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Research article

Experimental analysis of laminated particleboard case-type furniture reinforced by polymer composite layer

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Abstract

In this study, the effects of reinforced corner joints by polymer composite layer in case-type furniture have been analyzed experimentally and statistically in laminated particleboard material. The failure loads of corner joints have been analyzed experimentally under compression and tension moments. These joint types are dowel (D), dowel+fabric from the outside (DCO), dowel+fabric from the inside (DCI), dowel+fabric from the outside and inside (DCOI), and dowel+fabric from the edge (DCE). The test results were analyzed statistically by Weibull distribution. Results show that the failure load takes its highest value in the DCOI case both for the test results and for 95% reliability under Weibull distribution. On the other hand, it takes its lowest value in the D case. Reinforced corner joints are more strength than unreinforced corner joints. In addition, the 95% reliability value for each corner joint configuration is approximately equivalent to the 0.52 value of the failure load.

Keywords: Composites, fabrics, reinforced, failure analysis, case-type furniture, corner joint

1. Introduction

In contemporary building technologies, glass-fiber fabric is used to increase the strength of beams, columns, plastic pipes and wood tubes that are made of materials such as concrete, wood and plastic. According to the studies, it is also observed that the strength of the beams, columns, plastic pipes and wood tubes that are reinforced with glass-fiber has increased more than unreinforced. A question is raised as a result of this information: Can using glass-fiber fabric increase the strength of furniture corner joints, too?

As already known, just as in construction technology, in furniture technology one of the functional roles of furniture is to carry loads and also to make the parts that carry loads more resistant against heavy weights. In furniture construction technology too, the weakest points against heavy weights are indicated as the corner joints of the furniture. Therefore, to strengthen furniture corner joints have a great deal of importance. If the resistance provided by the glass-fiber fabric in construction technology enables an increase in the same proportion in furniture corner joints, this will be a significant landmark in the furniture sector.

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Researchers have conducted several studies related to glass fiber. In the study by Ghassan [1] concluded that addition of FRP has significant impact on strength and behavior of structural wooden elements. He also concluded that testing results revealed a 14% increase in compression, 18% increase in bending, and 10% increase in tension. Heiduschke *et al*. [2] concluded that when compared to the unreinforced columns, the load-carrying capacity of the reinforced columns increased by factors of 1.46. Stevens and Criner [3] determined that the FRP-reinforced beams are stronger than non-reinforced glulam beams because the reinforcement absorbs some of the most damaging tension stresses endured by conventional wooden glulam beams. In the study by Rowlands *et al.* [4], they concluded that glass-fiber reinforced Douglas fir (18% glass by volume) produced a 40% stiffness enhancement and doubled the strength over similar unreinforced wood. Heiduschke and Haller [5] concluded that when compared to unreinforced tubes, the ultimate load of FRP reinforced tubes is increased by about 60%. Cabrero *et al*. [6] explained that the failure response stress for the corresponding unreinforced tube was also depicted; a clear improvement of the performance of the tube in the material controlled area was noticed; and the strength of the unreinforced material was about 2/3 of the reinforced. Windorski *et al*. [7] concluded that the ultimate strength of a three-layer reinforced connection was 33% greater than the unreinforced connection for parallel-to-grain loading and more than 100% for perpendicular to grain loading.

Researchers have conducted several studies related to the dowel joints. Norvydas *et al*. [8] determined that the weakest place of doweled joints in case furniture is the edge member, thus 98% of all joints fail due to its fracture. Liu and Eckelman [9] concluded that probably because of the adhesive added to the joint area, corner joints constructed with dowels could exceed the bending strength of the board itself. Tankut and Tankut [10] found that samples with edge banding gave higher diagonal tension and compression strength than control samples. In compression tests of control specimens, they concluded that the edge of the face member split within its thickness and the split was continuous, parallel and very close to the glue line throughout the length of the specimens. In the tension test, they concluded that butt members split inside the corner of the joints near the glue line and linearly continuously throughout the length of specimens.

Many fastener components were examined for the effect of the corner joints in case-type furniture by many researchers. On the other hand, glass-fiber fabric has been examined by many researchers. But, the effects of reinforcing available corner joining methods with glass-fiber fabric in terms of the strengthening of case-type furniture products are not known for wood-based materials. The reinforcement with fabric of corner joints in case-type furniture is a new research topic. The study by Yerlikaya and Aktas [11], and Yerlikaya [12] in this topic, the failure loads of L-type corner joints in case-type furniture were analyzed experimentally and statistically in laminated medium-density fiberboard material [11], and laminated particleboard [12]. They used dowel, minifix, and glass-fiber fabric as fastener components. They were analyzed statistically the test results by Weibull distribution to obtain a 95% reliability level for failure load. They concluded that the failure load takes its highest value in the dowel+minifix+composite layer (DMC) case for both average values of the test results and for 95% reliability under Weibull distribution, while it takes its lowest value in the dowel (D) case.

All studies, which are related to the strength of case-type furniture, concluded by researchers are based on average failure load values. The reliability of these values isn't determined. The highest reliability of these values is approximately 50-55% and that is not reliable enough. That is not confidence. Average failure load values obtained with this reliability level lead to errors in point of failure load for corner joints in case-type furniture. Therefore, failure load values must be determined to a 95-99% reliability level in order to safely use manufactured furniture. To obtain failure loads at the 95-99% reliability level, Weibull distribution can be used. Yerlikaya and Aktas [11], and Yerlikaya [12] analyzed statistically the test results by Weibull distribution to obtain a 95% reliability level for failure load. They concluded that the 95% reliability value for each corner joint configuration is approximately equivalent to the 0.53 average value of the failure load [11], and the 0.52 average values of the failure load [12].

The aims of this study are (1) to determine the effects of diagonal compression and tension failure load behavior in different joints, which are reinforced with polymer composite layer (fabric), (2) to determine the effects of the fastener type, namely dowel (D), dowel+fabric from the outside (DCO), dowel+fabric from the inside (DCI), dowel+fabric from the outside and inside (DCOI), and dowel+fabric from the edge (DCE) on failure loads in L-type furniture corner joints, (3) to determine the effects of fabric on failure loads in L-type furniture corner joints constructed with a laminated particleboard (LPB), and (4) to statistically analyze, using Weibull distribution, the effects of failure loads in L-type furniture corner joints.

2. Materials and Methods

2.1. Materials

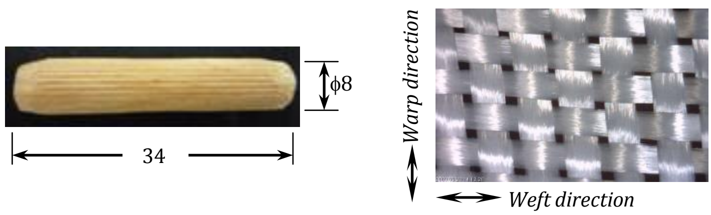
Eighteen-mm thick LPB was selected for this study. The panels were tested for moisture content (MC), specific gravity (SG), and modulus of elasticity (MOE). Properties of the LPB materials are given in Table 1. The tests were carried out according to ASTM D1037 [13] Standard.

Table 1
Average MC and mechanical properties of the LPB used in the test

MC (%)	SG	MOE (N/mm^2)
8.32	0.65	2838

MC: Moisture content, SG: Specific gravity, MOE: Modulus of elasticity

In this study, dowels and polymer composite layers (fabrics) were used as fastener components (Fig. 1). Multi-groove beech dowels 8 mm in diameter and 34 mm in length were used (Fig. 1a). Fabrics having 400 g/m^2 were used (Fig. 1b). The mechanical properties of the fabric were given in Table 2.



(a) (b)

Fig. 1 Fastener materials (a) Dowel and (b) Fabric (dimensions in mm)

Table 2
Mechanical properties of the polymer composite layer

E1 [GPa]	E2 [GPa]	G12 [GPa]	ν_{12}	Fiber [%]
28	28	7.2	0.23	60

Dowels were assembled with polyvinyl acetate (PVAc) adhesive. Fabrics were fastened with epoxy resin and hardener. The type of epoxy resin used in the matrix material was Bisphenol ACY-225 and the hardener was Anhydride HY-225. As a result of that the fiber volume fraction of the polymer composite layer was calculated approximately 60%.

2.2. Methods

2.2.1. Specimen Preparation

In order to enhance failure load of L-type joints, D, DCO, DCI, DCOI, and DCE corner joint methods were used. Five specimens were prepared and tested for every configuration. All the specimens were drilled according to drilling plans with a drilling machine (Three Lines Multi-Boring Machine BJK65) at the speed of 500 rpm (Fig. 2). Typical configuration of the specimens used in the tests is given in Fig. 3. In all the specimens, after only the dowel holes on both the butt and face member were glued with PVAc adhesive, dowels were driven into this glued hole for the butt member by a mould (Fig. 3a). Then, face and butt members were placed in conjunction. For the specimen using fabric joints, areas where the fabrics were to be placed were glued with a mixture of epoxy resin and hardener. Two layers of fabric were placed on these areas and epoxy applied (Fig. 3b, c, d and e). These specimens were left to dry for 2 days.

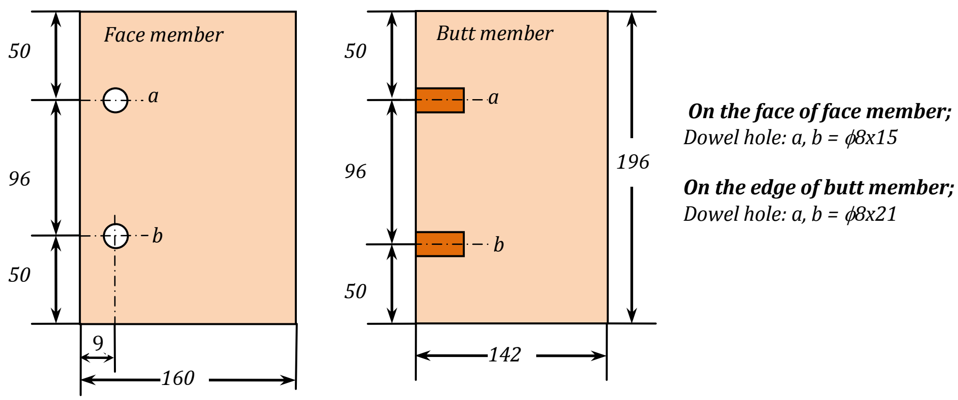


Fig. 2 Drilling plans of specimen (dimensions in mm)

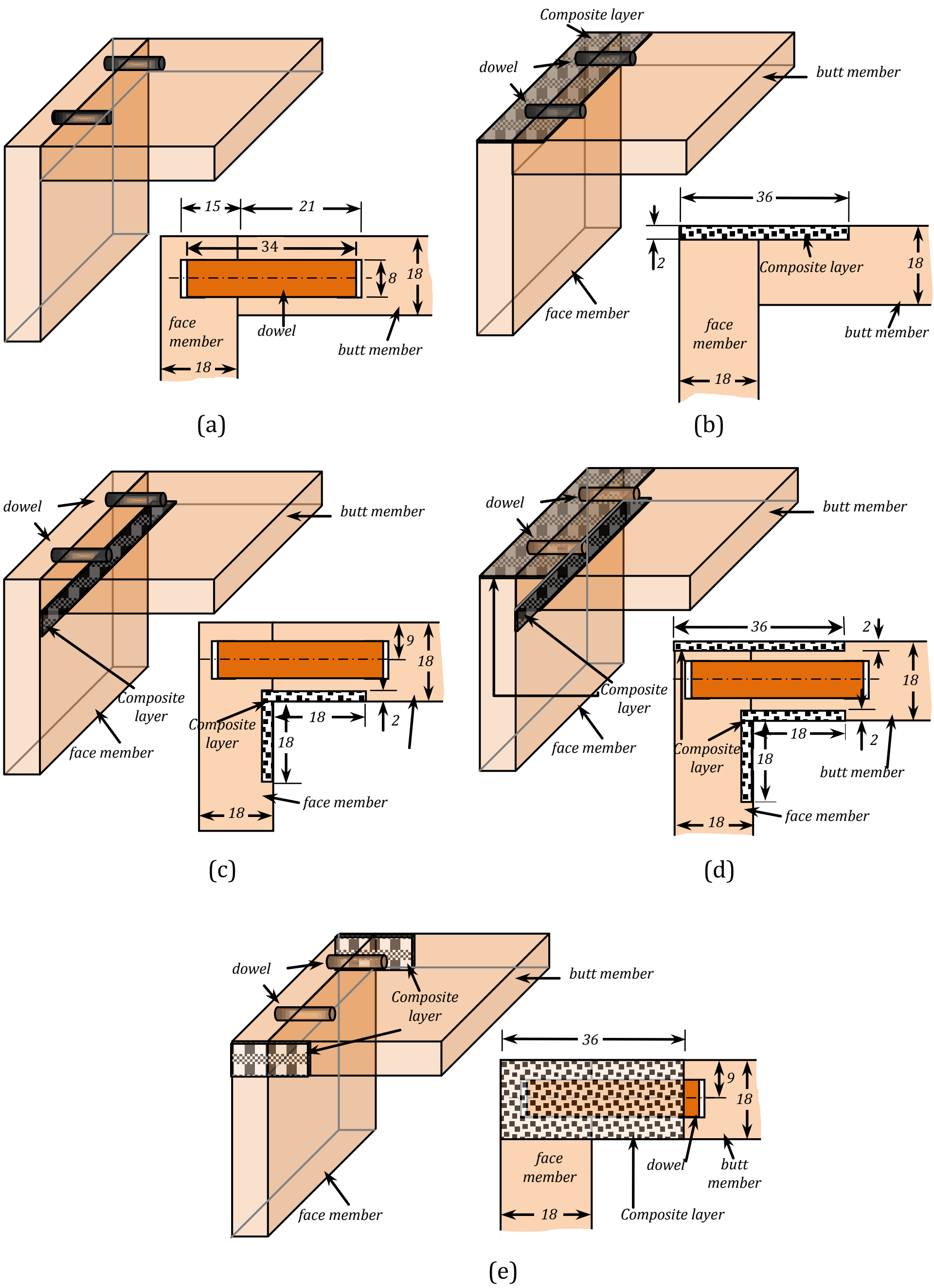


Fig. 3 Typical configuration of the L-type corner joint specimens used in the test (a) dowel joint (D), (b) dowel+fabric from the outside joint (DCO), (c) composite layer from the inside (DCI), (d) dowel+ fabric from the outside joint+ fabric from the inside joint (DCOI) and (e) dowel+ fabric from the edge joint (DCE) (dimensions in mm)

2.2.2. Testing Procedures

When a vertical force is applied to a typical case-type construction, one corner of the construction is subjected to a moment trying to close the joint (Fig. 4 point A), and the other corner is subjected to a moment trying to open the joint (Fig. 4 point B). In order to simulate these forces, two tests were developed. One is a corner joint subjected to compression force causing a moment tending to close the joint (Fig. 5a), and the other is a corner joint subjected to tension force causing a moment tending to open the joint (Fig. 5b). In the tension test setup, each of the supports was placed on metal plates with four bearings so that the two joint members were free to move sideways. Load was applied to each specimen until some separation occurred between face and butt members. The load and displacement graphs were plotted by a computer for all tests. The tests were carried out at room temperature of ~20 °C with a 10 kN loading capacity Universal testing machine at a speed of 1.5 mm/min.

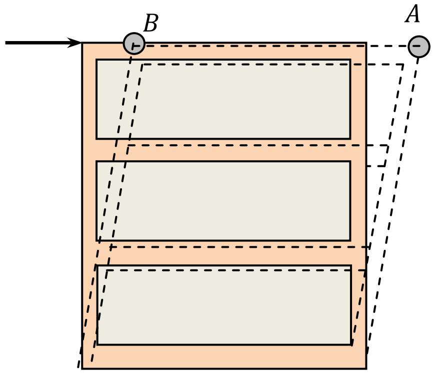


Fig. 4 A typical case-type construction applied by a force

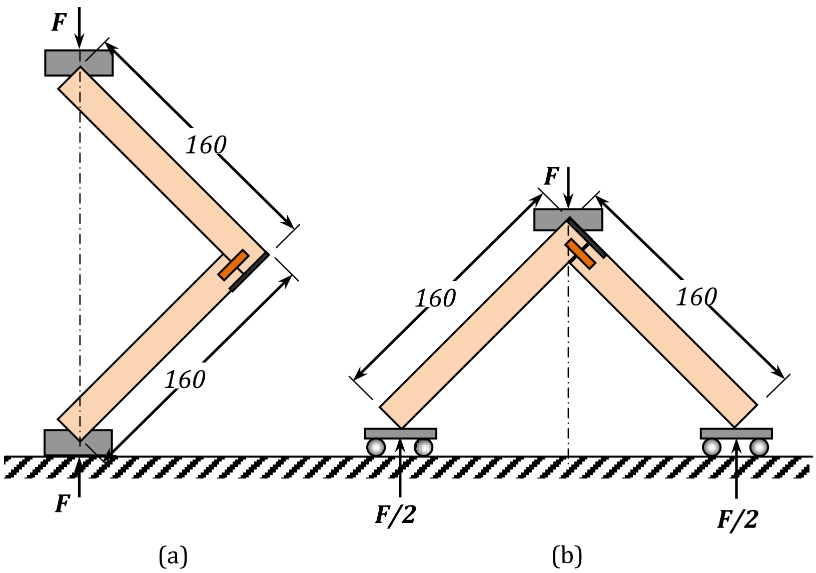


Fig. 5 The loading forms of specimen subjected to compression (a) and tension (b) loads (measurements in mm)

2.2.3. Weibull Distribution

This and the next five sections are taken from the study by Aktas [14]. Weibull distribution was used to model extreme values such as failure times and failure load. Two popular forms of this distribution are two- and three-parameter Weibull distributions. In this study, the two-parameter Weibull distribution is considered. The distribution function in this case can then be written as follows:

$$F(x;b,c)=1-exp\left(-(\frac{x}{b})^{c}\right),\quad b\geq 0, c\geq 0 \tag{1}$$

In the context of this study, *F(x; b, c)*, represents the probability that the failure load is equal to or less than *x*. Using the equality *F(x; b, c)* + *R(x; b, c)* = 1, the reliability *R(x; b, c)*, that is, the probability that the failure load is at least *x*, is defined as

$$R(x;b,c)=exp\left(-(\frac{x}{b})^{c}\right),\quad b\geq 0, c\geq 0 \tag{2}$$

The parameters *b* and *c* of the distribution function *F(x; b, c)* are estimated from observations. The methods usually employed in estimation of these parameters are the method of linear regression, the method of maximum likelihood and the method of moments. In this paper, linear regression is still common among practitioners, and is used for parameter estimation. However, software programs with statistical abilities MS Excel™ have replaced the use of Weibull graph papers.

Method of Linear Regression is based on transforming Eq. 1 into $1-F(x;b,c)=exp\left(-(\frac{x}{b})^{c}\right)$ and taking double logarithms of both sides. Hence, a linear regression model in the form *Y = m X + r* is obtained:

$$ln\left[ln\left(\frac{1}{1-F(x;b,c)}\right)\right]=c\,ln(x)-c\,ln(b) \tag{3}$$

F(x; b, c) is an unknown in Eq. 3 and so it is estimated from observed values: order *n* observations from smallest to largest, and let $x_{(i)}$ denote the i^{th} smallest observation (*i*=1 corresponds to the smallest and *i* = *n* corresponds to the largest). Then a good estimator of $F(x_{(i)}; b, c)$ is the median rank of $x_{(i)}$:

$$\hat{F}(x_{(i)};b,c)=\frac{i-0.3}{(n+0.4)} \tag{4}$$

When linear regression, based on least squares minimization, is applied to the paired values *(X, Y)* = $\left(ln(x_{(i)}),ln\left[ln\left(\frac{1}{1-\hat{F}(x_{(i)};b,c)}\right)\right]\right)$ for the model in Eq. 3, the parameter estimates for *b* and *c* are obtained.

In this study, the variation of the failure load of corner joints has been modeled using Weibull distribution. Five test specimens have been performed for each specimen configuration. Using the test data, the corresponding Weibull distribution has been determined. Finally, the 95% reliability values of each failure load configuration were compared with respect to failure load values of the same set.

3. Results and Discussion

3.1. Failure Load

The results obtained from the experiments are given in Fig. 6. Compression moment tends to close the corner. The average values of failure loads are obtained 210, 1260, 250, 1298 and 408 N for D, DCO, DCI, DCOI, and DCE, respectively. It can be seen clearly from the Fig. 6 that the failure loads take their highest values when DCOI joints are considered. On the other hand, they take their lowest values when D joints are involved. The values for DCO joints and DCOI joints are nearly the same. In addition, the values for D joints and DCI joints are nearly the same. Although the failure loads for D, DCI, and DCE joints are at the low level, for DCO and DCOI joints they are at the high level. These high results are also obtained when the polymer composite layer from outside is used in the corner joint. The failure loads increase considerably. Since the polymer composite layer is at the outer surface of the corner, the polymer composite layer is subjected to tension.

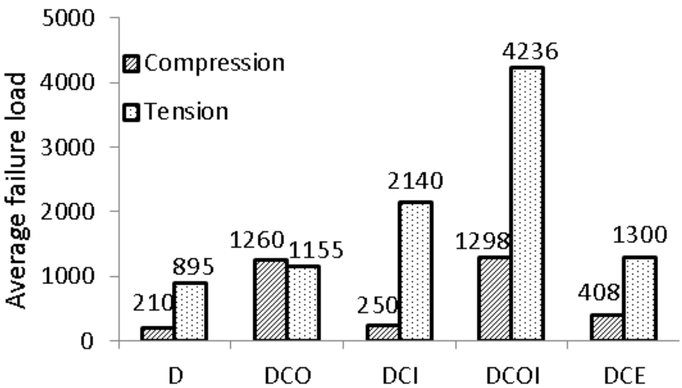


Fig. 6 The average failure load (N) results obtained from the experiments

Tension moment tends to open the joint. The average values of failure loads are obtained 895, 1155, 2141, 4236 and 1301 N for D, DCO, DCI, DCOI, and DCE, respectively. It can be seen from the Fig. 6 that the failure load takes its highest value for DCOI joints and minimum value for D joints. Although the failure loads for D, DCO, and DCE joints are at the low level, for DCOI joints they are at the high level. In addition, the failure loads for DCI joints are at the mid-level. These middle and highest results are also obtained the polymer composite layer from inside is used in the corner joint. Since the polymer composite layer is at the inner surface of the corner, the polymer composite layer is subjected to tension.

In compression tests, the failure loads of reinforced corner joints (for DCO, DCI, DCOI, and DCE joints, respectively) increased 500%, 19%, 518% and 94% more than the failure loads of unreinforced corner joints (D joints). In other words, the failure loads of reinforced corner joints (for DCO, DCI, DCOI, and DCE joints, respectively) increased by factors of 6, 1.2, 6.2 and 1.9 of the failure loads of unreinforced corner joints (D joints). Ghassan [1] also concluded that testing results of addition of FRP revealed a 14% increase in compression.

In tension tests, the failure loads of reinforced corner joints (for DCO, DCI, DCOI, and DCE joints, respectively) increased 29%, 139%, 373% and 45% more than the failure loads of unreinforced corner joints (D joints). In other words, the failure loads of reinforced corner joints (for DCO, DCI, DCOI, and DCE joints, respectively) increased by factors of 1.29, 1.2, 6.2 and 1.9 of the failure loads of unreinforced corner joints (D joints). Ghassan [1] obtained that the effect of FRP on the pine wood revealed a 10% increase in tension.

Heiduschke and Haller [5] concluded that when compared to unreinforced tubes, the ultimate load of FRP reinforced tubes is an increase of about 60%. Rowlands *et al*. [4] concluded that glass-fiber reinforced Douglas fir (18% glass by volume) produced a 40% stiffness enhancement and doubled the strength over similar unreinforced wood. Cabrero et al. [6] obtained that the strength of the unreinforced material was about 2/3 of the reinforced. Windorski *et al*. [7] obtained that the ultimate strength of a three-layer reinforced connection was 33% greater than the unreinforced connection for parallel-to-grain loading and more than 100% for perpendicular-to-grain loading. Heiduschke *et al*. [2] concluded that when compared to the unreinforced columns, the load-carrying capacity of the reinforced columns increased by factors of 1.46 and 1.22. Stevens and Criner [3] obtained that the FRP-reinforced beams are stronger than non-reinforced glulam beams because the reinforcement absorbs some of the most damaging tension stresses endured by conventional wooden glulam beams.

The tension average failure load was greater than the compression average failure load of L-type reinforced corner joints except for DCO joints as shown Fig. 6. However, compression and tension failure loads for DCO joints are nearly the same. The tension failure load increased 326%, 757%, 226% and 219% more than the compression failure load for D, DCI, DCOI, and DCE joints, respectively. For DCO joints, the tension failure load decreased 9% more than the compression failure load. According to several researches [9, 10, 12, 13], the reason for the phenomena that the tension strength was greater than the compression strength is that the bending strength of joints loaded in compression is presumably related to the internal bond strength of the board, whereas the bending strength of joints loaded intension is presumably related to the surface tensile strength parallel to the plane of the board.

3.2. Weibull Distribution

In order to compute b and c, the results obtained from the experiments are first ordered from the smallest to largest and (X_i, Y) values are computed. Then applying linear regression to these (X, Y) values, the linear regression model with the regression line in Fig. 7 (e.g. DCO joint type at compression) is obtained. The first point in Fig. 7 does not appear to fit the line well. However, this is an expected situation in the method of linear regression; among consecutive $(Y_{(i)}, Y_{(i+1)})$ pairs, $(Y_{(1)}, Y_{(2)})$ has the largest absolute difference. The slope of the line is 4.84, which is the value of the shape parameter c.

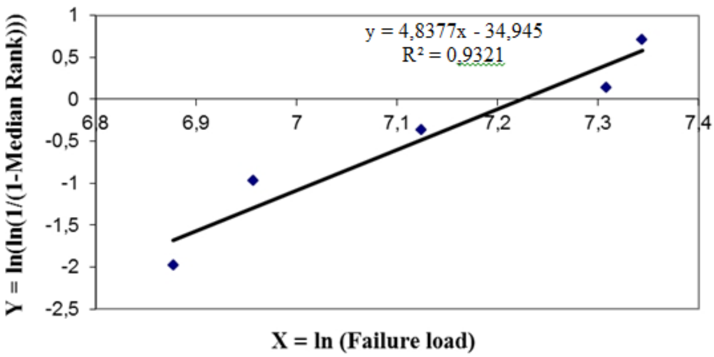


Fig. 7 Regression line for DCO joint type at compression

A finding that $c < 1.0$ indicates that the material has a decreasing failure rate. Similarly, a finding that $c = 0$ indicates constant failure, and that $c > 1.0$ indicates an increasing failure rate. The b value is computed as $b = 1371$ *and,* using the point the line intersects the Y axis $(= -34.945)$ in $b = e^{(-Y/c)}$. Therefore, $c = 4.84$ indicates that there is a higher probability that the material will fracture with every unit of increase in applied compression. The scale parameter b measures the spread in the distribution of data. As a theoretical property, $R(b; b, c) = 0.368$. Therefore, $R(1371; 1371, 4.84) = \exp(-(x/b)^c) = 0.368$, that is 36.8 % of the tested specimens have a failure load of at least 1260 N.

The plot of $R(x; b, c)$ is shown in Figs. 8 and 9. In other words, Weibull distribution plots of the data obtained from failure load tests is shown in Figs. 8 and 9. For compression, the reliability curve in Fig. 8 shows that failure load values roughly less than or equal to 100, 400, 80, 400 and 250 N (for D, DCO, DCI, DCOI, and DCE, respectively) will provide high reliability. For a more certain assessment, consider 0.95 a reliability level. When these values are put as $R(x; b, c)$ in Eq. 2 and the equation is solved for x, the failure load value 161, 742, 150, 770 and 324 N (for D, DCO, DCI, DCOI and DCE, respectively) are obtained. In other words, this material will fracture with 0.95 probability for compression of these failure loads or more. For tension, the reliability curve in Fig. 9 shows that failure load values roughly less than or equal to 400, 750, 1600, 2700 and 500 N (for D, DCO, DCI, DCOI and DCE, respectively) will provide high reliability. For a more certain assessment, consider a 0.95 reliability level. When these values are put as $R(x; b, c)$ in Eq. 2 and the equation is solved for x, the failure load values 602, 936, 1866, 3427 and 824 N (for D, DCO, DCI, DCOI and DCE, respectively) are obtained. In other words, this material will fail with 0.95 probability for tensions of these failure load values or more.

The 95% reliability values are given for compression and tension test in Table 3. In compression situations, the 95% reliability values of reinforced corner joints (for DCO, DCI, DCOI, and DCE joints, respectively) increased 635%, 49%, 662% and 220% more than the 95% reliability values of unreinforced corner joints (D joints). In other words, the 95% reliability values of reinforced corner joints (for DCO, DCI, DCOI, and DCE joints, respectively) increased by factors of 7.35, 1.49, 7.62 and 3.21 the 95% reliability values of unreinforced corner joints (D joints). In tension situations, the 95% reliability values of reinforced corner joints (for DCO, DCI, DCOI, and DCE joints, respectively) increased 56%, 210%, 469% and 37% more than the 95% reliability values of unreinforced corner joints (D joints). In other words, the 95% reliability values of reinforced corner joints (for DCO, DCI, DCOI, and DCE joints, respectively) increased by factors of 1.06, 3.1, 5.69 and 1.37 the 95% reliability values of unreinforced corner joints (D joints).

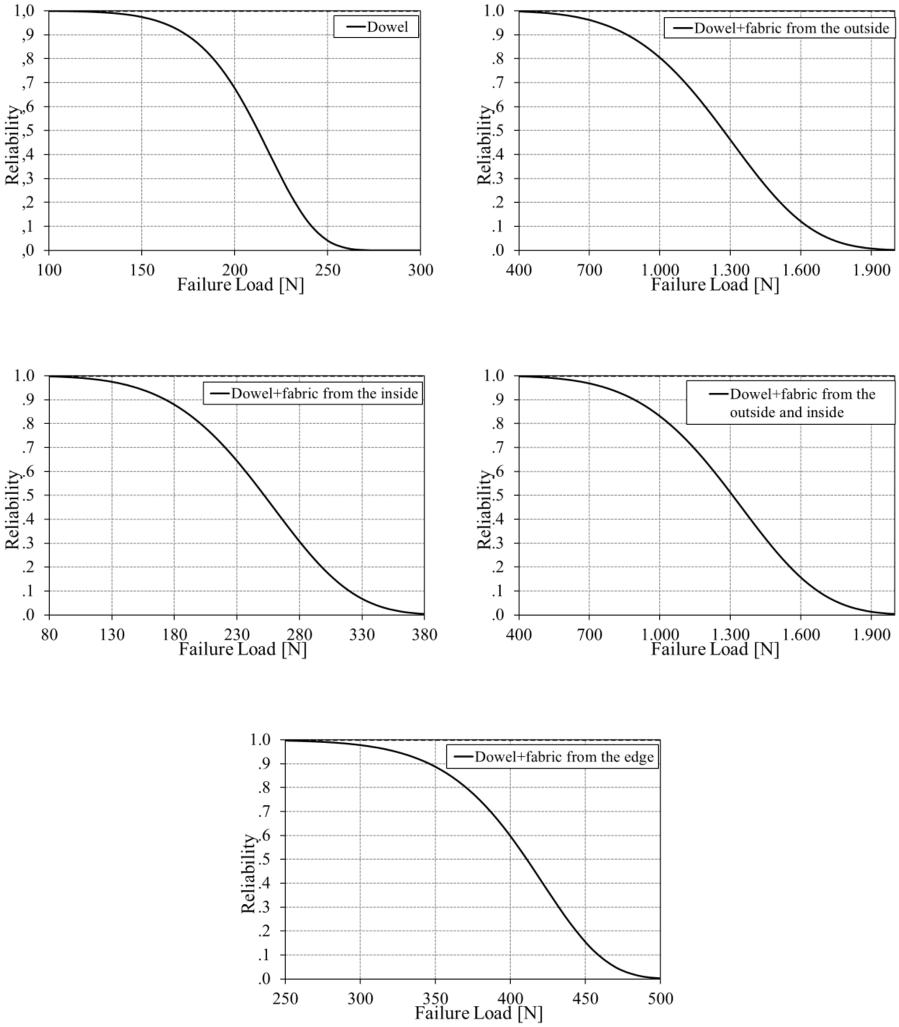


Fig. 8 Weibull reliability distribution (for compression test)

Table 3
The 95% reliability values

Joint type	Compression [N]	Tension [N]
D	161	602
DCO	742	936
DCI	150	1866
DCOI	770	3427
DCE	324	824

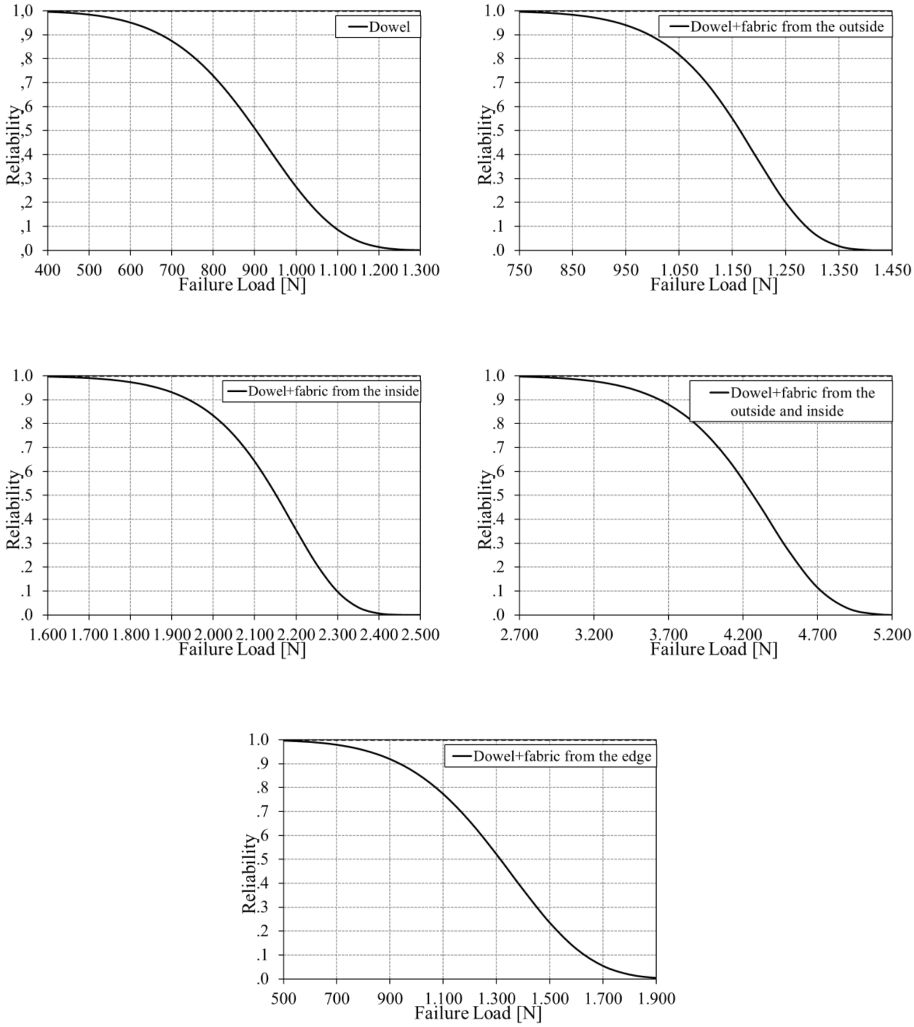


Fig. 9 Weibull reliability distribution (for tension test)

The failure loads obtained from the average values of the experiments and the 95% reliability obtained by Weibull distribution are given in Figs. 10 and 11. In compression situations, the average failure load was obtained at 54%, 51%, 51%, 52% and 53% of reliability for D, DCO, DCI, DCOI, and DCE, respectively. In other words, the 95% reliability of failure load was obtained at 54%, 51%, 51%, 52% and 53% of average failure load values for D, DCO, DCI, DCOI, and DCE, respectively. As for tension situations, the average values of failure load were obtained at 52%, 53%, 54%, 53% and 52% of reliability for D, DCO, DCI, DCOI, and DCE, respectively. In other words, the 95% reliability of failure load was obtained at 52%, 53%, 54%, 53% and 52% of average failure load values for D, DCO, DCI, DCOI, and DCE, respectively.

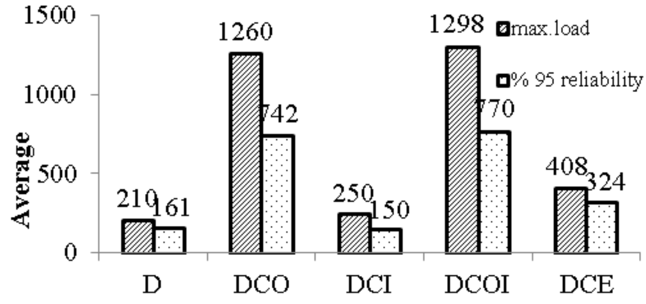


Fig. 10 Failure load (N) for compression test

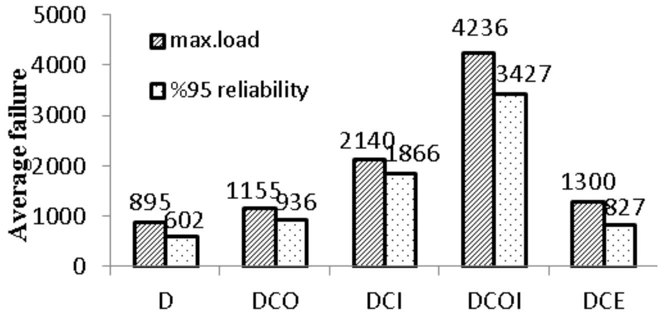


Fig. 11 Failure load (N) for tension test

3.3. Failure Mode

Photographs of failed specimens for joint configurations subjected to compression moment are shown in Fig. 12. For D joints, failures occurred at the point of entry of the dowel in the face members (Fig. 12a). For DCO and DCOI joints, failures occurred as a result of cracking on the outer face of face member (Fig. 12b, c). The reason for this is that joint rigidity of joints with the fabric from the outer is higher than the board. That is because applied compression load did not open the joint places and fabrics, the face members cracked from the outer face. The cracks in the DCOI joints occurred away from the end of face member, whereas the cracks in the DCO joints occurred just on the end of the face member and fabrics. For DCI joints, failures occurred at the inner face of the face member (Fig. 12d). In addition, failures occurred at the point of entry of the dowel fasteners. As for DCE joints, failures occurred as a result of cracking from near the fabrics in the face members (Fig. 12e).

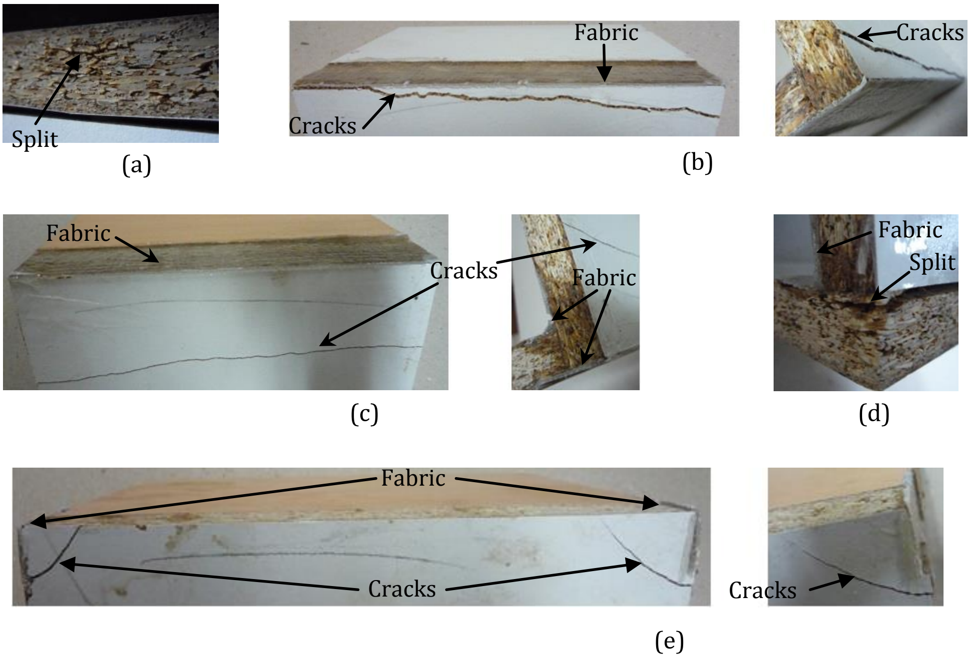


Fig. 12 Photography of failed specimen (a) D, (b) DCO, (c) DCOI, (d) DCI and (e) DCE joints for compression moment

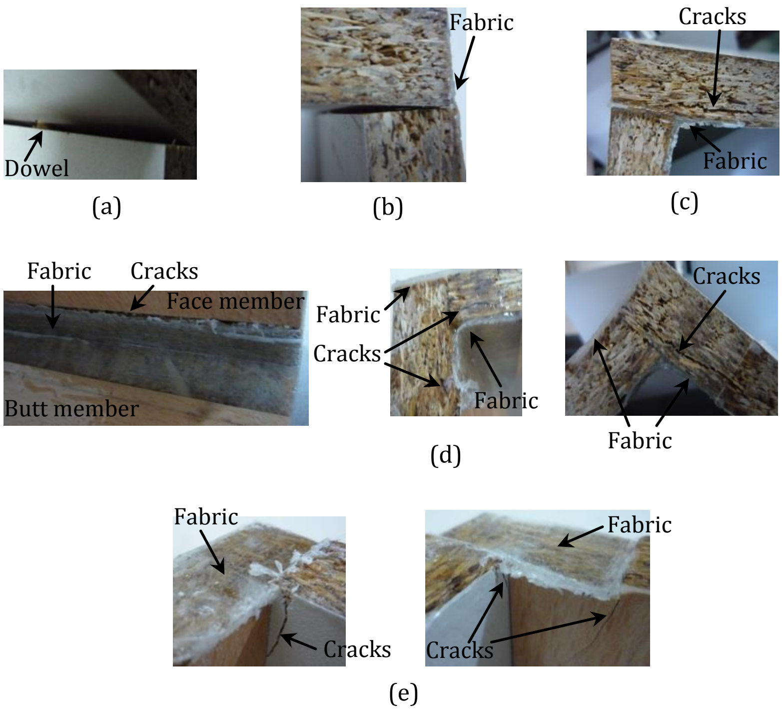


Fig. 13 Photography of failed specimen (a) D, (b) DCO, (c) DCI, (d) DCOI and (e) DCE joints for tension moment

Fig. 13 shows photographs of failed specimens for joint configurations subjected to tension moment. For D and DCO joints, failures initially occurred as openings at the inner face of joints (Fig. 13a, b). For DCI joints, failures occurred as a split of particleboard in the face member (Fig. 13c). For DCOI joints, failures occurred in three types as shown in Fig. 13d: (1) cracks occurred at the junction end of particleboard with a glass fiber fabric in the face member, (2) failures occurred as a split of particleboard in both the face and butt members, (3) failures occurred as a split of particleboard in the face member. For DCE joints, cracks occurred on the inner face of the butt members or on the inner face of both the face and butt members (Fig. 13e).

4. Conclusion

The study questions and then rejects the assumption that the failure load of corner joints of case-type furniture is taken as an average of the experimental results. In this respect, the Weibull distribution allows researchers to describe the failure load of corner joints of case-type furniture in terms of a reliability function. It also provides furniture manufacturers with a tool that will enable them to present the necessary mechanical properties with certain confidence to the end users. Weibull distribution has been employed here to model failure load, but it can also be used in areas with similar uncertainties as described in this study.

In this study the 95% reliability values of each failure load configuration were compared with respect to average failure load values of the same set. For the compression situation, the failure loads obtained from the experimental data are approximately 52% reliability. For the tension situation, the failure loads obtained from the experimental data are approximately 53% reliability. This means that if designers take the average values into consideration, then they will have a little reliability. If they want assurance they should take the failure load obtained from the statistical analysis.

Experiments show that the failure loads take their highest values in the DCOI joints and their lowest values in the D joints for both compression and tension moments. In addition, for the corner joints subjected to compression moment, although the failure loads for D, DCI, and DCE joints are at the minimum level, for DCO and DCOI joints they are at the maximum. These maximum results are also obtained when the composite layer from outside is used in the corner joint. However, for the corner joints subjected to tension moment, although the failure loads for D, DCO, and DCE joints are at the minimum level, for DCOI joints they are at the maximum. In addition, the failure loads for DCI joints are at the mid-level. These middle and highest results are also obtained the composite layer from inside is used in the corner joint.

Additional work is needed in order to establish the failure sensitivity of the reinforced corner joints for all wood composite materials and wood panels, e.g. medium-density fiberboard, massive panels, and for different thickness of panels, e.g. 16mm, 22mm, and different layers of fabric.

References

1. Ghassan AC. Performance of wood members strengthened with fiber reinforced polymers (FRP). Research Structural Engineer ERDC-CERL, 2011: 37.
2. Heiduschke A, Cabrero JM, Manthey C, Haller P and Günther E. Mechanical behaviour and life cycle assessment of fibre-reinforced timber profiles. in: Braganca L, Koukkari H, Blok H, Cervasio R, Velkovic MR, Plewako UV, Landolfo

Z, Silva L and Haller P. (Eds.) COST C25 Sustainability of Constructions - Integrated Approach to Lifetime Engineering. COST C-25; European Commission: Dresden. 2008: 3.38–3.46.

3. Stevens ND and Criner GK. Economic analysis of fiber-reinforced polymer wood beams. Maine Agricultural and Forest Experiment Station. University of Maine. Bulletin 848. June 2000: 42.
4. Rowlands RE, Deweghe RP, Laufenberg TL and Krueger GP. Fiber-reinforced wood composites. Wood and Fiber Science, 1986; 18(1): 39 – 57.
5. Heiduschke A and Haller P. Load-carrying behavior of fiber reinforced wood profiles. World Conference on Timber Engineering, 2010: 7.
6. Cabrero JM, Heiduschke A and Haller P. Parametric analysis of composite reinforced wood tubes under axial compression. World Conference on Timber Engineering, 2010: 20 – 24.
7. Windorski DF, Doltis LA and Ross RJ. Feasibility of fiberglass-reinforced bolted wood connections. Res. Pap. FPL–RP–562: Madison: WI: U.S. Department of Agriculture. Forest Service. Forest Products Laboratory 1997: 9.
8. Norvydas V, Juodeikiene I and Minelga D. The influence of glued dowel joints construction on the bending moment resistance. Materials Science, 2005; 11(1): 36 – 39.
9. Liu WQ and Eckelman CA. Effect of number of fasteners on the strength of corner joints for cases. Forest Product Journal, 1998; 48(1): 93 – 95.
10. Tankut AN and Tankut N. Evaluation the effects of edge banding type and thickness on the strength of corner joints in case-type furniture. Materials and Design, 2010; 31: 2956 – 2963.
11. Yerlikaya NC and Aktas A. Enhancement of load-carrying capacity of corner joints in case-type furniture. Materials and Design, 2012; 37: 393 – 401.
12. Yerlikaya NC. Effects of glass-fiber composite, dowel, and minifix fasteners on the failure load of corner joints in particleboard case-type furniture. Materials and Design, 2012; 39: 63 – 71.
13. ASTM D 1037. Evaluating the properties of wood-base fiber and particle panel materials. ASTM, 1973.
14. Aktas A. Statistical analysis of bearing strength of glass-fiber composite materials. Journal of Reinforced Plastics and Composites, 2007; 26: 555 – 564.