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Considering lateral loads of multi-stapled and glued alder wood joints connected with two different gusset-plates

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Keywords

staple
gusset-plate
wood joint
glue
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Abstract

Lateral shear strengths of the glued and multi-stapled (2, 4, 6, 8) alder joint attached with two different gusset-plates (plywood and beech) were investigated. Results indicated that the glued and multi-stapled joints with plywood gusset-plate indicated increasing trend from 2 staple to 6 staple for each 2 staple increments, however; the ones with beech gusset-plate indicated the highest strength in the joints with glue and 2 staples. The joints with plywood gusset-plate mostly failed gusset-plate bending or shearing between layers. On the other hand, the joints with beech wood gusset-plate failed with the mode of staple legs withdrawn from main members and staple legs bent and materials underneath of staple legs crushed in main and side members. Additionally, this study revealed that using plywood gusset-plate in glued-multistapled did not show the exact strength of the joints and showed different shaped of load-displacement curves compared to the ones with beech gusset-plates. The glued and multistapled joints with beech gusset-plate showed a load-displacement curve in a manner for each 2 staple increment for all furniture joints.

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Introduction

Alder wood has been recently widely used in the Turkish furniture manufacturing industry. The increased use of alder wood as upholstery furniture frame stock is due to several of its inherent advantages such as being very common wood specie in Blacksea region of Türkiye and being of the fast growing wood specie in Türkiye compared to beech wood which is one the most popular wood material in Turkish furniture industry, especially in sofa frame making.

Staple-connected, gusset-plate joints were considered in this study because of their wide use in upholstered furniture frame manufacturing. The gusset-plate joints, connected with power-driven multi-staples and glue, are commonly used at very critical joints in sofa frames. A gusset-plate joint is a point in a frame structure where two members are connected with plates fastened to the member sides with glue and fasteners driven perpendicularly through the plates into the member faces (Demirel, 2012).

The strength design of upholstered furniture frames constructed of wood needs fundamental information on static lateral resistances of joints with various configurations (Zhang and Maupin, 2004) such as different type of component like gusset-plate and also connected with different types of fasteners like staple. Since staples are very practical for attaching furniture parts, they are the most commonly used mechanical fasteners to attach structural members in upholstered furniture frames (Erdil et al., 2003; Demirel et al., 2013; 2016; Demirel and Zhang, 2014; 2018). Limited information exists on the lateral resistance of staple-connected joints in alder wood for furniture frame construction, especially about the data related to the lateral resistance of multi-staple connected joints.

The main objective of this study is to investigate the lateral shear resistances of gusset-plate joints. The specific objectives were to investigate the effect of using different gusset-plate materials on the lateral shear resistances of the multi-staples and glued wood joints and investigate the manner of load-displacement curves of the joint based on staple increment.

Methods and materials

Materials

The general view of the joint samples for this study is shown in Fig. 1. The specimen consisted of two principal structural members, a main member (base member) and

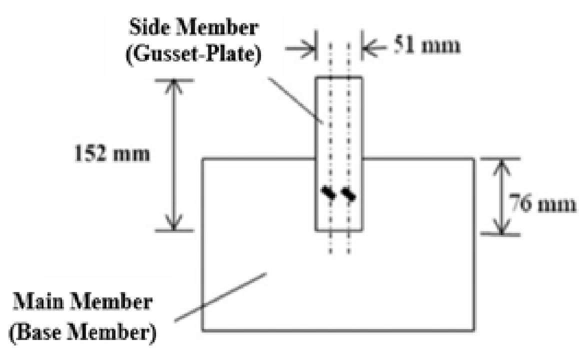

Fig. 1. General view of a glued gusset-plate wood joint connected with multi-stapled and glue

a side member (gusset-plate), assembled together by multi-staple and glue. The main member was alder. The gusset-plate were produced from pine plywood and beech wood. 40 multi-stapled and glued joints prepared with plywood gusset-plate while 40 of them prepared with beech gusset-plate.

Methods

Joint specimen preparation and testing

Before joint preparation, all cut base member and gusset-plates were conditioned in an equilibrium MC chamber controlled at 25 ±5ºC temperature and 45 ±5 percent relative humidity. In the joint attactment, glue was applied member then staples were driven to them. All tests were carried out right after 48 hours for glue curing between the joints members in the laboratory conditions (23 ±2ºC and 50 ±5%).

Fig. 2 illustrates the test setup for measuring the lateral shear resistance of joints. All joints were tested on a Universal MTS Criterion 45 testing machine at a loading rate of 2,5 mm/min in reference with ASTM D 1761 (ASTM 2010). In joint preparation, the joint sample was first clamped in Universal MTS machine and loading head

Fig. 2. Test setup for measuring the lateral shear resistance of joints

was calibrated before loading. After the loading initiated, ultimate lateral shear load, load-displacement curves, and specimen failure modes were recorded.

Results and discussion

Load-displacement curve

Figures 3, 4, 5, and 6 indicate the load-displacement curves of the glued and multi-staple joints connected with plywood gusset-plates. As shown in the figures, only one peak was observed in each graph no matter which staple number was used. Additionally, no clear trend was observed among the load-displacement curves based on the staple number of 2, 4, 6, and 8.

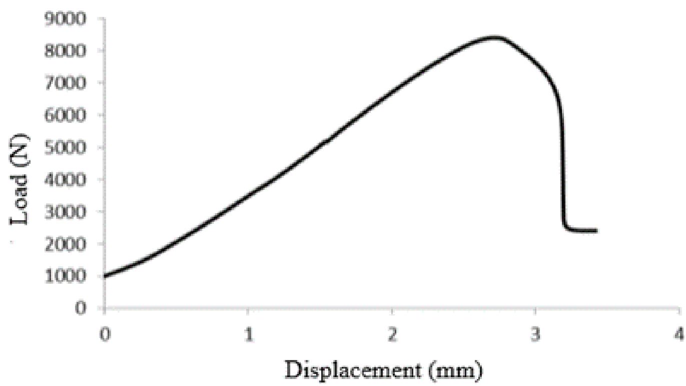

Fig. 3. 2 stapled and glued joint with plywood gusset-plate

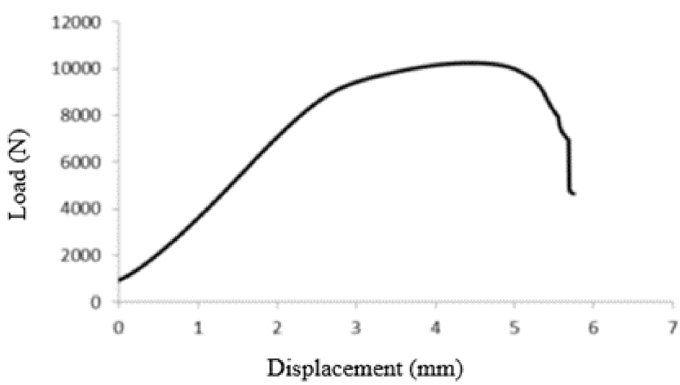

Fig. 4. 4 stapled and glued joint with plywood gusset-plate

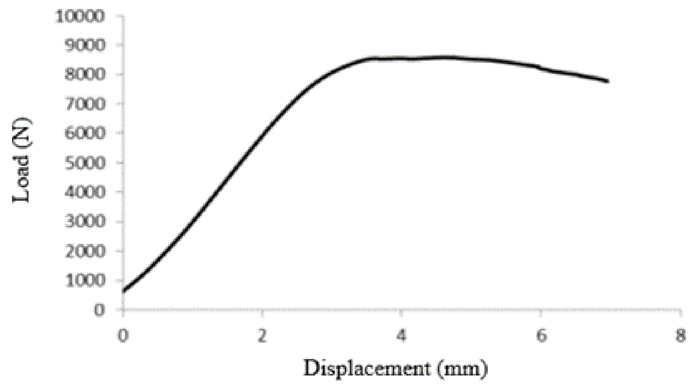

Fig. 5. 6 stapled and glued joint with plywood gusset-plate

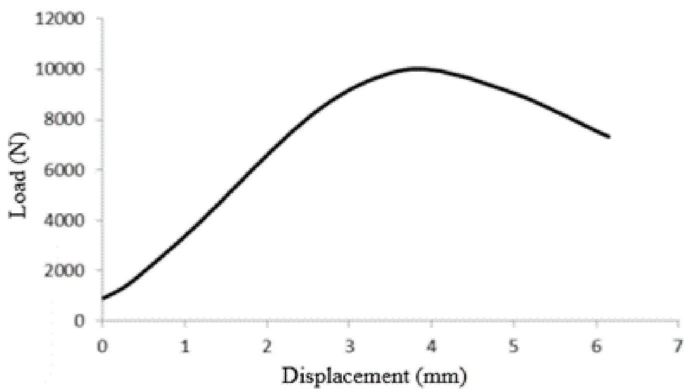

Fig. 6. 8 stapled and glued joint with plywood gusset-plate

Table 1 indicates the average lateral shear resistances of multi-stapled and glued joints connected with plywood gusset-plates. Based on the table, that the glued-multistapled joints with plywood gusset-plate indicated increasing trend from 2 staple to 6 staple for each 2 staple increment. Increasing number of staple increased the strength of the joint (Demirel et al., 2013; Demirel and Zhang, 2014; Demirel et al., 2016; 2018).

Figs 7, 8, 9, and 10 indicate the load-displacement curves of glued and multistapled joints connected with plywood gusset-plates. Figure 7 has only one peak, on the other hand Figures 8, 9 and 10 have two peaks which belong glue and staple connections separately and successively.

Table 1. Lateral shear resistances of multi-stapled and glued joints connected with plywood gusset-plates

Number of sample	Number of staple			
	2	4	6	8
1	9 338	10 191	9 655	9 660
2	8 312	9 387	10 593	9 523
3	8 116	8 305	9 135	9 651
4	7 648	10 244	7 744	10 140
5	10 374	11 176	11 162	9 367
6	6 991	8 334	9 680	9 740
7	8 689	9 075	9 669	8 478
8	7 928	8 300	10 818	7 423
9	9 227	11 607	11 048	10 014
10	6 694	10 122	8 573	8 851
Average	8 332	9 674	9 808	9 285

A sharp curve after maximum point is very common behavior for the joints with glue connection (Demirel and Kalayci, 2019). Demirel 2012 indicated a similar curve for OSB based furniture joint connected with only glue. In current study, Fig. 7, 8, 9 and 10 shows a sharp behavior beloging to glue behaviour.

Based on the figures, load-displacement curves indicates a manner. To explain this manner more clearly, it may be said that the 2 stapled-glued joint with beech gusset-plate indicated only glue connection by showing only one peak while 4, 6, and 8 stapled-glued joint with beech gusset-plate indicated glue and staple connection by showing two succesive peaks. Especially, the second peak of the joint with 8 stapled-glued is higher and stronger compared to the others.

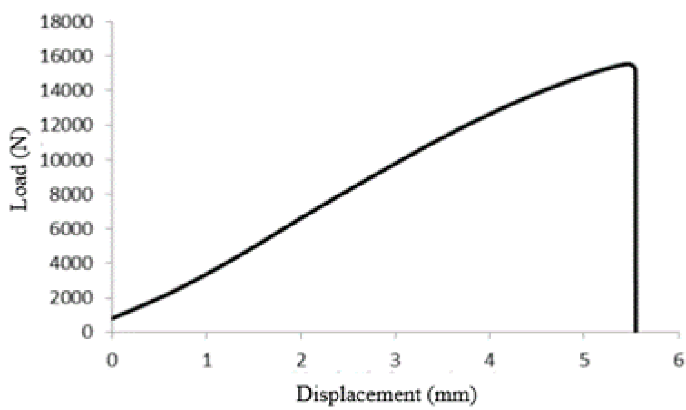

Fig. 7. 2 stapled-glued joint with beech gusset-plate

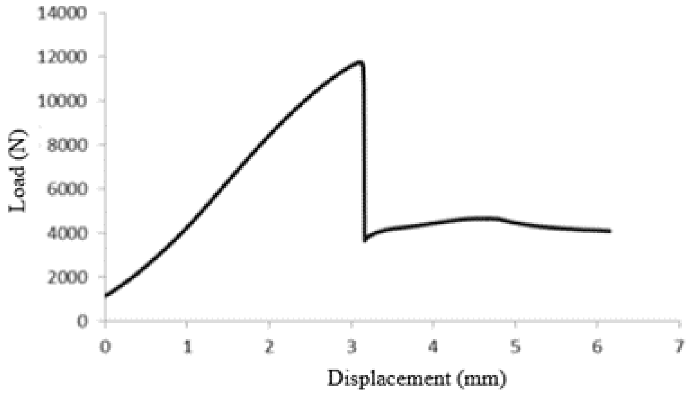

Fig. 8. 4 stapled-glued joint with beech gusset-plate

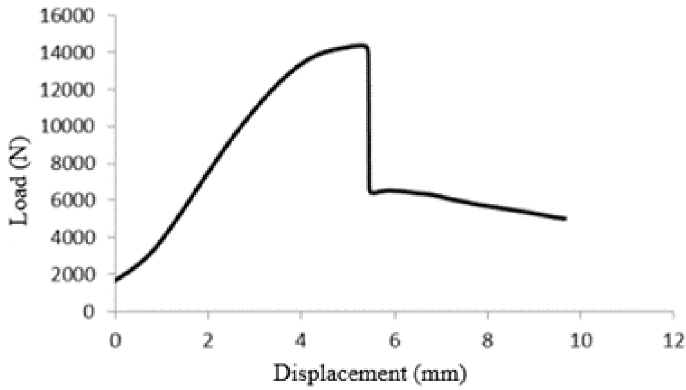

Fig. 9. 6 stapled-glued joint with beech gusset-plate

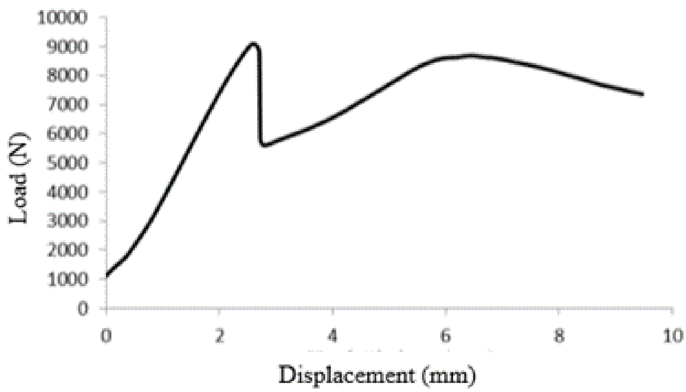

Fig. 10. 8 stapled-glued joint with beech gusset-plate

Table 2 indicates average lateral shear resistances of multi-stapled and glued joints connected with beech gusset-plates. Results indicated that the multi-stapled and glued joints with beech wood gusset-plate indicated highest strength in the joints with 2 staples. This could be explained with using more than 2 staples causes weaker wood and glue structure.

Table 2. Lateral shear resistances of multi-stapled and glued joints connected with beech gusset-plates

Number of sample	Number of staple			
	2	4	6	8
1	11 243	15 143	12 174	14 165
2	15 546	11 208	8 823	10 388
3	14 056	12 468	12 458	14 060
4	13 877	12 828	11 436	13 215
5	20 870	7 298	11 361	9 093
6	16 583	11 766	14 317	11 439
7	12 138	14 956	14 382	15 154
8	9 041	12 087	13 556	14 156
9	14 916	15 084	12 246	12 315
10	15 342	13 414	12 161	13 116
Average	14 361	12 625	12 292	12 710

Failure mode

Figure 11 shows failure modes of glued and multi-stapled joints connected with plywood gusset plates. Based on the results, 24 out of 40 joints with plywood gusset-plate failed with gusset-plate layer shear, 9 out of 40 joints failed with separation between members, and 7 out of 40 joints failed with main member rupture.

Figure 12 shows failure modes of glued and multi-stapled joints connected with beech gusset plates. Based on the results, 39 out of 40 joints connected with beech gusset-plate failed with separation between members while only one joint failed with main member rupture. This result indicated that using beech gusset-plate allows to see real strehgt of the joints because beech gusset-plate did not fail itself compared to plywood gusset-plate, which showed shear among the layers. Demirel and Kalayci, 2019 found that a typical load-displacement curve of the only glue connected joints with pine plywood gusset plate did not show a sharp behavior after ultimate point. They stated that this could be a reason of failure mode because most of the joints with plywood gusset-plate failed with shear among gusset plate layers. This type of failure did not allow to show a sharp behavior after ultimate point.

Fig. 11. Failure modes of the joints: a) shear among the layers of gusset-plate; b) seperation from connection points; c) main member rupture

Fig. 12. Failure modes of the joints: a) seperation from connection points; b) main member rupture

Conclusions

The alder wood joints constructed with multi-staple (2, 4, 6, 8) and gusset-plates (pine plywood and beech wood) were mechanically tested, their lateral shear resistances were investigated and compared.

Results indicated that the glued-multistapled joints with plywood gusset-plate indicated increasing trend in strength from 2 staples to 6 staples for each 2 staple increment, however; the ones with beech gusset-plate indicated highest strength in the joints with glue and 2 staples.

The joints with plywood gusset-plate mostly failed gusset-plate shearing between layers. On the other hand, the joints with beech wood gusset-plate failed with separation between the members.

Additionally, this study revealed that using plywood gusset-plate in glued-multistapled did not show the exact strength of the joints and showed different shaped of load-displacement curves compared to the ones with beech gusset-plates. The glued-multistapled joints with beech gusset-plate showed load-displacement curve in a manner for each 2 staple increment for all furniture joints.

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