MOMENT CAPACITY OF FURNITURE CORNER JOINTS MADE FROM BAMBOO-ORIENTED STRAND BOARD

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Abstract. As an alternative to wood, bamboo-oriented strand board (BOSB) demonstrates immense potential for applications in architecture and furniture. In this study, the corner joint performance of its L-type components under different failure modes and joint techniques was analyzed to evaluate the safety and stability of BOSB as structural materials. Results revealed that the component using wooden dowel pins exhibits the highest bending moment capacity, and the joint strength of BOSB is ~1.5 times greater than that of particleboard (PB), indicating that the BOSB performance meets product applications. Furthermore, the corner joint of the component in the compression failure mode was more likely to fail in comparison with the tensile failure mode, and the ultimate bending moment capacities for BOSB and PB in the tensile mode were 1.5 and 1.7 times those in the compression mode, respectively. Experimental results are thought to contribute to the understanding of a more reasonable structural design.

Keywords: Bamboo-oriented strand board, particleboard, joint technique, joint strength.

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INTRODUCTION

Oriented strand board (OSB) is a multilayer structure board prepared from wood strands by drying, sizing, oriented formation, and hot pressing, where the strands comprise uniformly thick, long, and narrow wood shavings obtained from small-diameter timber and branches by a special shaving method to ensure that its fiber orientation is consistent with the wood grain direction (Sumardi et al 2007). OSBs exhibit key applications in construction and furniture. In 2014, the "Alberta Cup" OSB Furniture Creative Design Competition of Nanjing Forestry University came into being. So far, it has been held for 5 yr. The competition, which is a collaboration between China and Canada, is "the only authorization of the Alberta Government of Canada to use the title overseas." Driven by this competition, the development of OSB board has become the focus of furniture industry. In addition, there have been cases of bamboo OSB (BOSB) board used in interior furniture in China, such as Dong Fang Gang International Wood Industry (Beijing) Co., Ltd., whose interior decoration drawings are described later (Fig 1). Therefore, OSB board will become an indispensable part of furniture manufacturing industry in the future. However, with the decrease in the total amount of forest resources, investigating alternatives to wood resources has been a direction for both industry and academia. In this regard, bamboo has been gradually attracting attention as one of the important perennial evergreen plants among nonwood resources. Bamboo is mainly distributed in the tropical, subtropical, and temperate (except Europe) regions from 46°N latitude to 47°S latitude (Tewari 1992; Williams et al 1994). Presently, more than 70 genera and 1200 species of bamboo are available worldwide (Scurlock et al 2000). As an alternative to wood, bamboo exhibits advantages of abundance and a short growth cycle. In addition, mature bamboo exhibits lower hygroscopic deformation as well as higher strength and density compared with wood. In addition, basic physical and mechanical properties can meet the requirements for industrial production; hence, bamboo can be used as a raw material for the production of BOSB, demonstrating immense potential for industrial production (Semple et al 2015).

To demonstrate the applicability of BOSB in architecture and furniture, a common L-shaped component using BOSB was designed, which was referred to as the common connection form of panel furniture components, and the bending moment capacities of the corner joint under different joint techniques and failure modes were investigated. As the corner joint is the weakest part of the panel furniture and building components, it considerably affects the safety and stability of the integral components. The scientific, rational design for corner joints plays a key role in the bearing capacity of furniture and building components (Eckelman 2003). Presently, several studies have examined the corner joints of furniture and building components. For instance, the ultimate bending moment of furniture corners under static compression and tension loading was examined, and the results revealed that the corner joint of a medium-density fiberboard is greater than that of a particleboard (PB, Kasal 2008;

Figure 1. Indoor furniture drawings made of oriented strand board.

Kasal et al 2008). Demirci et al (2011) have reported the highest ultimate bending moment for a trapezoidal pin joint constructed of plywood, whereas the lowest value was observed for a three-in-one connector constructed of PB. Meanwhile, the plywood composite structure can improve the bending moment bearing capacity of furniture corners (Yuksel et al 2015). Another study examined the corner joint performance of a melamine-surfaced particleboard (MCP) and melamine-surfaced fiberboard (MCF). With the increase in the number of wooden tenon and the distance of wooden tenon, the bending moment capacity of MCP and MCF significantly increased (Malkoçoğlu et al 2013). In addition, the effect of three edge-sealing materials (ie polyvinyl chloride, melamine, and veneer) on the strength of corner joints revealed that tensile stress strength is better than compressive stress strength for all L-type corner joint components (Tankut and Tankut 2010). In addition, for compressive stress and tensile stress experiments, the bending moment of furniture corner joint can meet public needs using a suitable raw material (Ozen et al 2014). All of these studies provide effective data supporting the optimal design for the corner joints of panel furniture and contribute to a safer, more stable corner joint design.

In addition, the property of materials is also an important factor affecting the performance of furniture. At present, most furniture on the market is made of melamine-faced particleboard and veneered particleboard. Compared with other materials, particleboard is cheap and easy to process. However, the shortcomings of common particleboard such as high density, easy moisture absorption deformation, large instantaneous elastic deformation, and serious creep problems lead to bending deformation of shelves made of particleboard furniture, which affects the use of furniture and overall aesthetics. Therefore, the development of new furniture materials has become the focus of the current problem. OSB board is a kind of structural material with high strength, good dimensional stability, and uniform material. It is also used in the field of furniture besides building materials. Demirel et al (2018) studied the transverse load of the nailed joint of OSB furniture directional shelf.

Hence, to promote the application of BOSBs in architecture and furniture, the corner joint performance must be examined. However, studies have revealed that for practical applications, in addition to the inherent characteristics of the material itself (such as density, strength, and dimensional stability), the type of the destructive form, fasteners, and its joint technique also affect its structural strength. Therefore, BOSB is used as the basic member of L-shaped components with different fasteners as well as loading failure modes (ie tension and compression modes) to examine its corner joint performance, aiming to provide effective data support for the furniture's practical application.

MATERIAL AND METHODS

Material

BOSB and PB specimens were provided by Yunnan Yongli FA Forestry Co., Ltd. (Yunnan, China). In the process of BOSB processing, 4-yr-old Longzhu from Yunnan Province was used as raw material and phenolic resin adhesive was used as adhesive, in which 25% of the adhesive was added. The conventional particleboard used in the experiments was commercially available (Ningguo Southeast Wood Co., Ltd., Ningguo, China). It is made of poplar particleboard and used urea–formaldehyde resin as adhesives. Among them, the amount of adhesives applied is 260-280 g/m^2. Because the density of common particleboard is low, to compare with BOSB board better, high-density particleboard is used in this study. Therefore, the density of particleboard is slightly higher. Table 1 summarizes the physical and mechanical properties of the BOSB

Table 1. Mechanical properties of different panels.

Panel type	Density (g/cm^3)	MC (%)	Modulus of elasticity (MPa)	Static bending strength (MPa)	Internal bond strength (MPa)
Bamboo-oriented strand board	0.8	12.71	12,811	107.76	2.72
Particleboard	0.7	9.59	3585.13	23.24	0.27

and PB (tested according to GB/T17657, 2013). The mechanical properties (mainly including the elastic modulus, static bending strength, and internal bond strength) of BOSB were superior to PB, which is mainly related to the BOSB internal structure. Figure 2 shows the L-type component structure, comprising the face and butt members. Dimensions of the BOSB (face member) and PB (butt member) were 270 × 150 × 18 mm and 270 × 132 × 18 mm, respectively. Meanwhile, the converse-spine nut joint, two-in-one connector, three-in-one connector, and wooden dowel pins were used as the fasteners for assembling L-type components. Figure 3 shows the dimensions of these fasteners.

Methods

Specimen preparation and processing. Figure 4 shows the position of the fasteners in the L-type component (assume that the pilot hole position is the backboard). A 32-mm system was used. In this article, gang drill is used to drill holes, so it is necessary to delineate the location of the hole manually in advance. Meanwhile, because the BOSB board is hard, it is easy to cause drill bit wear and even fracture when drilling, so it is necessary to predrill. In this experiment, dimension planning is carried out on the material surface in advance to determine the location and size of the guide hole, and then drilling with row drills. The aperture of the guide hole is 6.4 mm and the depth of the hole is 22.5 mm. In addition, a white latex layer was applied on the wooden dowel pin surface to facilitate fastening. The model number of white latex is PASCO wood glue-250 g, and the amount is 350-400 g/m^2. The solid content of white latex is 40.5% with a viscosity of 4.5-6.5 Pa·s. White latex was used as an adhesive in the study.

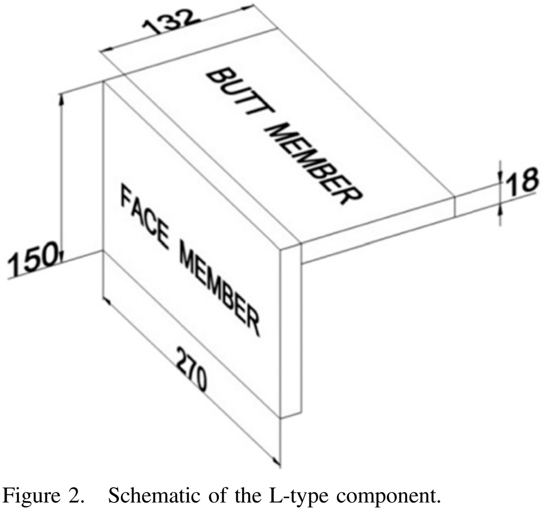

Figure 2. Schematic of the L-type component.

Figure 5 shows the two forms of force applied on the corner joints of the panel furniture (L-type component). The tension in Fig 5(a) tended to open the corner joint, whereas the compression in Fig 5(b) tended to close the corner joint. Both the stress methods can damage the corner joints of the components. Furthermore, the opening angle of the corner joint was measured using a protractor after breaking the specimen (Figs 6-9). To decrease external effects, the component was stored in a control room at 20 ± 2°C and an RH of 65 ± 3% to ensure that the MC is in equilibrium before the test (Küçüktüvek et al 2016). In addition, 80 specimens and five replicates for each treatment were examined using a computer-controlled universal test machine (WDW-100E, Jinan Shidai Shijin Testing Machine Group Co., Ltd., Jinan, China) and a loading speed of 10 mm/min.

Data processing. Bending moment capacities of the L-type component were calculated by the following equation (Küçüktüvek et al 2016):

$$M_{\mathrm{T}} = 0.5F_{\mathrm{t}} \times 0.5L_{\mathrm{t}}(\mathrm{Nm}) \quad (1)$$

$$M_{\mathrm{C}} = F_{\mathrm{c}} \times \left[\sqrt{}(150^2 - (0.5\mathrm{Lc})^2) - 25.456\right](\mathrm{Nm}) \quad (2)$$

where M_{T} and M_{C} represent the bending moment capacities under the tensile and compression loading, respectively. F_{t} and F_{c} represent the maximum values of the applied tension and compression forces, respectively; L_{t} and L_{c} are the arms of force under tension and compression, respectively, which were calculated by a triangle relationship. $L_{\mathrm{t}} = L_{\mathrm{c}} = 0.09334$ m. Collected data were statistically normalized using 19.0 SPSS software. The main statistical indexes were tested by the Levene Statistic to confirm the homogeneity

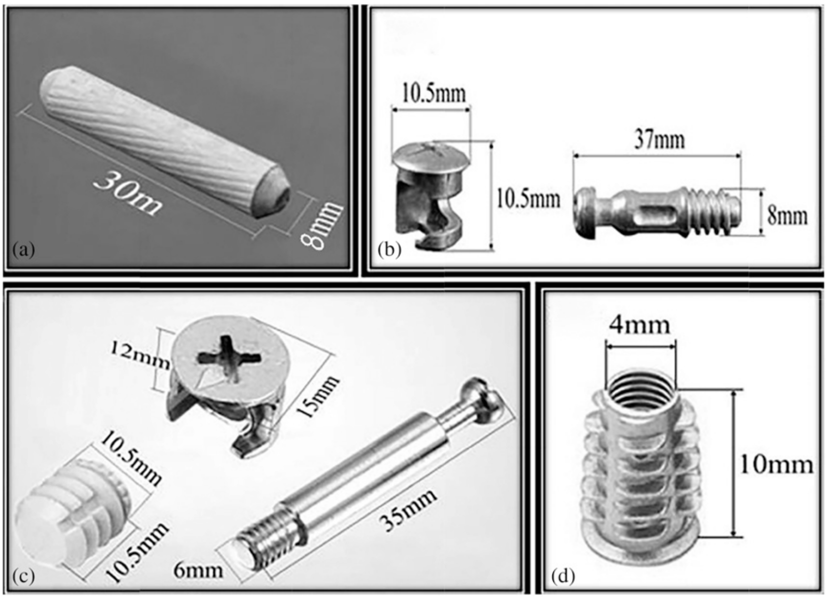

Figure 3. Fasteners used in the experiment: (a) wooden dowel pins, (b) two-in-one connector, (c) three-in-one connector, and (d) converse-spine nut joint.

of variance between groups (at a significance level of 0.05).

RESULTS AND DISCUSSION

Failure Modes of L-Type Components

The failure of fasteners in all components occurs between 120 and 350 s under the tension and compression loading; meanwhile, the corner joints of specimens were slowly opened and closed during loading. Finally, the face and backboard were separated at the corner joint. During the pullout of the fasteners, some of the wooden dowel pins collapsed inside, a part of the plate within the pilot hole edges was broken, and the PB suffered more damage than the BOSB plate. These results were in agreement with that reported previously (Sun et al 2015). This result suggested that the corner joint strength of BOSB is greater than that of PB.

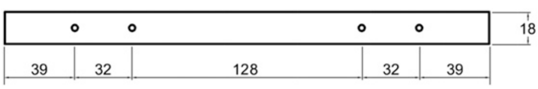

Figure 4. Pilot hole position in the butt member of the L-type component.

Figures 6 and 7 show the opening angles of the corner joints in BOSB and PB by different joint techniques at a maximum loading. The opening angle of the BOSB components decreased in the order of wooden dowel pins, converse-spine nut joint, three-in-one connector, and two-in-one connector. The opening angle size for the PB components decreased in the order of the wooden dowel pins, two-in-one connector, three-in-one connector, and converse-spine nut joint. The results shown in Figs 6 and 7 suggest that the L-type component with wooden dowel pins exhibits the largest deformation; the connection performance of the joint is the most unstable as the joint was subjected by external forces. Hence, this type of connection causes significant damage to furniture corners and affects the furniture performance.

Meanwhile, BOSB and PB components with the wooden dowel pins also exhibited the largest deformation in the compression test (Figs 8 and 9). In addition, the opening angle size revealed that the deformation of the corners in the PB component is greater than that in the BOSB component by the loading of an external force (Figs 6–9) and that BOSB exhibits a better nail

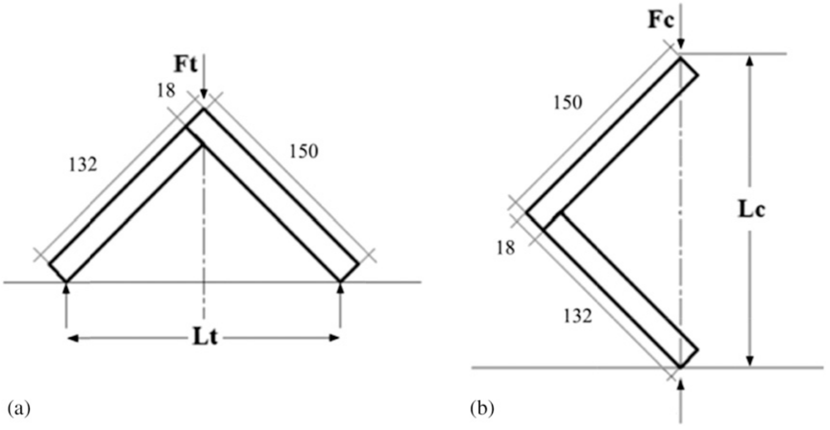

Figure 5. Schematic of the force load on the L-type component: (a) tension and (b) compression.

holding power and connection performance than traditional PB.

Bending Moment Capacities of the L-Type Corner Joints

Table 2 summarizes the ultimate bending moment capacities of BOSB and PB under different failure modes as well as joint techniques. Results revealed that the ultimate bending moment capacities of the L-type components (BOSB and PB) are the highest by using wooden dowel pins as the connecting members, whereas the mean bending moment capacities of BOSB are 50.87% and 48.99% greater than those of PB in the tension and compression modes, respectively. In addition, the bending moment capacities in the tension mode were 71.51% and 69.37% greater than those in the compression mode by using wooden dowel pins as the fasteners in the BOSB and PB components, respectively. However, by using the two-in-one connector in the BOSB component and the converse-spine nut joint in the PB component, the bending moment capacities in the compression mode were slightly greater than those in the tension mode.

To analyze the significance of differences in the bending moment capacities of the L-type components under different panel types and joint techniques, analysis of variance was performed (Table 3). The significance level was 0.0; these results revealed a significant difference in bending moment capacity of the component with different panel types and joint techniques. Furthermore, the interaction of the panel type and joint technique also exhibited a significant difference, and these results were in agreement with that of a previously reported study (Küçüktüvek et al 2016). In addition, this result further revealed a difference in the corner joint performance between BOSB and PB, and the selection of an

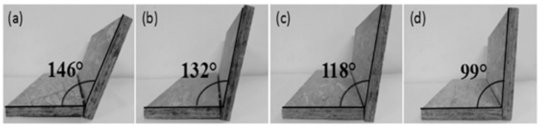

Figure 6. Opening angle of the corner joint in bamboo-oriented strand board by different joint techniques for the tension test, (a) wooden dowel pins, (b) converse-spine nut joint, (c) three-in-one connector, and (d) two-in-one connector (the opening angle size gradually decreases from [a] to [d]).

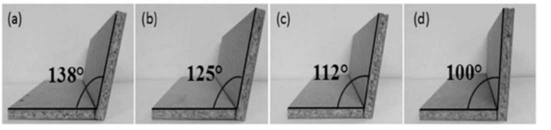

Figure 7. Opening angle of the corner joint in particleboard by different joint techniques for the tension test, (a) wooden dowel pins, (b) two-in-one connector, (c) three-in-one connector, and (d) converse-spine nut joint (the opening angle size gradually decreases from [a] to [d]).

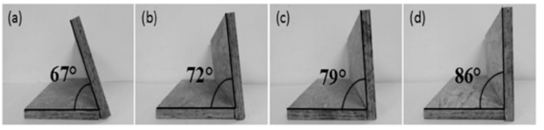

Figure 8. Opening angle of the corner joint in bamboo-oriented strand board by different joint techniques for the compression test, (a) wooden dowel pins, (b) two-in-one connector, (c) converse-spine nut joint, and (d) three-in-one connector (the opening angle size gradually increases from [a] to [d]).

appropriate panel type and joint technique considerably affects the performance of the furniture and building components, and studies reporting this difference will help promote the development of this industry.

Comparison of the Bending Moment Capacities between the Tension and Compression Failure Modes

Table 4 shows the ultimate bending moment capacities of the L-type components with different joint techniques in the tension and compression modes (regardless of the panel type). Results revealed that different joint techniques significantly affect the ultimate bending moment capacities, and the ultimate bending moment capacities in the tension mode are typically greater than those in the compression mode. Moreover, irrespective of the tensile or compression failure mode, the L-type component forming a joint with the wooden dowel pins exhibited the maximum bending moments capacities, whereas the component with the three-in-one connector exhibited the minimum values, probably because the nylon nut of the three-in-one connector cannot be well inserted into the

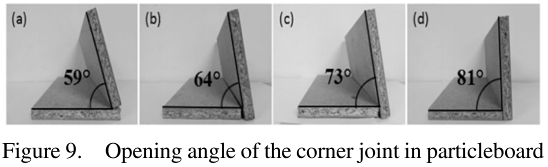

Figure 9. Opening angle of the corner joint in particleboard by different joint techniques for the compression test, (a) wooden dowel pins, (b) converse-spine nut joint, (c) three-in-one connector, and (d) two-in-one connector (the opening angle size gradually increases from [a] to [d]).

Table 2. Limit bending moment of BOSB and PB under different failure modes as well as joint techniques.

Panel type	Failure mode	Joint technique	Mean squares (Nm)	SD
BOSB	Tension	Converse-spine nut joint	36.759	1.947
		Two-in-one connector	20.212	3.277
		Three-in-one connector	21.520	0.582
		Wooden dowel pins	43.018	1.956
	Compression	Converse-spine nut joint	19.058	1.230
		Two-in-one connector	21.880	1.090
		Three-in-one connector	13.640	1.187
		Wooden dowel pins	25.082	1.819
PB	Tension	Converse-spine nut joint	10.502	1.270
		Two-in-one connector	22.204	0.434
		Three-in-one connector	17.158	1.538
		Wooden dowel pins	28.514	3.111
	Compression	Converse-spine nut joint	10.916	0.930
		Two-in-one connector	8.270	0.822
		Three-in-one connector	10.600	0.180
		Wooden dowel pins	16.835	0.743

BOSB, bamboo-oriented strand board; PB, particleboard.

panel, thereby possibly loosening the nut of the connector by the application of an external force; hence, the nut can be easily pulled out, and the joint strength is affected (Sun et al 2015). However, for the components using wooden dowel pins, the connection was tighter; the load along the corner was effectively dispersed; and the stress concentration was weakened, thereby increasing the bearing capacity of the components.

Table 5 shows the ultimate bending moment capacities of the BOSB and PB components in the tension and compression failure modes (regardless of the joint technique). Results revealed that the ultimate bending moment capacities of the

Table 3. Summary of the ANOVA results for tension and compression tests.

Source	Sum of squares	Degrees of freedom	Mean squares	*F*-value	Prob. (Sig)
ANOVA for tension test results					
Panel type	934.927	1	934.927	62.716	0.0
Joint technique	1504.286	3	501.429	33.636	0.0
Panel type × joint technique	1016.619	3	338.873	22.732	0.0
Error	477.037	32	14.907	—	—
Total	2932.869	39	—	—	—
ANOVA for compression test results					
Panel type	605.984	1	605.984	117.999	0.0
Joint technique	425.428	3	141.809	27.613	0.0
Panel type × joint technique	163.511	3	54.504	10.613	0.0
Error	164.337	32	5.136	—	—
Total	1359.260	39	—	—	—

BOSB components are 1.6 times greater than those of the PB component irrespective of the tension or compression failure mode. The ultimate bending moment capacities of the BOSB and PB components in the tension failure mode were ~1.5 times those in the compression failure mode. In other words, the internal structure performance of BOSB is better than traditional PB, mainly related to the fact that the BOSB is formed from narrow bamboo shavings via directional orientated paving, whereas traditional PB shavings are randomly paved and processed, leading to the nonuniform distribution of the material density across the cross-section. Hence, the processing technology of BOSB avoids the unevenness of the panel's internal structure caused by the random paving of shavings, further confirming the mechanical properties of BOSB. Hence, the ultimate bending moment capacities of the BOSB components are always greater than those of PB when the components are subjected to different failure forces.

CONCLUSIONS

In this study, the joint strength of BOSB and PB in the L-type components under tension and compression forces as well as the resistance to the deformation of BOSB in the L-type components by using different fasteners are investigated. Experimental results are expected to provide data support for the practical applications of BOSB in furniture and construction. The following conclusions were obtained.

1. The destruction of the corner joints in the L-type components is mainly manifested as the failure of the fasteners during the application of a large external force, eventually causing the fasteners to pull out from the panel members and affecting the safety and stability of the components. Finally, the overall service life of furniture or building components is reduced.
2. Different joint techniques and loading failure modes significantly affect the corner joint performance of the L-type component. The maximum values for the ultimate bending

Table 4. Ultimate bending moment capacities of the component with various joint techniques under different failure modes.

Failure mode	Joint technique	Mean squares (Nm)	SD	95% confidence interval for mean	
				Lower bound	Upper bound
Tension	Converse-spine nut joint	22.172	13.146	19.664	24.639
	Two-in-one connector	21.208	2.541	18.036	23.010
	Three-in-one connector	19.097	2.483	16.036	21.011
	Wooden dowel pins	35.766	7.703	31.760	36.734
Compression	Converse-spine nut joint	14.534	4.186	13.061	15.981
	Two-in-one connector	14.319	6.829	13.160	16.080
	Three-in-one connector	11.839	1.741	9.761	12.681
	Wooden dowel pins	21.417	4.345	18.831	21.751

Table 5. Ultimate bending moment capacities of BOSB and PB under different failure modes.

Failure mode	Panel type	Mean squares (Nm)	Standard deviation	95% confidence interval for mean	
				Lower bound	Upper bound
Tension	BOSB	29.773	10.561	26.937	30.455
	PB	18.954	6.833	17.268	30.785
Compression	BOSB	20.219	4.477	18.023	20.088
	PB	11.426	3.170	10.239	12.303

BOSB, bamboo-oriented strand board; PB, particleboard.

moment capacity are obtained for the components connected by wooden dowel pins via the application of external forces (tensile and compression) on the L-type components, revealing that the wooden dowel pins should be used for components with high stress and firmness requirements. In addition, the ultimate bending moment capacities of BOSB and PB in the tensile mode are 1.5 and 1.7 times those in the compression mode, respectively, indicating that the corner joint of the component is more susceptible to failure in the compression mode.

3. Significant differences in the corner joint performance of the various panels are observed. The joint strength of BOSB is ~1.6 times greater than that of PB when the components are subjected to a failure force (tension or compression), mainly because the fiber arrangement in OSB is more even and ordered compared with PB. Therefore, for the furniture manufacturing industry that prioritizes the use of PB, the mechanical properties of BOSB completely satisfy the actual application requirements.

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REFERENCES

Demirci S, Efe H, Kasal A, Imrzi HO, Ozen E (2011) The moment capacity of disassembled "L" type furniture corner joints produced with various connection elements. Kastamonu Univ J For Fac 11(2):138-145.

Demirel S, Tor O, Yu X, Zhang J (2018) Lateral loads of stapled-glued surface-to-surface joints in oriented strandboard for furniture. Wood Fiber Sci 50(3):1-11.

Eckelman CA (2003) Textbook of product engineering and strength design of furniture. Purdue University, West Lafayette, IN. Pages 65-67.

Kasal A (2008) Effect of the number of screws and screw size on moment capacity of furniture corner joints in case construction. For Prod J 58(6):36-44.

Kasal A, Erdil YZ, Zhang J, Efe H, Avci E (2008) Estimation equations for moment resistances of L-type screw corner joints in case goods furniture. For Prod J 58(9):21-27.

Küçüktüvek M, Kasal A, Kuşkun T, Erdil YZ (2016) Utilizing poppy husk-based particleboards as an alternative material in case furniture construction. BioResources 12(1):839-852.

Malkoçoğlu A, Yerlikaya NÇ, Cakirogluet FL (2013) Effects of number and distance between dowels of ready-to-assemble furniture on bending moment resistance of corner joints. Wood Res 58(4):671-680.

Ozen E, Goktas O, Kasal A, Efe H, Demirci S (2014) Bending moment capacity of l-type furniture corner joints constructed of particleboard produced from vine pruning residues. Wood Res 59(2):313-322.

Scurlock JMO, Dayton DC, Hames B (2000) Bamboo: An overlooked biomass resource. Biomass Bioenergy 19(4): 229-244.

Semple KE, Zhang PK, Smith GD (2015) Hybrid oriented strand boards made from Moso bamboo (*Phyllostachys pubescens* Mazel) and Aspen (*Populus tremuloides* Michx.): Species-separated three-layer boards. Eur J Wood Wood Prod 73(4):527-536.

Standardization Administration of the People's Republic of China (2013) Test methods GB/T17657. Test methods for evaluating the properties of wood-based panels and surface decorated wood-based panels. Standardization Administration of the People's Republic of China, Beijing, China.

Sumardi I, Ono K, Suzuki S (2007) Effect of board density and layer structure on the mechanical properties of bamboo oriented strand board. J Wood Sci 53(6):510-515.

Sun J, Li N, Xie ZH (2015) Research on the *Eucalyptus* laminated veneer lumber furniture's joint strength of "L-components." China For Prod Ind 1:016.

Tankut AN, Tankut N (2010) Evaluation the effects of edge banding type and thickness on the strength of corner joints in case-type furniture. Mater Des 31(6):2956-2963.

Tewari DN (1992) A monograph on bamboo. International book distributors, Dehra Dun, India.

Williams JT, Dransfield J, Ganapathy PM, Liese W, Nor SM (1994) Research needs for bamboo and rattan to the year 2000. INBAR, New Delhi, India.

Yuksel M, Kasal A, Erdil YZ, Acar M, Kuskun T (2015) Effects of the panel and fastener type on bending moment capacity of L-type joints for furniture cases. Ligno 11(4): 426-444.