EFFECT OF THE FABRIC REINFORCEMENT OF STRUCTURAL HOLES IN WOOD BASED PANELS

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ABSTRACT

The objective of this study was to determine the effects of the glass fiber fabric reinforced holes in MDF, PB, OSB, and PL. The fabrics of 19 mm or 50 mm wide were used to reinforce the edge or flat surface of test specimens. The experimental sample groups were formed in 34 different ways. Three different holes configurations were prepared. The samples were subjected to the 3 points bend testing in the flatwise and edgewise directions. As a result of tests, bending strength and modulus of elasticity were determined. The data obtained separately in flatwise and edgewise bending tests were subjected to multiple variance analysis. According to experiment results, the lowest values were obtained in the "fabricless" in both tests. The lowest value was obtained as 12.35 $N \cdot m^{-2}$ (in PB material) in the group 12, which has samples with the fabric on the edge and 2 holes on the surface in the flatwise test, while the highest value was obtained as 49988 $N \cdot m^{-2}$ (in PL material) in the group 19, which has samples with the fabric on the bottom edge and holeless in the edgewise test. According to the materials, the lowest values were as 18.32 $N \cdot m^{-2}$ in PB material, while the highest values were 49988 $N \cdot m^{-2}$ in PL material. It was determined that the BS and MOE values decreased between 0.3 and 49% in terms of the effect of the hole with fabric on the edge. In the holeless groups, the lowest values 18.32 $N \cdot m^{-2}$ in flatwised were obtained in fabricless group in PB, while the highest values 49988 $N \cdot m^{-2}$ in edgewised were obtained in the group of fabric on top surface in PL. The results showed that the fabric reinforcement has a positive impact on the strength.

KEYWORDS: Wood based panel, bending strength, modulus of elasticity, glass fiber fabric, reinforced.

INTRODUCTION

The use of the panel products such as medium-density fiberboard (MDF), particleboard (PB), oriented strandboard (OSB), and plywood (PL) for application areas such as all type furniture or roof and wall sheathing increased in recent years. These panel products need to be drilled several holes during their production. In particular, as Cai and Ross (2010) stated, the bending strength (BS) and modulus of elasticity (MOE) of the panel products are important for the performance characteristics of the panels. As a result, they point out that to understand the effect of holes on strength properties is very important. Eckelman (1975) stated that when constructing furniture frames, it is normally necessary to bore holes through the members to join them together by means of fasteners such as dowels and screws. He specified that these holes must be expected to have a weakening effect upon the members, particularly if they occur at points of high stress. He points out that it is important to take into account any such reductions in strength in the design process to ensure that members are sufficiently designed to withstand the force that would be applied to them in service.

In relation to the BS and MOE of wood-based materials, a lot of research has been done to determine the BS and MOE values of the different panels (Hosseinpourpia et al. 2019, Chen et al. 2019, Ghasemi and Moradi 2017, Akgul et al. 2017, Yoshihara 2016, Xu and Que 2016, Chen et al. 2015, Gao et al. 2015, Svoboda et al. 2015, Yildirim et al. 2015, Baidaea et al. 2015, Zhou et al. 2012, Ayrılmış et al. 2010, Bekhta and Marutzky 2007, Alfredsen and Larnoy 2006, and Eckelman 1975). But there is not another information about the effects of the hole on the BS and MOE of the MDF, PB, OSB, and PL in the literature. Eckelman (1975) developed and presented the expressions which were required to calculate the residual strength of members with holes in them. He carried out static bending tests to determine their BSs on both douglas-fir and PB beams of rectangular cross section to evaluate the predictive power of the expressions which had been developed. He determined by the test results that observed results dropped nearly 15% to 20% below predicted values when holes were drilled near the edge of PB beams tested on edge. In these results obtained, he stated that stress concentrations around the hole in the PB beams could occur. Chen et al. (2019) analyzed the effects of hole sizes on mechanical properties (BS and MOE) of the spruce and Douglas fir samples with and without open-hole. They were prepared four groups (one group without open-hole, and three groups with open-hole which had 13, 16, and 20 mm diameters). They found that open-hole had significant impact on the bending strength.

A lot of researches have been done to determine the effect of drilled holes on the BS of lumber (Falk et al. 2003), timber (Franke et al. 2015), laminated veneer lumber (LVL) (Ardalany et al. 2013a,b). Falk et al. (2003) concluded that hole location may be as important as hole size. Ardalany et al. (2013a, b) state that the larger holes decreased the capacity of the LVL members by up to 52%. Some researcher was investigated the effect of the laminated timber beams (Hallström 1996) or LVL (Ardalany et al. 2013b) reinforced with glass fiber fabric on the holes. Hallström (1996) stated that when the beams were reinforced, a significant increase of the strength. He indicated that great improvements of strength were obtained with the glass fibers.

In this study, in addition to Eckelman's work, the effect of the hole reinforced with glass fiber fabric (hereinafter referred to as "fabric") on the BS was investigated. The aims of this study were to determine the effect of some factors (material, the hole, the fabric, and the reinforced with the fabric of the negative effect of the hole) on the BS and MOE at the wood based materials (hereinafter referred to as "panels").

MATERIALS AND METHODS

Materials

In the preparation of the test samples, 18 mm thick MDF, PB, OSB, and 11-ply PL, were used. The fabrics 19 mm and 50 mm wide were used to reinforce the test specimens. These fabrics were fastened with the DTE 1000 epoxy resin and DTS 1105 hardener on the panels. DTE 1000 epoxy resin is a solvent-free epoxy resin. DTS 1105 hardener is a solvent-free epoxy hardener. The epoxy adhesive mixture was prepared by mixing 3 parts of epoxy resin and 1 unit of hardener.

Methods
Preparation of samples

All panels were cut the 50 mm x 410 mm using the CNC cutting machine. Pre-tests on MDF were carried out to decide the length (100, 200, 300, and 400 mm) of the fabric (wide 50 mm) to be glued. The samples were subjected to bending test according to TS EN 310 and ASTM D 1037 standards. According to the test results, it was decided to use the 200 mm long fabric. Fabrics wide 19 mm were glued to be 410 mm long (from one end to the other) on the edge of the samples which having the dimensions of 50 x 410 mm. The experimental sample groups were formed in 34 different ways. Thus, in total 680 samples were prepared for this study (4 different materials, 34 configurations, 5 repeats).

The samples to be applied to the fabric were treated as follows: 50 mm wide fabrics were cut 200 mm long. The mixture of epoxy adhesive was applied on the areas, where the fabric was to be placed, with a brush by a mold. Then, the fabric was placed on these areas and then epoxy adhesive was applied again. Then the nylon bag was laid on. Then the bag was laid on the samples so that the samples would not stick together. After that these specimens were left to dry 2 days. And then, these samples were removed from the molds and they were allowed to dry thoroughly for 2 more days. Then the excess parts overflowing from the edges of the samples were cleaned by cutting with a circular saw machine. The hole locations and dimensions to be opened on the parts is shown in Fig. 1.
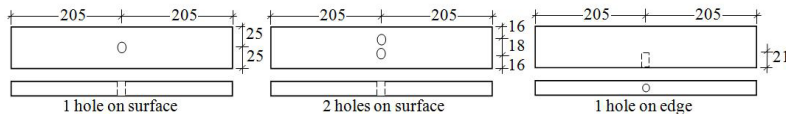

Fig. 1: Hole locations in boards (18 x 50 x 410 mm).

Testing procedures

The specific gravity (SG), and moisture content (MC), BS, and MOE of the samples were determined according to TS EN 323, TS EN 322, TS EN 310, and ASTM D 1037 standards, respectively. The samples were subjected to the 3 points bend testing in the flatwise and edgewise directions shown in Fig. 2. The samples were placed and were bent in the middle of the length (in the flat and edge position) on the Universal test machine Zwick Roel/Z200 at the Mechanical Laboratory of the Yalova University.
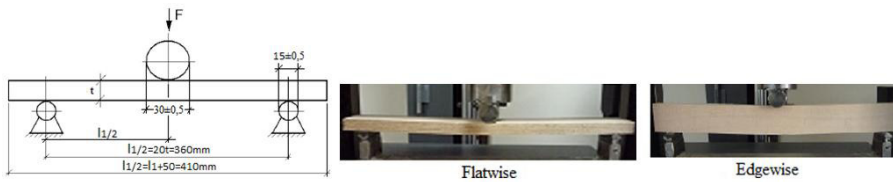
Fig. 2: Bending strength test setup.

The loading speed was adjusted so that failure would occur within an average of 60 ± 30 sec. The F_{max}, BS and MOE values were calculated automatically by the computerized testing device. The BS was calculated in accordance to Eq.1:

$$BS = 3*F_{max}*l_1/2*b*t2 \qquad (N \cdot mm^2) \qquad (1)$$

where: BS - bending strength ($N \cdot mm^2$); F_{max} - the maximum force (N); l_1 - the distance between supports (mm); b - the width of the sample (mm); t - the height (thickness) of the sample (mm).

The MOE were calculated in accordance with Eq. 2:

$$MOE = l_1^3 (F_2 - F_1)/4*b*t^3(a_2 - a_1) \quad (N \cdot mm^2) \qquad (2)$$

where: MOE - modulus of elasticity ($N \cdot mm^{-2}$); $F_2 - F_1$ - the load increase in the proportional section of the load-deflection diagram (N); F_1 = approx. 10% of the largest force (N); F_2 = approx. 40% of the largest force (N); $a_2 - a_1$ - the deflection increase in the half of the sample length corresponding to the load increase (mm).

In determination of the MOE in bending, the 1/3 amount of the greatest force obtained in the BS test was chosen as the elastic region. Load-deflection graphs measured with ± 0.01(unit) sensitivity corresponding to each 50 N force applied were plotted. And the 10% and 40% values of the failure load were recorded. And the 10% and 40% values of the failure load were recorded. The MOE was calculated by using the recorded these values in the elastic deformation zone of the drawn curve.

Analyses of the data

The data obtained separately in flatwise and edgewise bending tests were subjected to multiple variance analysis in SPSS program. And 16 (in flatwise) or 18 (in edgewise) experimental groups, 4 material types, 4 hole groups, 3 (in flatwise) or 4 (in flatwise) hole location groups, 3 fabric groups and 4 fabric location groups on BS and MOE effects were determined. The relationship between these main factors was determined at $p < 0.001$ significance level. When these main factors or their interactions with each other were found to be statistically significant, Duncan test was applied to determine the differences between the groups and to establish homogeneous groups.

RESULTS AND DISCUSSION

Some physical and mechanical properties of the panels used in the experiments were given in Tab. 1. The BS and MOE values of the raw materials (control samples) were in parallel with the values given in chapter 12 of the wood handbook written by Cai and Ross (2010).

Tab. 1: Density and moisture content of wood-based panels.

	MDF	PB	OSB	PL
Moisture content (%)	6.9	8.1	8.6	10.9
Density (g·cm^{-3})	0.759	0.642	0.564	0.62
BS (N·mm^{-2})	35.99	18,29	22,73	63.9
MOE (N·mm^{-2})	3410	3241	4848	8894

The results obtained from the pre-tests were given in Tab. 2. As shown in the table, it was determined that the results of the samples of 20, 30, and 41 cm long glued fabric were almost the same. Therefore, the length of the fabric to be glued to the surfaces of the test samples was determined to be 20 cm.

Tab. 2: Pre-test bending test results (MDF).

Fabric length	Flatwised						Edgewised					
	Control	5 cm	10 cm	20 cm	30 cm	41 cm	Control	5 cm	10 cm	20 cm	30 cm	41 cm
F max (N)	1030	1050	1330	1650	1440	1530	2600	2570	2630	2780	2960	3100
MOE (N·mm^{-2})	3350	3480	3380	3910	3890	3890	20300	21600	22700	21300	21300	22900

The BS and MOE results obtained in experiments were given in Tab. 3. The results show that, in the flatwise test, the lowest value as 12.35 N·m^{-2} (in PB material) was obtained in the group 12, which has samples with the fabric on the edge and 2 holes on the surface, while the highest value as 12912 N·m^{-2} (in PL material) was obtained in the group 2, which has samples with the fabric on the bottom surface and holeless. On the other hand, in the edge test, the lowest value was obtained as 30.27 N·m^{-2} (in PB material) in the group 29, which has samples fabricless and 1 hole on the bottom edge, while the highest value was obtained as 49988 N·m^{-2} (in PB material) in the group 19, which has samples with the fabric on the bottom edge and holeless.

In the flatwise tests, according to the tests groups, the highest BS and MOE values were obtained in the "holeless-fabric on bottom surface" group (group no 2) for MDF, PB, and PL materials, and in the "holeless-fabric on top surface" group (group no 3) for OSB material. Additionally, the lowest BS values for MDF and PB materials and the lowest MOE values for PB material were obtained in the "2 holes on surface-fabric on edge" group (group no 12), while other lowest values were obtained in the "2 holes on surface-fabricless" group (group no 9).

On the other hand, in the edgewise tests, the highest BS values for MDF and PB materials were obtained in the "1 hole on surface-fabric on bottom edge" group (group no 23), while other highest values were obtained in the "holeless-fabric on bottom edge" group (group no 19). Additionally, the lowest BS values were obtained; in the "1 hole-fabric on bottom edge" group (group no 33) for PL material, and in the "1 hole on bottom edge-fabricless" group (group no 29) for other material, while the lowest MOE values were determined in the "1 hole on top edge-fabric on surface" group (group no 32) for MDF material, in the "1 hole on surface-fabricless" group (group no 21) for PB material, in the "2 holes-fabric on surface" group (group no 26) in OSB material, and in the "1 hole on top edge-fabricless" group (group no 30) for PL material.

Tab. 3: Test results (N·m⁻²).

Group No	Hole	Glass fiber fabric	Scheme	MDF		PB		OSB		PL	
				BS	MOE	BS	MOE	BS	MOE	BS	MOE
					(Flatwised)						
1	No	No		35,99	3410	18,32	3214	22,73	4848	63,9	8894
2	No	on bottom surface		47	4423	33	4098	32	5832	73,02	12912
3		on top surface		40	4315	32	3918	33	5928	69	10480
4	No	on edge		39	3710	20,9	3518	23	5000	64,1	9003
5	1 hole on surface	No		26,5	3294	14,12	2988	22,54	5124	53,90	8555
6	1 hole on surface	on bottom surface		37,73	3620	26,88	3495	22,95	4875	62,70	9260
7		on top surface		28,6	3710	14,93	3250	26,53	5460	59,07	9077
8	1 hole on surface	on edge		26,25	3455	16,18	3347	20,53	4383	57,15	8475
9	2 holes on surface	No		22,56	3260	12,74	3044	18,04	4130	45,8	7894
10	2 holes on surface	on bottom surface		33	3677	21,18	3320	24,17	5023	53,5	8683
11		on top surface		24	3447	12,57	3283	20,17	5207	52,03	8967
12	2 holes on surface	on edge		21,98	3380	12,35	2962	19,4	4225	53	8400
13	1 hole on edge	No		35,32	3364	17,22	2976	19,75	4408	57,26	9560
14	1 hole on edge	on bottom surface		44,7	3870	31,6	3625	30,45	5150	66	9040
15		on top surface		35,03	3967	17,3	3440	23,05	5150	64,63	9380
16	1 hole on edge	on edge		36,43	3443	18,5	3223	20,1	4350	51,55	8978
					(Edgewised)						
17	No	No		82,2	20147	34	14553	46,1	19200	194,6	39440
18	No	on surface		93	23587	40	16010	57	22010	209	43014
19	No	on bottom edge		88	25365	47	23282	60	28918	230	49988
20		on top edge		86	24387	43	21025	58	27825	225	48783
21	1 hole on surface	No		82,12	19800	32,36	13640	42,46	21220	184,6	37820
22	1 hole on surface	on surface		97,83	21333	37,77	13800	53,8	20133	198,67	39767
23	1 hole on surface	on bottom edge		98,93	22867	56,07	18867	55,45	24250	204,4	43300
24		on top edge		90,90	22933	41,23	19200	49,45	23550	206,33	46533
25	2 holes on surface	No		77,44	20280	33,56	15480	42,58	20140	156,6	38700
26	2 holes on surface	on surface		82,68	19825	37,7	14700	45,25	18600	170	40933
27	2 holes on surface	on bottom edge		90,87	23567	53,07	18933	49,1	23000	165,67	43500
28		on top edge		85,2	23500	33,7	18700	53,65	24400	170	43600
29	1 hole on bottom edge	No		58,65	19750	30,27	14333	38,2	19733	173,67	40767
30	1 hole on top edge			61,65	18900	32,3	14000	44,33	20067	161	34550
31	1 hole on bottom edge	on surface		63,33	19100	34,57	14900	57,55	21300	162,33	40267
32	1 hole on top edge	on surface		70,25	18700	40	14450	58,7	19500	160,5	35300
33	1 hole on bottom edge	on bottom edge		62,5	20667	37,9	16533	47,3	23900	150	41433
34	1 hole on top edge	on top edge		75,77	21267	41,80	18133	55,65	23950	174,33	37900

In Tab. 3, according to the flatwise tests, the presence of 2 holes on the surface of the sample caused much more strength decrease. On the other hand, according to the edgewise tests, the

presence of 1 hole on the edge of the sample caused much more strength decrease than others.

When the test results were evaluated in terms of materials, in both flatwise and edgewise tests, the BS and MOE values were the lowest in PB, the highest in the PL. The reason why these values are high or low can be explained as the BS and MOE values of the material itself are higher or lower than others. According to the results of variance analysis, it was determined that 4 different homogeneous groups were formed (Tab. 4).

Tab. 4: Homogenous groups (HG) according to the materials (N·mm^{-2}).

Materials	Flatwised				Edgewised			
	BS	HG	MOE	HG	BS	HG	MOE	HG
MDF	33.38	B	3647	C	80.41	B	21443	C
PB	19.99	D	3356	D	39.24	D	16697	D
OSB	23.65	C	4943	B	50.81	C	22317	B
PL	59.16	A	9222	A	183.15	A	41422	A

The test results of the "fabricless" groups (group 1, 5, 9, and 13 in flatwise tests and group 17, 21, 25, 29, and 30 in edgewise tests) were evaluated to determine the effect of the hole. As a result, BS values were found generally that in the flatwise tests, the "holeless" groups was high and the "2 holes on surface" groups was low, whereas, in the edgewise tests, the "holeless" groups was high and the "1 hole on edge" groups was low. The MOE values were determined generally; the "holeless" was high in both tests; the "2 holes on surface" in flatwise tests, and also "1 hole on edge" in edgewise tests were low. According to these results, it was clear that the existence of a hole on the material and the increase in the number of such holes reduces the strength. The reason for this decrease can be explained as the reduction of the cross-section area of the material to react to the applied load. In parallel with the results obtained in the studies of Eckelman (1975), Falk et al. (2003), and Chen et al. (2019), the hole was determined to reduce strength. The effect of the hole was evaluated statistically and their homogeneous groups in Tab. 5 were obtained according to variance analysis. 4 homogeneous groups were obtained for BS in PB and MDF and for MOE in MDF and PL in the flatwise tests and for BS in MDF and for MOE in PB in the edgewise tests. 3 homogeneous groups were observed in others.

Tab. 5: Homogenous groups (HG) according to the hole.

Groups	Flatwised								Edgewised							
	MDF		PB		OSB		PL		MDF		PB		OSB		PL	
	BS	HG	BS	HG	BS	HG	BS	HG	BS	HG	BS	HG	BS	HG	BS	HG
1	41	A	26	A	28	A	68	A	87	B	41	A, B	55	A	215	A
2	30	C	18	C	23	B	58	B	93	A	42	A	50	B	199	B
3	25	D	15	D	21	C	51	C	84	C	40	B	48	C	166	C
4	38	B	21	B	23	B	60	B	65	D	36	C	50	B	164	C
	MOE	HG	MOE	HG	MOE	HG	MOE	HG	MOE	HG	MOE	HG	MOE	HG	MOE	HG
1	3965	A	3687	A	5402	A	10322	A	23371	A	18718	A	24488	A	45306	A
2	3520	C	3270	B	4961	B	8842	C	21733	B	16377	C	22288	B	41855	B
3	3441	D	3153	C	4646	C	8486	D	21793	B	16953	B	21535	C	41683	B
4	3661	B	3316	B	4764	B, C	9239	B	19731	C	15392	D	21408	C	38370	C

Groups: 1= holeless, 3 = 2 holes on surface, 4 = 1 hole on edge.

When the results were analyzed statistically according to the hole location, homogeneous groups were obtained as seen in Tab. 6.

Tab. 6: Homogenous groups (HG) according to the hole location.

	MDF		PB		OSB		PL		MDF		PB		OSB		PL	
Flatwised																
Groups	BS	HG	BS	HG	BS	HG	BS	HG	MOE	HG	MOE	HG	MOE	HG	MOE	HG
1 (holeless)	41	A	26	A	28	A	68	A	3965	A	3687	A	5402	A	10322	A
2 (on surface)	28	C	17	C	22	B	55	C	3480	C	3211	C	4803	B	8664	C
3 (on edge)	38	B	21	B	23	B	60	B	3661	B	3316	B	4764	B	9239	B
Edgewised																
Groups	BS	HG	BS	HG	BS	HG	BS	HG	MOE	HG	MOE	HG	MOE	HG	MOE	HG
1 (holeless)	87	A	41	A	56	A	215	A	23371	A	18718	A	24488	A	45306	A
2 (on surface)	88	A	41	A	49	C	182	B	21763	B	16665	B	21912	B	41769	B
3 (on bottom edge)	62	C	34	C	48	C	162	C	19839	C	15256	C	21644	B, C	40822	C
4 (on top edge)	69	B	38	B	53	B	165	C	19622	C	15528	C	21172	C	35917	D

In the flatwise tests, 2 different homogeneous groups were formed in both BS and MOE values of OSB. In edgewise tests, 4 different homogeneous groups were obtained for the MOE values of PL. In the others, 3 different homogeneous groups were formed. The highest values were obtained mostly in the "holeless" groups both tests. The lowest BS and MOE were obtained in the "on surface" groups in the flatwise tests. the lowest BS were determined mostly the "bottom edge" groups and the lowest MOE were determined generally in the "top edge" group in the edgewise tests. As a result, Falk et al. (2003) stated that the hole location affects the bending strength.

The groups without holes (in groups 1-4, 17-20) were evaluated to determine the effect of the fabric (Tab. 3). The lowest values were obtained as 18.32 $N \cdot m^{-2}$ (in flatwised) and as 34 $N \cdot m^{-2}$ (in edgewised) in fabricless groups in PB, while the highest values were obtained as 10480 $N \cdot m^{-2}$ (in groups of fabric on top surface in flatwised) and 49988 $N \cdot m^{-2}$ (in groups of fabric on bottom edge in edgewised) in PL. The highest BS and MOE were obtained; in the "on top surface" group for OSB and PL and in the "on bottom surface" group for MDF and PB in the flatwise tests (in groups 1-4); in the "on bottom edge" group in all materials except for the BS value (was obtained in the "on surface" group) of the OSB in edgewise tests. In flatwise tests, as can be seen, in all materials, the sample group which was "fabric on surface" was seen to cause higher strength. However, in OSB, it was determined that the fabric on the bottom surface of the sample was more effective than the fabric on the top surface. The reason for this is due to the structural features of the OSB as seen in the failure shapes. It can be confirmed as the top surface of the material was swelled and deformed by the fabric on the bottom surface.

When the test results were analyzed statistically in terms of the effect of fabric, homogeneity groups that obtained according to variance analysis results were obtained as shown in Tab. 7. In all materials, the highest values were obtained; in the "fabric on surface" in the flatwise tests; in the "fabric on edge" in the edgewise tests. The lowest values were obtained in the "fabricless" in both tests. It was determined that the fabric on surface provided compared to the fabricless samples an increase of; between 12 and 52% in the flatwise tests; between 1 and 28% in the edgewise tests. Statistically, it was seen that the "fabric on surface" was in the highest. It was also clearly seen that the effect of the fabric on surface was higher than the effect of the fabric on edge. Similar to

these results, Hallström (1996) stated that when the beams were reinforced, a significant increase of the strength.

Tab. 7: Homogenous groups (HG) according to the fabric.

Groups	Flatwised								Edgewised							
	MDF		PB		OSB		PL		MDF		PB		OSB		PL	
	BS	HG	BS	HG	BS	HG	BS	HG	BS	HG	BS	HG	BS	HG	BS	HG
1	30	C	16	C	21	B	55	B	72	C	33	C	43	B	174	C
2	36	A	24	A	27	A	63	A	81	B	38	B	55	A	180	B
3	31	B	17	B	21	B	57	B	85	A	44	A	54	A	191	A
	MOE	HG	MOE	HG	MOE	HG	MOE	HG	MOE	HG	MOE	HG	MOE	HG	MOE	HG
1	3332	C	3056	C	4628	B	8726	B	19775	C	14401	B	20072	B	38255	C
2	3879	A	3554	A	5328	A	9725	A	20509	B	14772	B	20309	B	39856	B
3	3497	B	3263	B	4490	B	8714	B	23069	A	19334	A	24974	A	44380	A

Groups: 1=fabricless, 2= fabric on surface, 3= fabric on edge.

The tests results were evaluated statistically in terms of the fabric location. And the obtained homogeneous groups were given in Tab. 8.

Tab. 8: Homogenous groups (HG) according to the fabric location.

Groups	Flatwised								Edgewised							
	MDF		PB		OSB		PL		MDF		PB		OSB		PL	
	BS	HG	BS	HG	BS	HG	BS	HG	BS	HG	BS	HG	BS	HG	BS	HG
1	30.09	D	15.6	D	20.77	B	55.22	B	72.41	C	32.5	D	42.73	B	174.09	D
2	40.61	A	28.16	A	27.39	A	63.81	A	81.42	B	38.01	C	54.46	A	180.1	C
3	31.91	B	19.2	B	25.69	A	61.18	A	85.08	A	48.51	A	52.96	A	187.52	B
4	30.91	C	16.98	C	20.76	B	56.45	B	84.47	A	39.93	B	54.19	A	193.92	A
	MOE	HG	MOE	HG	MOE	HG	MOE	HG	MOE	HG	MOE	HG	MOE	HG	MOE	HG
1	3332	D	3056	D	4628	B	8726	C	19775	C	14401	B	20072	B	38255	C
2	3897	A	3635	A	5220	A	9974	A	20509	B	14772	B	20309	B	39856	B
3	3860	B	3473	B	5436	A	9476	B	23116	A	19404	A	25017	A	44555	A
4	3497	C	3263	C	4490	B	8714	C	23022	A	19265	A	24931	A	44204	A

Groups: 1=fabricless, 2=on bottom surface, 3=on top surface, 4=on edge.

Furthermore, the results were examined in terms of the effect of the hole with fabric on the edge (groups 4, 8, 12, and 16) in the flatwise tests. And, the BS and MOE values were as follows respectively it was found. It decreased in the "1 hole on edge" group, 7% and 7% for MDF, 12% and 8% for PB, 13% and 13% for OSB, and 20% and 0.3% for PL. It decreased in the "1 hole on surface" group, 49% and 7% for MDF, 23% and 5% for PB, 11% and 12% for OSB, and 11% and 6% for PL. It decreased in the "2 holes on surface" group, 44% and 9% for MDF, 41% and 16% for PB, 16% and 19% for OSB, and 17% and 7% for PL. According to these ratios, the presence of 2 holes on the surface was seen to cause the most decrease in strength.

Failure mode

In the "fabricless" groups, all samples except MDF and OSB samples in edgewise were cracked. MDF samples in edgewise were broken. Any deformation was seen in OSB samples. However, a cracking sound was heard during the experiment. Possibly separations in the inner layers of the OSB have occurred.

Only MDF samples in groups 17, 21, 23, 24, 25, 27-30, 33, and 34 were broken. On the other hand, in the groups 6, 14, and 23 in OSB was surged by squeeze from the side of the load

line applied to the top surface. In PL, in groups 1, 5, 6-11, 14-16, 22, and 32, the layers of the PL were separated from each other. Besides, the almost other samples were cracked.

The failure shapes of the "fabric on edge" samples (in groups 4, 8, 12, and 16) in flatwise tests similar. The fabric was separated from the edge and the material was cracked. On the other hand, it was found that the reduction ratio in strength for the samples with hole on the edge was less than the others (Tab. 3). As it was understood from the shape of deformation, the fabric on the edge carried more load than the others and as a result, the fabric was opened by wriggle from below to the hole. It also appears that the samples were broken up to the hole and cracked upwards through the hole. On the other hand, in other materials, the fabric was slightly opened and the material was cracked on the bottom surface. In addition, it was seen that the PL samples were separated from its layers.

The "hole on edge" group had been determined to have higher strength than the "1 hole on surface" group and "2 holes on surface" group. In addition, in the "1 hole on edge" group, the material was cracked by being squeezed from the hole to both upwards and towards the side of the load line applied on the top surface. This was shown that the fabric was higher than the strength of the material. In the "fabric on bottom surface" and "1 hole on edge" groups, in the MDF, OSB, and PL, the fabric was not deformed, and the material was not also cracking. In PL, the material was separated from the layer at the level of the hole. The fabric in PB was opened and torn and the material was cracked.

CONCLUSIONS

According to the results, in the flatwise test, the lowest value was obtained as 12.35 $N \cdot m^{-2}$ in the samples with the fabric on the edge and 2 holes on the surface for PB material, while the highest value was obtained as 12912 $N \cdot m^{-2}$ in the samples with the fabric on the bottom surface and holeless for PL material. On the other hand, in the edge test, the lowest value was obtained as 30.27 $N \cdot m^{-2}$ in the samples fabricless and 1 hole on the bottom edge for PB material, while the highest value was obtained as 49988 $N \cdot m^{-2}$ in the samples with the fabric on the bottom edge and holeless for PB material.

According to the materials, for the BS and MOE values in both tests, the lowest values were as 18.32 $N \cdot m^{-2}$ for BS and as 2962 $N \cdot m^{-2}$ for MOE in PB, while the highest values were as 230 $N \cdot m^{-2}$ for BS and as 49988 $N \cdot m^{-2}$ for MOE in the PL.

In the holeless groups, the lowest values were obtained as 18.32 $N \cdot m^{-2}$ (in flatwised) and as 34 $N \cdot m^{-2}$ (in edgewised) in fabricless groups in PB, while the highest values were obtained as 10480 $N \cdot m^{-2}$ (in groups of fabric on top surface in flatwised) and 49988 $N \cdot m^{-2}$ (in groups of fabric on bottom edge in edgewised) in PL.

It was determined that the BS and MOE values of the samples with hole in terms of the effect of the hole with fabric on the edge decreased between 0.3 and 49%. The existence of a hole on the material and the increase in the number of such holes reduces the strength. The presence of hole on the sample caused much more strength decrease.

The lowest values were obtained in the "fabricless" in both tests. It has been determined that the fabric on the surface increases resistance up to 52% compared to fabricless samples. The fabric on the bottom surface of the sample was more effective than the fabric on the top surface. The effect of the fabric on the surface of the sample was higher than the effect of the fabric on the edge of the sample. The effect of the fabric on the edge of the sample was cause for increase compare to the samples the fabricless. If the sample has any holes, it may be advisable to reinforce, for example, with a fabric.

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