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EFFECTS OF WOOD SPECIES OF THE DOWELS AND FIBER WOVEN FABRIC TYPES ON BENDING MOMENT RESISTANCE OF L-SHAPED JOINTS

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Abstract

This study investigated the bending moment resistance of L-Shaped, two-pin dowel joints connected with Scots pine dowel (*Pinus slyvestris* Lipsky), beech dowel (*Fagus orientalis* Lipsky), chestnut dowel (*Castanea sativa* Mill.) and oak dowel (*Quercus petraea* Lieble) and reinforced with basalt and glass woven fabrics (BFRP and GFRP). The tests were carried out to determine the bending moment resistance of dowel joints. As a result of bending test, it was determined that one layer and two surfaces the reinforced with fiber woven fabrics increases the mechanical performance of furniture fasteners according to obtained data from tests conducted on the L-Shaped, two pin dowel joints. Experimental results showed that joints constructed of Oak wood had the higher bending moment resistance than Beech wood. Joints connected with Oak dowel had the highest bending moment resistance, and the joints of Scotch pine dowel had the weakest bending moment resistance. The bending moment resistance value of oak was approximately 12%, 25% and 55% higher than for joints constructed with chestnut, beech, and Scots pine, respectively, The bending moment resistance value reinforced with BFRP (79.77 N.m), and the lowest was in unreinforced joints (49,36 N.m). The mean bending moment resistance of reinforced joints (BFRP, GFRP) was 14% and 62% higher than unreinforced samples (control), respectively. In general, it has been found that the bending moment resistance of dowel joints is influenced by wood species, wooden dowel species and fiber woven fabric types.

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EFFECTS OF WOOD SPECIES OF THE DOWELS AND FIBER WOVEN FABRIC TYPES ON BENDING MOMENT RESISTANCE OF L-SHAPED JOINTS

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1. Introduction

Wood material is among the most widely used building materials due to the fact that it is renewable, low cost, natural, easy to recycle and aesthetic, It is known that one of the most important advantages of reinforcement with basalt and glass fabrics is to strengthen and repair the wood material, Although the application of these methods brings a cost burden to the user, it increases the useful life of the wood structure, For this aim, it is an ideal reinforcement element for wood materials since it has a high degree of hardness and higher strength compared to its light weight and it is a non-abrasive corrosion resistant flexible material which ensures the reduction of long-term maintenance costs and provides fast installation on site, Also, these materials demonstrate high durability in corrosive environments thanks to their high resistance to fatigue, The production of reinforced wood materials with high economic value and their increasing use can benefit economically.

Joints represent a critical part of the structure of furniture. The joints provide continuity to the member and strength and stability to the structure. Proper joint design is important so that joints can carry a load safely in service conditions without excessive deformation or failure (Hajdarevic and Martinovic 2014). The mechanical strength of a piece of furniture depends mostly on the strength of its joints. (Gaff and Babiak 2017). With a suitable Shaped of joint, it is possible to achieve considerable simplification of the structure itself and improve its integrity (Svoboda et al. 2015). The mechanical behaviour of wooden joints is a complex problem governed by a number of geometric, material and loading parameters (e.g. wood species, fastener diameter, end distances, edge distances, spacing, number of fasteners, fastener/hole clearances, friction) (Eckelman 2003).

L-shaped corner-joint is one of the most important furniture structures Shaped manufactured and used nowadays for connecting leg, transom, and handrail. There is an important joint style usually used in a L-shaped corner-joint which is called butt joint with dowels (Ke et al. 2016). Dowel joints are widely used Types of structural joints, both as (load-bearing structure) connections and also as simple part positioning elements. Two-pin dowel joints are among the most important structural joints in upholstered furniture frame construction (Segovia and Pizzi 2012). Calculating the bending moment resistance and the strength of the dowel joints is a complex problem depending on many factors. The most significant of these factors are wood species, dowel length, depth of dowel embedment, dowel Shaped, hole diameter, distance between holes, number of dowels, the method of loading, and the strength of glue lines appearing in the joint (Eckelman 2003).

Hajdarevic and Martinovic (2014) investigated stress and strain analysis of double-dowel case-Shaped furniture corner joint. They showed that dowel spacing, distance between the dowels, and edge of board have considerable impact on the stress state of the face and edge member; joints became stiffer when distance between the dowels and board edge were rationally defined. Georgescu and Bedelean (2017) reported that the compressive and tensile strengths of heat- treated dowel joints increases when the dowel length increases, the distance between holes increases, and the ratio of dowel embedment in the rail of the joint decreases. Chen and Lyu (2018) determined optimum parameters for double dowels in medium density fiberboard components, and the maximum value of the strength of joints loaded in tension and compression bending. and found that the optimal parameters for double dowel joints with maximum bending strength were determined a dowel diameter of 10 mm, an interference fit of 0,10 mm and a spacing of 48mm. The results revealed that the optimal parameters for double dowel joints with maximum tensile strength were a dowel diameter of 10mm, an interference fit of 0,20mm, and a spacing of 64mm.The optimal parameters for double dowel joints with maximum bending strength were a dowel diameter of 10mm, an interference fit of 0,10mm and a spacing of 48mm. Chen et al. (2018) investigated the effects of dowel penetration depth, shear strengths of connection member and dowel materials, dowel surface texture, and member grain orientation on ultimate direct withdrawal loads of single dowels withdrawn from wooden materials, and the results showed that the mean values of ultimate direct withdrawal loads of dowels increased significantly as dowel penetration depth increased from 12.7 to 38.1 mm at increments of 6.35 mm. Uysal and Haviarova (2018) investigated the estimation of reasonable design values for two-pin moment-resisting dowel joints by using the lower tolerance limits (LTLs) method. They showed that the dowel diameter and length for double dowel joints with the shear strength were determined a dowel diameter of 12 mm for red oak and 13.1 mm for white oak, dowel lengths were 31.5 mm for red oak and 28.5 mm for white oak. Georgescu et al. (2019) investigated the influence of dowel diameter, adhesive consumption, and dowel length on the bending moment resistance of heat-treated wood dowel joints using response surface methodology (RSM) and determined that the dowel length and dowel diameter had significant effects on the bending moment resistance of heat-treated wood dowel joints. Hao et al. (2020) studies focused on the quantitative effect of dowel dimension, dowel position, loading distance on bending moment resistance. The results showed that the dowel space has positive effect on the bending moment resistance while the impact of loading distance can be neglected. But the top dowel, rather than bottom dowel, plays a critical role in deciding joint moment resistance. Increasing dowel diameter and length, fortifying dowel rupture and withdrawal strength, enlarging dowel space, or moving bottom dowel far away from the bottom edge will promote the joint performance. Podlena et al. (2020) compared the withdrawal strength of plain dowels, and the spiral dowels manufactured from beech (*Fagus sylvatica* L.) and oak wood (*Quercus robur L.*) and found that that the higher withdrawal strength of spiral dowels was statistically significant and the lowest withdrawal strength was found for plain beech dowels (3 MPa), which, in addition to higher relative humidity (RH 85%), was also caused by a combination of plain structure and greater diameter of the dowels.

To overcome the inferior mechanical properties of wood elements, fiber reinforced polymer (FRP) composite (Johns and Locroix, 2000) can be one of the solutions. The commonly utilized FRP composites as reinforcement for wood beams are carbon FRP (CFRP), E-glass FRP (GFRP) and aramid FRP (AFRP) (Johns and Locroix, 2000; Borri et al. 2005; Wang et al. 2019). However, the production processes of these fibers are the initial costs are still high. Recently, mineral-based natural FRP, such as BFRP has been introduced. BFRP has low material cost, high fire resistance, good thermal, electrical and sound insulating properties (Fiore et al. 2015). Moreover, their specific mechanical properties are comparable with, or better than, those of E-glass ones (Fiore et al. 2011).

Basalt-based materials are environmentally friendly and non-hazardous. The current production technology for continuous basalt fibres is very similar to that used for E-glass manufacturing. The main difference is that E-glass is made from a complex batch of materials whereas basalt filament is made from melting basalt rock with no other additives and, as a consequence, with an advantage in terms of cost. Their specific mechanical properties are comparable with, or better than, those of E-glass ones. The GFRP material value of density, elasticity modulus, tensile strength and elongation to fracture were 2,6 g/cm^3, 76 GPa, 2,0 GPa, and 2,5 %, respectively (Fiore et al. 2011). The BFRP value of density, elasticity modulus, tensile strength, and elongation to fracture were 2,8 g/cm^3, 89 GPa, 2,8 GPa, and 3,2 %, respectively (Colombo et al. 2009). Dorigato and Pegoretti (2012) explained that the basalt fibers have exhibit mechanical properties fully comparable with those of glass fibers, the elastic modulus of basalt and the tensile strength were greater than glass fibers.

Recently, A great deal of investigations has been studied wooden reinforced with the FRP (Yerlikaya 2013; Osmannezhad et al. 2014; Yerlikaya 2014; McConnell 2015; Raftery and Kelly 2015; Schober et al. 2015; Brol and Wdowiak 2017; Brol et al. 2018; Zhou et al. 2018; Gaff et al. 2019; Wang et al. 2019; Yerlikaya 2019; Zhou et al. 2019; Zhou et al. 2020; Wdowiak-Postulak, 2021).

On the bending moment resistance of T-type, two-pin dowel joints with reinforced basalt fiber woven fabrics (BFRP) are not applied and it is considered that there is a deficiency in the literature. The reinforcement with BFRP reinforced joints in frame-type furniture is a new research topic.

The aim of study is to determine the effects of wood species of the dowels and fiber woven fabric Types (BFRP and GFRP) on the bending moment resistance of the L-shaped joints, two-pin dowel joints.

2. Materials and Methods

2.1 Materials

In this study, Scots pine (*Pinus sylvestris* Lipsky), Oriental beech (*Fagus orientalis* Lipsky), Oak (*Quercus petraea* Lieble) and Chestnut (*Castanea sativa* Mill) were used for preparing the specimens. These species are widely utilized in the manufacturing of furniture frames. Wood materials were randomly selected from the commercial suppliers in Karabük, Turkey (Figure 1e, f, g, h, and ı, respectively). The test specimens were selected natural colour uniformity, smoothness of fibers, absence of knots, heart uniformity, absence of reaction wood, and absence of fungal and insect damage. It has been paid attention that the wood material used in experimental studies is not exposed to physical damage, mechanical impacts, or biological damage. Moisture contents (MC) and densities of the wooden materials were tested according to TS 2471 (TSE 1976) and TS 2472 (TSE 1976) standards, respectively. The ovendried density values were 0.50, 0.67, 0.69, and 0.57 g/cm³, for Scots pine, Oriental beech, oak, and chestnut, respectively. Beech dowels, oak dowels, chestnut dowels and Scots pine dowels 8 mm in diameter and 40 mm in length were chosen for this study (Figure 1f, g, h, and ı). Glass-fiber woven fabrics (GFRP) and basalt-fiber woven fabrics (BFRP) having 200 ± 10 g/m² were used. These materials used in the study was obtained by Dost Chemical Industry Raw Material Industry and Trading (Figure 1c and d). Fiber woven fabrics were prepared by cutting to 100 mm in long and 50 mm in width. The dowels were assembled with the polyvinyl acetate (PVAc) adhesive which is commonly used in the wood industry. The glue was applied to the dowel surfaces and dowel holes with an average of 200 ± 10 gr/m² with a brush (Beta Chemical Industry and Trade Inc., Istanbul, Turkey) (Figure 1b).

Figure 1: Materials used in experiments samples

Fiber woven fabrics were fastened with epoxy adhesive and hardener. The Shaped of epoxy resin used in the matrix material was MGS L285 resin and hardener was MGS H285 (Dost Chemical Industry Raw Material Industry and Trading Co., Istanbul Turkey) (Figure 1a). The technical parameters of the two adhesives are shown in Table 1.

Table 1: Technical data and characteristics of the adhesives

Technical Data	Polyvinyl acetate (PVAc-D4)	Epoxy (L285 Resin+ H285 Hardener)
Viscosity (mPas)	19000±5000 at 21 °C	600 - 900 at 25 °C
Working time (min)	35-40 at 21 °C	45-240 at 25 °C
Density (g/cm3)	1.055±3 at 21 °C	1.21 at 25 °C
Solids content (%)	51±2	-
pH	2.5-3.5	-
Main agent/Hardener Ratio (w/w)	100/5	100/50

2.2. Preparation and construction of specimens

The general configuration of the L-shaped specimens is shown in Figure 2. The specimens consisted of two parts, namely, a rail member and a post member. The rail part measured 150 mm long 50 mm width 25 mm thick, whereas the post member measured 125 mm long 50 mm width 25 mm thick. The members were jointed to each other with 2 pieces of 8 mm diameter and 40 mm length beech (*Fagus orientalis* Lipsky), oak (*Quercus petraea* Lieble), Scots pine (*Pinus sylvestris* Lipsky), and chestnut (*Castanea sativa* Mill) dowels with polyvinyl acetate (PVAc) glue. The dowels were produced from wood species measured 100 mm long by 11 mm wide by 11 mm thickness of wood pieces with using a dowel drawing machine. The rail and post members were drilled with a drilling machine. Depth of the dowel holes in both the post and the rail was 21 mm. Then the holes in the member were cleaned with compressed air. The adhesive was spread over the dowel surfaces and dowel holes with approximately

200 g/m² calculation. Figure 2 shows a typical placement of dowel centers in the L-shaped joints used in this study. In all samples, a piece of wax paper was included between the two members to prevent any possibility of the members adhesion. Then, areas where the fiber basalt woven fabric and fiber glass woven fabric were to be placed were bonded with an average of 200 ± 10 gr/m² with a brush with a blend of epoxy adhesive and hardener. Joint instances were left to dry for two days.

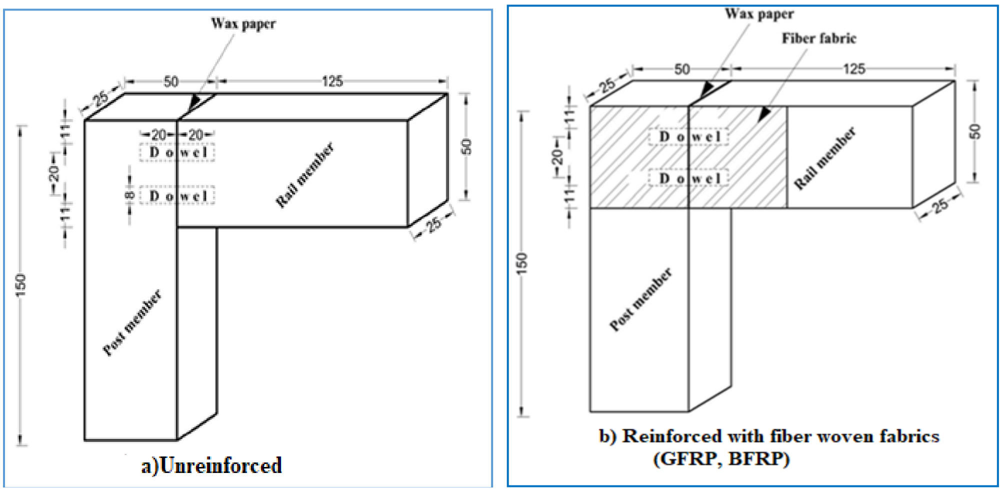

Figure 2: General configuration oh L-shaped joint specimens (dimensions in mm)

According to this, two wood species four wooden dowel species, and two fiber reinforced polymers (BFRP, GFRP, and control), and 5 sample of each material (2 x 4 x 3 x 5) were the variables, totally a number of 120 specimens was constructed in this research. Prior to testing, all samples were conditioned in a humidity chamber controlled at 20 °C ± 2 °C and 65 % ± 5 % relative humidity (RH) for two weeks.

2.3. Methods of Loading and Testing

All of the bending tests of the L-shaped were carried out on a 10-kN Resistance universal-testing machine (SHIMADZU Corp., Sydney, Australia)) in the mechanical test laboratory of Wood Science and Industrial Engineering Department of Karabük University with a 8 mm/min loading rate under static loading. A concentrated load was applied to the rail member of each specimen at a point 100 mm from the front edge of the leg. The moment arm was 100 mm (Figure 3). The loading was continued until a breakage or separation occurred in the specimens. The ultimate loads carried by the joints were recorded with a tolerance of 0.01. The ultimate loads were then converted to corresponding bending moment resistance values by means of the expression. The strength of the joints (modulus of rupture) to bending forces was calculated using the following Eq. (1)

$$M = F \times L \quad (1)$$

where M is the bending moment resistance (N.m), Fmax is the maximum force that caused the destruction of the joint (Max. rupture load) (N), and L is the length of the vertical element of the joint, measured till the loading point and in this experiment this distance was for both corner joints 0.1 (m).

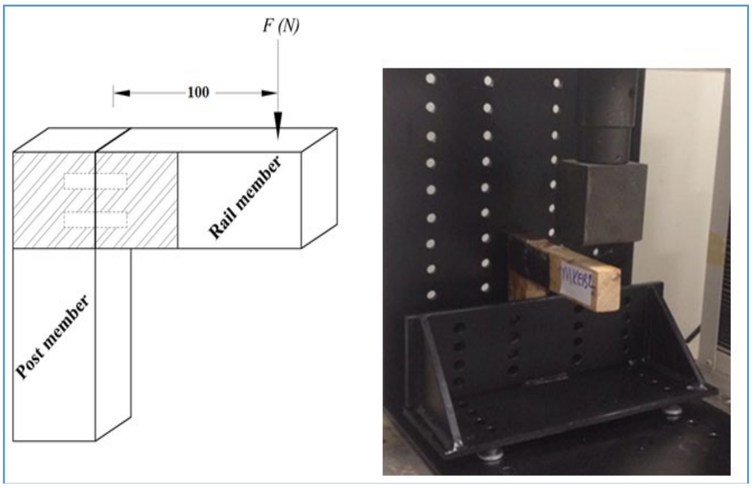

Figure 3: Diagrams showing the bending loading forms and attachments of L-shaped joint specimens to the test rig

A two-way analysis of variance (ANOVA) statistical analysis was used applying the statistical package the statistical package Minitab 18 program. The two-way analysis of variance was carried out on the data at the 0.05 significance level for the individual data to examine the main factors (the wood species of the dowels and reinforced fiber woven fabric types) and their interactions on the bending moment resistance of the joints. It was to be determined by the Tukey test. Tukey test carried out to determine the importance of the differences between the groups

3. Results and Discussion

The mean values bending moment resistance under compression of L-Shaped, two pin dowel joints with their standard deviation and coefficients of variation were presented in Table 2.

Table 2: Mean values of the bending moment resistance of L-shaped joints with their coefficients of variation

Wood Material	Wood species of the dowels	Reinforced fiber woven fabrics (FRP)	Mean (N.m)	SD	COV (%)
Oak	Beech	Control (No-SMT)	44.87	1.56	3.48
		GFRP	59.09	7.37	12.48
		BFRP	83.91	7.05	8.40
	Chestnut	Control (No-SMT)	51.14	4.25	8.32
		GFRP	75.16	6.78	9.02
		BFRP	82.97	7.70	9.28
	Oak	Control (No-SMT)	65.69	7.46	11.36
		GFRP	77.28	9.65	12.49
		BFRP	92.13	9.01	9.78
	Scots pine	Control (No-SMT)	35.75	4.61	12.89
		GFRP	55.94	2.19	3.91
		BFRP	60.10	4.63	7.70

GFRP: Glass fiber woven fabric, BFRP: Basalt fiber woven fabric, SD: Standard devision, COV: Coefficient of variation.

According to multiple comparisons on the bending moment resistance, the highest bending moment resistance value was obtained from jointed with an oak dowel and reinforced with BFRP (92.13 N.m), while the lowest value was acquired in joint with beech dowel and not reinforced (control) (44.87 N.m).

The results of the two-way ANOVA analysis of the wood species of the dowels and reinforced fiber woven fabrics on the bending moment resistance of the L-Shaped, two pin dowel joints under the compression load were given in the Table 3.

Table 3: Summary of the ANOVA results for moment resistance

Source	df	Adj SS	Adj MS	F-Value	P -Value
Wood species of the dowels (A)	3	6209.7	2069.90	39.69	0,000
Reinforced fiber woven fabric Types (B)	2	9318.8	4659.41	89.34	0.000
A×B	6	787.1	131.19	3.10	0.012
Error	54	52.15	2816.3		
Pure Error	2029.2	42.27			
Total	59	18344.8			

R-sq = 84.65%, R-sq (adj)= 82.23% df: Degrees of Freedom.

According to the analysis of variance as presented in Table 3, the effects of the main factors including, the wood species of the dowels (A), the reinforced fiber woven fabric types (B), and interactions of the dowel species and the reinforced fiber woven fabrics (A×B) were found to be statistically significant at the level of 0.05. Tukey test was carried out in order to determine these differences. The bending moment resistance means according to independent effects of test variables were given in Table 4.

Table 4: The results from the Tukey's test for independent effects of test variables

Source		Bending moment Resistance (N.m)	SD	HG
Wood species of the dowels	Oak	78.36	13.83 (17.64)	A
	Chestnut	69.76	15.22 (21.82)	B
	Beech	62.62	17.59 (28.08)	C
	Scots pine	50.59	11.60 (22.94)	C
Reinforced fiber woven fabrics (FRP)	BFRP	79.77	13.92 (17.45)	A
	GFRP	66.87	11.65 (17.42)	B
	Control	49.36	12.06 (24.44)	C

SD: Standart deviation, HG: Homogeneity groups, Values in parentheses are coefficients of variation (CV, %)

For the wood species of the dowels, the oak dowel showed significantly higher the bending moment resistance value than other dowels (Table 4), The bending moment resistance value of oak was approximately 12%, 25% and 55% higher than for joints constructed with chestnut, beech, and Scots pine, respectively, The situation with the species of lumber used for dowels can explain with the structural properties of the materials, The reasons for these may be based on the density of wooden materials, As a general rule, mechanical properties increase as the density of solid wood material increases, There is an increasing-linear relationship between bending strength, modulus of elasticity and shock resistance and density, In previous studies, many researchers have identified this relationship (Bozkurt and Erdin 1995, Bal and Bektaş 2018),

According to fiber woven fabrics, the highest bending moment resistance value were obtained in basalt fiber woven fabric (BFRP) (79.77 N.m), and the lowest was in control samples (49.36 N.m), The mean bending moment resistance of joints with BFRP was 19 % and 62 % higher than joints with GFRP, and not reinforced joints (control), respectively,

Chairman and Kumaresh Babu (2013) obtained that compressive and tensile ultimate strength of BFRP laminates are higher than GFRP laminates of about 43 % and 23 %, respectively, Borri et al, (2013a) investigated flax and basalt FRP strengthened low-grade (bending strength of 18,4 MPa) and high-grade (bending strength of 41,3 MPa) wood beams, The results showed an increase of bending strength of 38,6% and 65,8%, This study concluded that both BFRP and FFRP provided the beams with higher strength and better ductile behaviour, Similar results can be found in another research by Borri et al, (2013b) for flax and basalt FRP, André and Johnsson (2010) applied FFRP and GFRP with similar fabric density (i,e,, 230 g/m^2 for flax and 250 g/m^2 for glass) perpendicular to grain on wood beams, It is reported that the maximum bending load of the entire specimen strengthened with GFRP (45,1 kN) was 23% higher than that one strengthened with FFRP (36,0 kN), McConnell et al. (2015) in their investigations into the reinforcement of wooden beams with BFRP tensile basalt fibres noted an increased load Resistance and rigidity of 28% and 8,7%, respectively, Monaldoa et al. (2019) explained that beams reinforced with BFRP have a bending ultimate load higher of by about 20 % than the case of GFRP,

Wdowiak-Postulak (2021) found that the load carrying resistance of beams reinforced with basalt fibre was higher by, respectively, 13% and 20% than that of reference beams, while their rigidity improved by, respectively, 9,99% and 17,13%. The most popularly used high-strength fibers are carbon fiber, glass fiber, and basalt fiber, In comparison to other fibers, basalt fiber has superior characteristics, that is, high strength to weight ratio, excellent ductility and durability, high thermal resistance, chemical resistance, good corrosion resistance, fire resistance, high temperature resistance, high performance in terms of strength, and cost-effectiveness (Fiore et al, 2011, Wang et al, 2013), as well as the lower potential cost with respect to other fibre-reinforced polymer (FRP) materials (Fiore et al, 2015).

In the literature, it has been reported that in reinforcements made with glass fiber and metal plates, there is usually an increase of over 40% in resistance values (John and Lacroix, 2000; Borri et al. 2013a). Windorski et al. (1997) concluded that the ultimate strength of a three-layer reinforced connection was 33% greater than nonreinforced connection for parallel-to grain loading. Speranzini et al. (2010) investigated solid wood beams externally strengthened with carbon, glass, basalt, hemp and flax FRP under a four-point bending test (the increase of the bending strength was 24.6% and 23.2% for glass and basalt respectively). Dorigato and Pegoretti (2012) compared the quasi static tensile and fatigue properties of epoxy-based laminates reinforced with woven fabrics of basalt, E-glass and carbon fibres with the same areal density (i.e., 200g/m^2). The experimental result showed that the basalt fibres laminates present elastic moduli and strength values higher than those of the corresponding laminates reinforced with glass fibres. Wang et al. (2019) observed that the gradient of the Resistance improvement of BFRP increased, i.e., 14.3%, 50.0% and 107.1% for one, two and three layers of BFRP.

The cost of elements used in traditional reinforcement methods is low compared to that of FRP materials, but in the long run, elements such as bolts, nails, etc, may not be effective on timber, therefore, it is more convenient to use FRP materials instead of traditional reinforcement methods as they require maintenance and repair over time and have low durability.

3.1 Failure modes

After testing, all connections were visually inspected in order to identify the failure mode of the dowels, In the bending moment resistance test of L-Shaped two pin dowel joints construction with Oak wood in not reinforced samples deformations as in Figure 4 were observed, While there was no deformation in the wooden members, bending deformation in the dowel used for the joint was observed, For all of the joint Types, failures initially occurred as opening at the inner face of joints when those joints were subjected to bending moment, The width of the gap between the rail and the post was measured to obtain the degree of decay of the dowel joints, As result, it was seen that the highest rate of the gap was in Oak wood + Chestnut dowel test samples (see Figure 4a4), Oak wood+Oak dowel, Oak dowel+Scots pine dowel, and Oak wood+Beech dowel samples followed respectively (see Figure 4a2, 4a3, and 4a1), respectively.

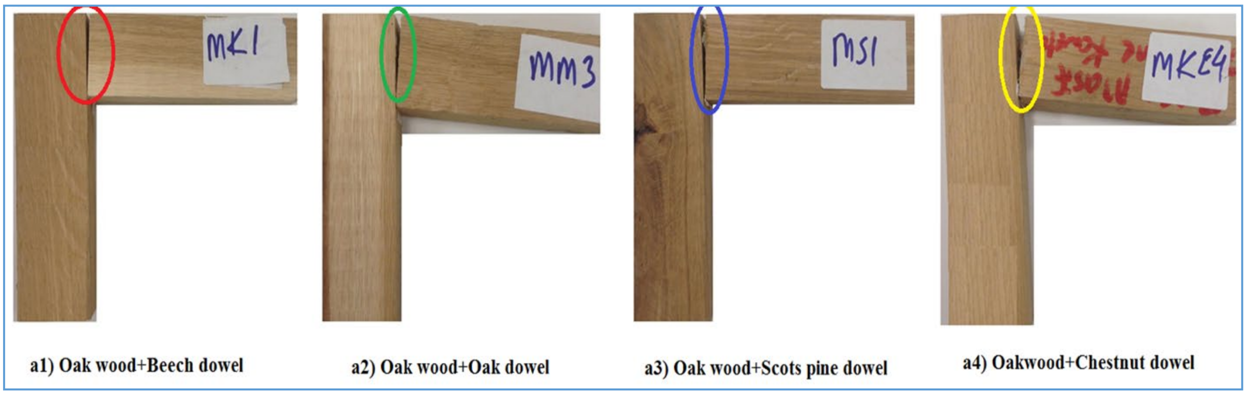

Figure 4: Mode of L-shaped, two pins dowel joint failure not reinforced

The deformation of dowel joints the reinforced with GFRP strengthened are shown in Figure 5, According to the reinforced joints, glass fiber woven fabric has prevented cracking, It was observed for all of the joint Types, failures not occurred as opening at the inner face of joints when those joints were subjected to bending moment,

The gaps were much shorter than the not reinforced samples, For the samples of the Oak wood+Beech dowel+GFRP, cracks occurred on the inner face of the face members (Figure 5c1), The deformation of dowel joints the reinforced with GFRP strengthened are than not reinforced samples, it is seen that the deformation of the dowel joints reinforced with GFRP is less than the samples in reinforcement.

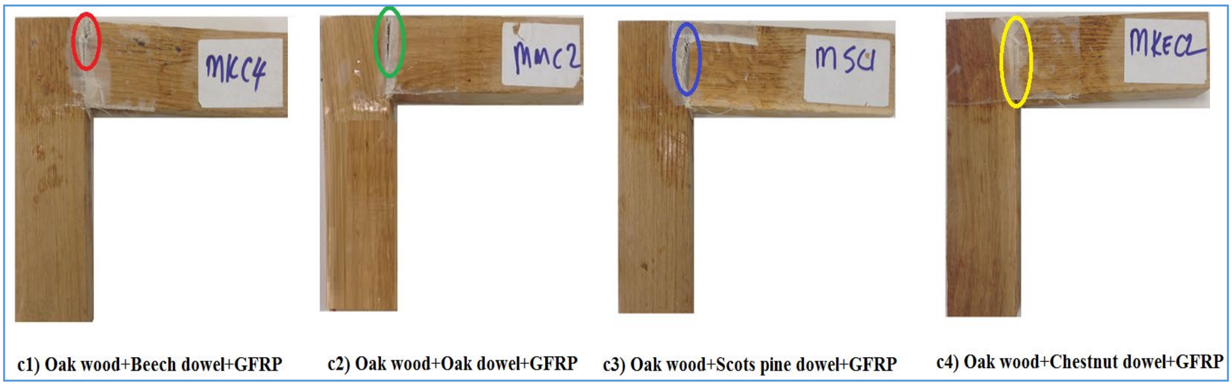

Figure 5: Mode of L-shaped, two pin dowel joint failure reinforced with GFRP

The deformation of the L- Shaped two pin dowel joints with inforced by basalt woven fabric under bending strength test is shown in Figure 6, According to test results, the failures that occurred as a split of particleboard in both the face and butt members, In the joints of the test samples reinforced with BFRP, failures have occurred on the outer face of the basalt woven fiber fabric, In all of the samples the beech dowel joints reinforced with BFRP (Figure 6e1), the failures are almost identical, For the samples of constructed with oak wooden, it is seen that the failures occurred as a result of cracking at the junction of the middle of the basalt woven fabric are more in the Oak wood+Beech dowel+BFRP (Figure 6e1) and Oak wood +Chestnut dowel+BFRP (Figure 6e4) samples.

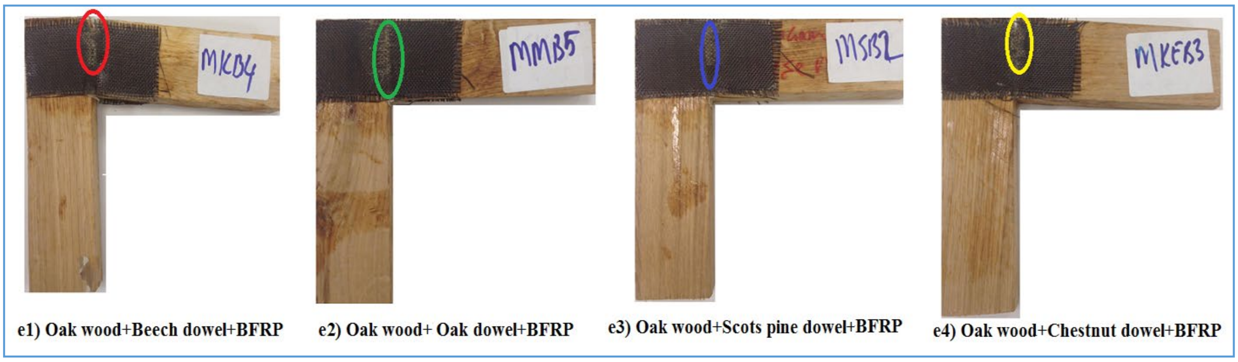

Figure 6: Mode of L-shaped, two pin dowel joint failure reinforced with BFRP

4. Conclusions

The bending moment resistance of L-Shaped, two-pin dowel joints constructed four wood species of the dowels and reinforced with basalt fiber woven fabric and glass fiber woven fabric was investigated. Experimental results indicated that traditional glued Oak dowel joints yielded the highest bending moment resistance among Beech dowel, Chestnut dowel and Scots pine dowel joints. Scots pine dowel joints had the lowest bending moment resistance among the joints evaluated. The mean comparison showed that Beech dowel joints could produce a higher bending moment resistance than chestnut dowel joints. The bending moment resistance value of reinforced joints (for GFRP and BFRP joints, respectively) were 35 % and 62 % higher than not reinforced joints. Researchers could be providing a range of optimum values, for the parameters (wood species, four different wood species of the dowels, fiber woven fabric Types) affecting frame furniture joint bending moment resistance and this could be helpful for engineering design of furniture structures, Future studies will have to investigate the bending moment resistance of L-shaped two-pin dowel joints reinforced with different reinforced fiber woven fabric materials.

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