results, eccentricity is one of the main influencing factors for the ultimate bearing capacity of the LBL columns. The ultimate load for the specimens with the eccentricity values of 30 mm and 110 mm decreased by 65.2% and 88.4% respectively.

(a) Face A

(b) Face B



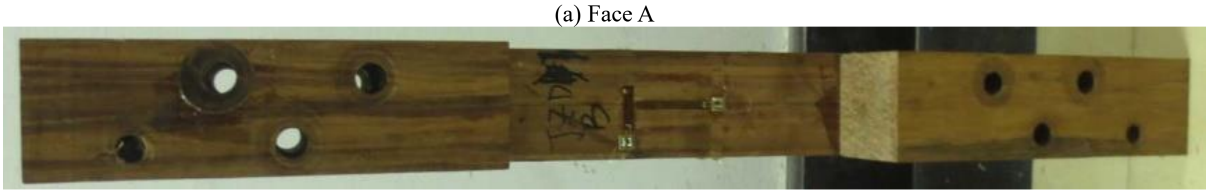
(c) Face C



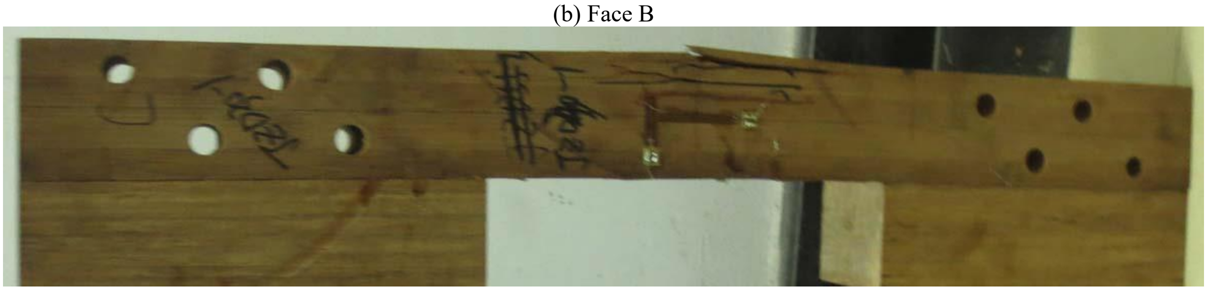
(d) Face D

Figure 4 Typical failure photos for axial compression specimen

(a) Face A



(b) Face B

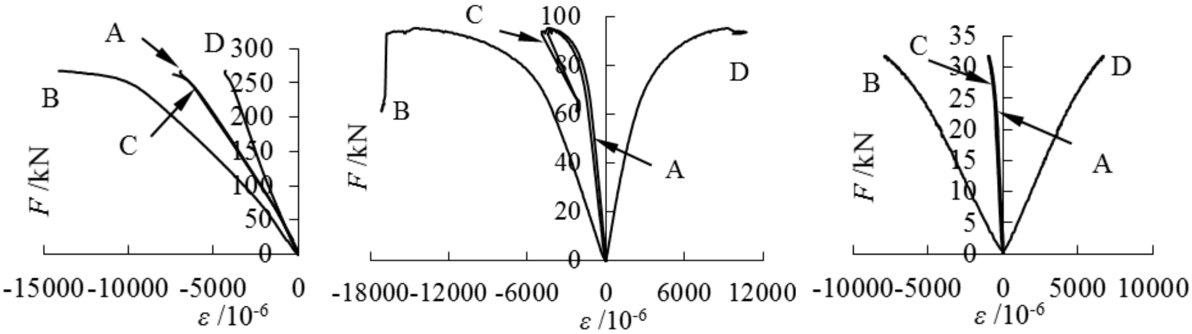


(c) Face C

Figure 5 Typical failure photos for eccentric compression specimen

4 Load vs strain relationship for LBL columns

Figure 6 shows the variations in longitudinal strains at the mid-heights of four side surfaces. As can be seen from the figures, all strains clearly displayed an initial elastic phase. The longitudinal strain values for face A and C were always consistent during the whole loading process, and with increasing eccentricity observed strains on faces A and C became insignificant. The mechanical behaviour of the columns with higher eccentricities resembled those observed for beams. Face B being subjected to the highest compression, always showed maximum deformations both in longitudinal and transverse direction. Although, failure was always triggered on the tension surface: firstly, because of the vulnerability of the mechanical connections or natural nodes to tensile stress and secondly, laminated bamboo is vulnerable to defects that has more detrimental influence on the tensile resistance of the material.

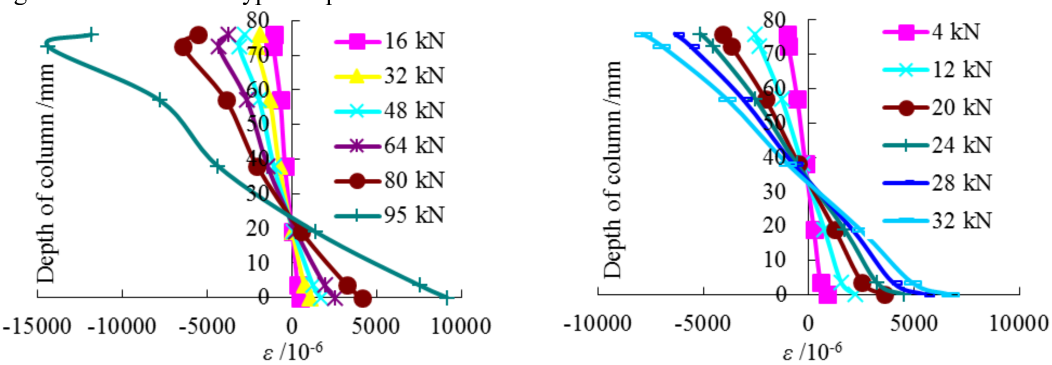


(a) JZD0-2 (b) JZD30 (c) JZD110

Figure 6 Load-longitudinal strain curves

5 Strain distribution over cross-sections

Fig. 7 shows the strain profile through the loading process for the mid-height cross-section of typical specimens for each group. The variation in strain for the laminated bamboo lumber column sections is linear throughout the loading process, following standard normal section bending theory which is similar as that for the beam (Li et al [19-21]).



(a) JZD30 (b) JZD110

Figure 7 Typical strain profile development for the mid-span cross-section

6 Conclusion

This paper presents and discusses the experimental study on the mechanical properties of LBL column both under axial and eccentric compression. The results shows that the ultimate load for the eccentric compression specimens with the eccentricity values of 30 mm and 110 mm are 95.2 kN and 31.8 kN respectively. Eccentricity is one of the main influencing factors for the ultimate bearing capacity of the LBL columns. The ultimate load for the specimens with the eccentricity values of 30 mm and 110 mm decreased by 65.2% and 88.4% respectively. Because of the vulnerability of the mechanical connections or natural nodes to tensile stress and secondly, laminated bamboo is vulnerable to defects that has more detrimental influence on the tensile resistance of the material. The variation in strain for the laminated bamboo lumber column sections is linear throughout the loading process, following standard normal section bending theory which is similar as that for the beam.

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