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Experimental Investigation on OSB Webbed Laminated Bamboo Lumber Box Shaped Joists

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Abstract. A novel bamboo-wood box beam was introduced in this paper, which consisted of laminated bamboo lumber flanges and OSB webs. Four-point bending tests were conducted on composite beams to investigate the effects of shear span ratio and stiffeners on failure mode and strength. The results showed that the composite beams with shear span ratio less than two failed in web shear failure, but for the others, the beams failed in twist and delamination of OSB in flanges. The load carrying capacity of beams decreased with the increase of shear span ratio. However, the mechanical performance of beams can be improved moderately by the presence of stiffeners, and theultimate bearing capacity and initial stiffness was increased by 16.5% and 13.1% respectively.

1 Introduction

In recent years, the high quality wood with large diameter worldwide has been decreasing year by year, resulting in the application of wood structure was limited seriously [1-4]. China is rich in bamboo resources and has a long history in utilizing bamboo. As a sustainable green building materials, increasing attention has been paid on the application of bamboo which is considered as an alternative to wood [5-6]. Recently, laminated bamboo lumber (LBL) has been manufactured by peeling bamboo culms to 4-5 mm thickness and 6-8 mm width strips and gluing them together with phenol formaldehyde resin, which overcomes the disadvantages of raw bamboo, such as thin-walled hollow and easy to crack when exposed to humid air [7-10].

Wood I joists are efficient and lightweight structural members that are widely used as floor and roof joists in residential buildings for decades [11-14]. However, because of the relatively stiffness and strength of flanges, the flanges of the joists are prone to fracture suddenly and exhibit brittle failure characteristic. To address these issues, steel plates and FRP sheet were usually used to paste on the bottom of joists, but the improvement on strength and stiffness was limited [15-17].

Therefore, OSB webbed laminated bamboo lumber box shaped joists are introduced, which can be used as an alternative to wood I joists. The objective of this study was to investigate the strength and deformation of composite box joists. The experimental results obtained can provide useful reference for the design and application of box joists.

2 Materials and methods

Prefabricated OSB webbed laminated bamboo lumber box shaped joists consisted of four components: a flange material, a web material, an adhesive and nails. The LBL flanges, 30 mm × 35 mm in dimension, were provide by Dongguan Xiangnan Bamboo Industry Co. Ltd. And the OSB webs typically was 9.5 mm in thickness [18-19]. The two component epoxy resin structural adhesive (Yijiayi New Material Technology Co., Ltd., Yancheng, China) cured at room temperature was used for flange-web connections. The consumption of adhesive is 250 g/m^2. Then smooth nails (2.8 mm × 40 mm) with 150 mm spacing were directly nailed into bamboo flanges from the side of the OSB plates. To avoid splitting of bamboo flanges occurred, the minimum edge distance of nails was 10mm. The finished specimens were stored in the lab at 20 °C ±2 °C and 65% ± 5% relative humidity for two weeks.

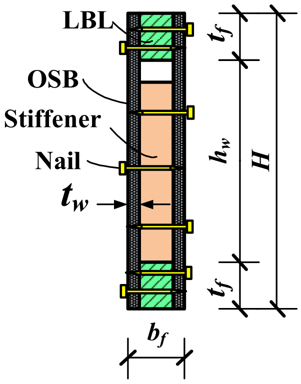

Fig. 1. Cross-section of specimen.

The experimental program comprised tests on 12 specimens, which were grouped into 2 series. The properties of composite joists, such as shear span ratio and stiffeners are presented in Table 1. All the specimens were 240 mm in height, 2.44 m in length and 49 mm in

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width. The shear span ratio ($\lambda=l_1/L$) was 1.2, 1.4, 1.6, 1.8, 2.0 and 2.5 for WB1-WB6 respectively. To investigate the effect of stiffeners on the mechanical performance of composite joists, stiffeners (30mm×35mm×227mm) were required at the two supports and also at points of concentrated loads for specimens (WB7-WB12). Install bearing stiffeners tight against the bottom flange of the I-joist, leaving 5 mm gap at the top. But the load stiffeners had the opposite installation (Fig. 1).

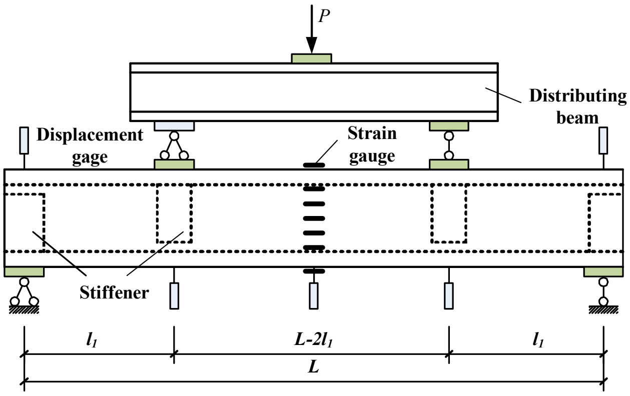


Fig. 2. Test set-up.

Table 1. Details of specimen parameters.

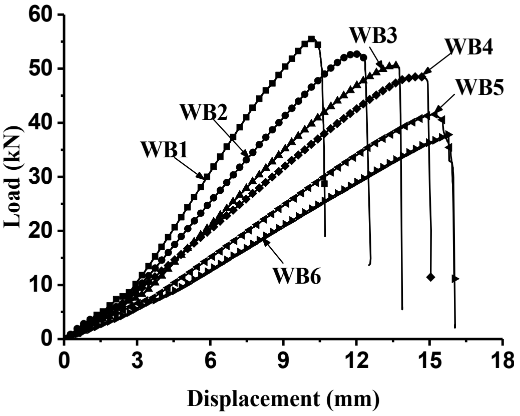
Specimens	b_f×t_f/mm	l_1/mm	λ	Stiffener
WB1	49×35	360	1.2	No
WB2	49×35	420	1.4	No
WB3	49×35	480	1.6	No
WB4	49×35	540	1.8	No
WB5	49×35	600	2.0	No
WB6	49×35	750	2.5	No
WB7	49×35	360	1.2	Yes
WB8	49×35	420	1.4	Yes
WB9	49×35	480	1.6	Yes
WB10	49×35	540	1.8	Yes
WB11	49×35	600	2.0	Yes
WB12	49×35	750	2.5	Yes

Four-point bending experiments on the specimens were conducted under monotonic loading condition. The testing apparatus is shown in Fig. 2. Vertical loading was applied using an Electro hydraulic servo loading system with a 500-mm stroke. The actuator was connected through another rectangular steel distributing beam to the top flange of the specimens. A total of seven instruments was installed on each joist to record the mid-span displacement, the applied force, the settlement of the two supports and the mid-span strains along beam depth. The testing was displacement-controlled until failure and the loading rates were 2 mm/min, according to the ASTM D5055 (2010). All the data were collected by a data acquisition system and the sampling frequency was 1 HZ.

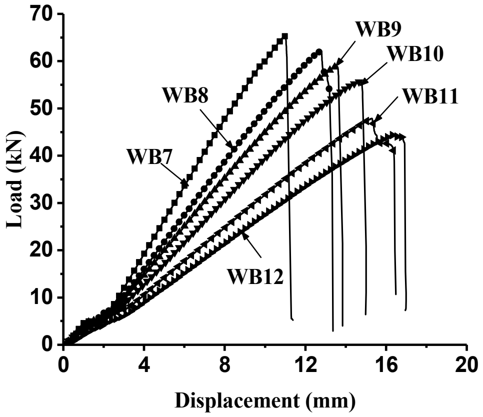
3 Results and discussion

3.1 Observed behavior and failure modes

The load-deflection curves for specimens with and without stiffeners were shown in Fig. 3. It was clear that the specimens behaved elastically up to ultimate load, followed by an abrupt drop in load carrying capacity. The present of stiffeners had positive effect on the mechanical performance of joists. At the initial stage of loading, the mid-span deflection of specimens increased linearly with increasing applied loading, and small cracking noise of wood could be heard. However, no visual damage of flanges and webs were observed until reaching to ultimate bearing capacity. Once the joists reached the ultimate strength, the joists soon lost suddenly and damage normally happened without any obvious symptom, exhibiting brittle failure characteristic.



(a) B1-B6



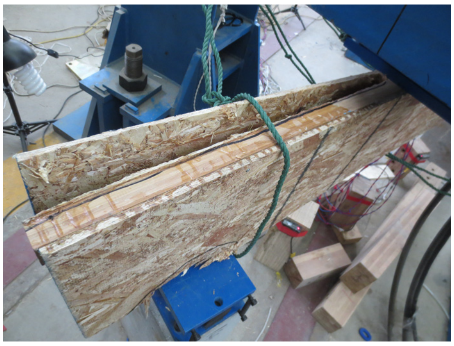
(b) BI7-B12

Fig. 3. Load- displacement curves.

Observed failure modes in specimens were different depending on the shear span ratio and stiffeners. Three typical failure modes were recorded, including web shear failure, local web buckling and delamination of OSB from flanges. As shown in Fig. 4(a), tested specimens with shear span ratio less than two, web shear failure was recorded at the mid-span of the joists. The graph in Fig. 4(b) illustrated the local web buckling for specimens without stiffeners. Nonetheless, failures in which the nails pulled through the OSB panels or fracture occurred, but was seldom investigated. When reaching to 50 percent of the ultimate load, the specimens with shear span ratio more than two began to twist and sawdust dropped from the web-flange connection. Although no visual damage could be observed at this moment, it was clear that the connections were damaged slightly. As shown in Fig. 4(c), once the joists reached the ultimate strength, the OSB separated from the flanges suddenly and nails were pulled out or sheared off. Surprisingly, unlike the sudden fracture flange failures of the wood joist [13, 17], the LBL flanges of composite joists in this study remained intact, which was extremely important to protect dwellers from injury or damage.

(a) web shear failure

(b) Local buckling



(c) Delamination of OSB in flanges
Fig. 4. Typical failure modes.

3.2 Strength and bending stiffness

It was showed that the strength of composite joists affected by the considered variables in the tests. The main test results of the specimens were presented in Table 2. Observed results revealed that the shear span ratio affected the strength of the joists, and the strength decreased with increasing shear span ratio. However, the effect of the stiffeners has more significant influence on the capacity of specimens than that of the shear span ratio. The local buckling performance of the web could be improved by the stiffeners, therefore, the load carrying capacity and displacement corresponding to ultimate load of specimens was significantly increased by about 16.5% and 3.6% respectively. According to the current Chinese code for design of timber structures (GB 50005-2003), the mid-span deflection of the wood beam at serviceability limit states shall not exceed L/250, that is, the deflection limit of specimen in this study was 8 mm. Usually, the bearing capacity of wood I joists and bamboo beams at the serviceability limit state was only 30% of the ultimate limit states [15, 20-22]. However, for OSB webbed bamboo box shaped joists, the relative ratio was about 60%. Of course, the composite beam in my research was controlled by stiffness rather than strength.

Table.2 Experimental results

Specimens	P_{cr} (kN)	P_u (kN)	$P_{L/250}$ (kN)	D_u (mm)
WB1	23.77	55.53	44.41	10.21
WB2	21.48	52.79	35.83	12.14
WB3	20.23	50.58	30.34	13.60
WB4	19.85	48.53	27.88	14.51
WB5	18.72	41.55	21.42	15.12
WB6	16.71	37.81	18.25	15.74
WB7	33.64	65.28	47.76	10.98
WB8	30.08	62.12	38.73	12.73
WB9	28.47	58.86	35.24	14.02
WB10	27.86	55.67	30.72	14.72
WB11	22.91	47.84	24.75	15.38
WB12	21.20	44.74	21.47	16.44

Note: P_{cr} is the cracking load, P_u is ultimate load, $P_{L/250}$ is mid-span deflection value is $L/250$ corresponding to the vertical load value, D_u is displacement corresponding to the ultimate load.

Another important parameter, the initial bending stiffness, defined as the secant rigidity of load-displacement curves from $0.1P_u$ to $0.4P_u$. Fig.5 showed that the initial bending stiffness was improved by 13.1% with the presence of stiffeners. However, the bending stiffness decreased with the increase of shear span ratio.

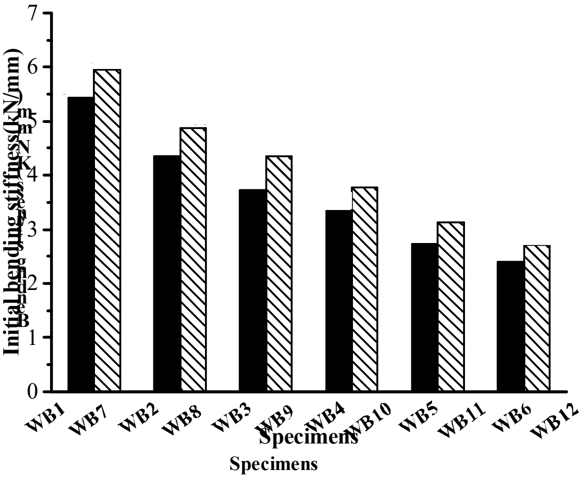


Fig.5. Bending stiffness.

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Conclusions

The OSB webbed bamboo box shaped joists were introduced and tested, which could greatly increase the economic efficiency and promote the development of bamboo/wood structure. The following conclusions can be drawn:

Three failures modes were recorded, including web shear failure, local buckling of the web and delamiation of OSB panel from the flange, depending on the shear span ratio and stiffeners. Once reaching ultimate bearing capacity, the specimen lost its bearing capacity suddenly, showing brittle failure characteristics. The composite joists did not collapse or break into two parts, which was conducive to protect dwellers from injury or damage.

The load carrying capacity of composite joists at serviceability limit states was about 60% of the ultimate limit states. The load carrying capacity of beams decreased with the increase of shear span ratio. The ultimate bearing capacity and the initial bending stiffness were improved increased by 16.5% and 13.1% respectively with the present of stiffeners.

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