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THE EFFECTS OF DIFFERENT EDGE JOININGS ON THE RESISTANCE OF EDGE GLUED WOODEN PANELS

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Abstract

Edge glued wooden panels (EWP) are composite materials obtained from natural solid wood after purifying them from defects and once again joining in the form of long, narrow strips of wood, thus having the closest characteristics to wood. Due to its not being harmful to human health and the environment, the importance of this material is increased. The application of flat edge joinings at a 90º angle from any joining application in the joining side-by-side of long, narrow strips of wood limits the mechanical resistance of the materials in the production of EWP. In this study, the effects of obtaining the long, narrow strips of wood at different angles other than the 90º angle on the across the grain bending strength and cleavage resistance to the fibers were investigated. At the conclusion of the study, the 45º cutting angle produced the best result.

Keywords: Edge Joining, Edge Glued Wooden Panel, Resistance

Short title: Effects of Different Edge Joinings on Resistance of EWPs

1. Introduction

It has been impossible to obtain the output and quality of natural solid wood in panels produced with various methods, although it has been desired. Furthermore, the panels based on wood also could not decrease the demand of consumers for solid wood. Nevertheless, since it is impossible to completely eliminate the negative characteristics in the structure of solid wood, such as knots, splits, resins and warps, it is necessary to cut down too many trees from the forests in order to be able to obtain high quality solid wood. One of the materials developed for being able to overcome these problems and for being able to utilize wood in the best manner is the composite called “edge glued wooden panel” (EWP), which has the characteristic of layered wooden-based material and the use of which has also become widespread in Turkey, especially in recent years. Since EWPs were developed with the logic of rejoining the width and length after purifying the defects from natural wood, it is the panel material having the closest characteristics to natural solid wood. Furthermore, the adhesives used are not harmful to human health and the environment. Due to these advantages, it has been in great demand in the production of furniture in recent years, especially in the United States and Europe [1,2,3].

While finger joints are applied in the end-to-end length joinings in the production of EWP, flat joinings are made without applying any joint form in the side-by-side edge joining applications. This situation creates some problems in the mechanical and physical characteristics. In the studies made it was observed that when the humidity is not within the suitable 12-16% range for EWP, then resistances decreased. Along with changes in humidity in particular, openings occur in parallel to the fibers and the bending strength decreases. Furthermore, it was determined that openings occurred in the top parts of the panels with 1% changes in humidity. When these problems were taken into consideration in studies made for increasing the joining resistance in the width direction, it appeared that better results were obtained in the applications of joinings other than flat joinings. Especially in the finger joints, it was observed that the mechanical resistance values increased as the length of the fingers increased [2,4,5,6,7].

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In this study, the effects on resistance will be examined when producing EWPs as a healthy and natural material, by using cuts at different angles in bringing the long, narrow strips of wood side-by-side, rather than the 90º flat cut used in the present production.

2. Materials and Methods

2.1. Materials

Scotch pine (*Pinus sylvestris* L.) was used in the study. This wood species was preferred because it is the wood used the most in Turkey. The kiln-dried first-class quality wood was procured through randomized selection from the market.

The PVA-D3 adhesive, which is not harmful to human health and the environment, was used in accordance with the cold pressing procedure in the preparation of the test specimens. The D3 adhesive, which is used extensively in the production of EWPs, is an adhesive that can be applied either hot or cold. Its viscosity value is 13,000+2,000 mPas at 20ºC, pH value is ~3, freezing point is -30ºC, the lowest film formation temperature is +10ºC and open life is 6-10 minutes at 20ºC. Its main characteristic features are the fact that it has a medium viscosity, a rapid hardening characteristic and a long period of remaining open [8].

2.2. Preparation of the test specimens

The preparation of the test specimens started with the production of the panels. For the study, solid long, narrow strips of wood were cut from the Scotch pine (*Pinus sylvestris* L.) lumber at 90º, 45º and 30º angles in the dimensions of 50x1020x23 mm. The long, narrow strips of wood were kept at a temperature of 20±2ºC and a relative humidity of 65±5% until they reached a humidity of 12±0.5%. Of the long, narrow strips of wood cut, those without knots, color and fiber defects were chosen and two each EWPs were produced in the dimensions of 1000x1000x20 mm by applying the D3 adhesive in the amount of 150-160 g/m² with a brush in a manner that would constitute an equal layer on a single side of the bonding surface according to the TS 4315 and prEN 286 standards (Figure 1). It was completed after applying the cold pressing for 30 minutes under workshop conditions. Test specimens were obtained from the panels produced in conformance with the TS EN 326-1 standards. Fifteen each specimens were prepared for each test.

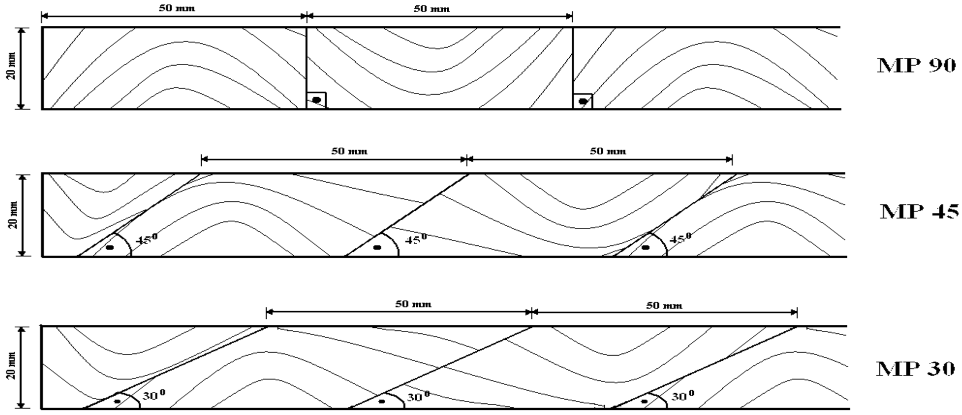

Figure 1. Cross-sectional appearance of the edge glued wooden panels (EWPs) produced

2.3. Methods

2.3.1. Test of across grains (across to grains) resistance and determination of the modulus of elasticity

After preparing the specimens in the dimensions of 450x50x20 mm for making across grains bending strength tests, they were kept in a climatization chamber at a temperature of 20±2ºC and a relative humidity of 65±5% until they reached an equivalent moisture of content of 12±2%. As it can be observed in Figure 2, the test specimens were placed in the universal test machine and tests were made according to TS EN 310.

The maximum resistance at the moment when the test specimen broke was read via the computer monitor connected to the test machine and the bending strength was calculated according to Equation 1.

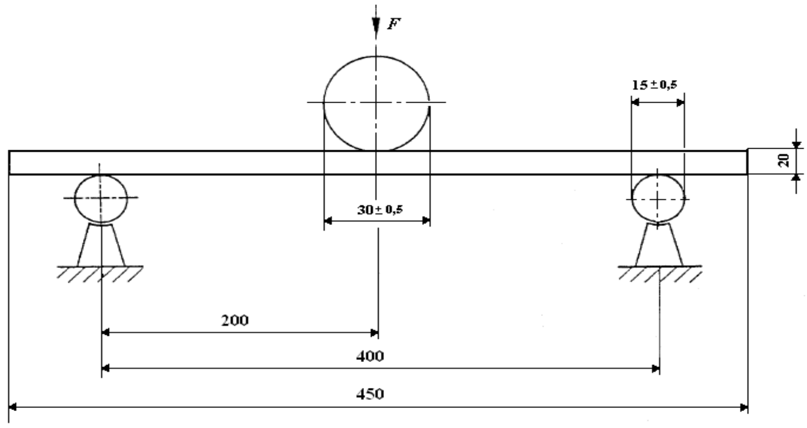

Figure 2. Bending strength test mechanism (measurements in mm)

$$\sigma_e = \frac{3.P_{max}.\ell}{2.b.h^2} \tag{1}$$

Here:

σ_e = Bending strength (N/mm²),

P_{max} = Largest force measured at the moment of breaking (N)

ℓ = Opening between the fulcrums (mm),

b = Width of test specimen (mm),

h = Height of test specimen (mm)

Equation 2 was used in the determination of the modulus of elasticity with the aid of the bending difference ($\Delta a = a_2 - a_1$) of the bending amounts in the specimens for the force difference (ΔF) implemented in the deformation region.

$$E = \frac{\Delta F.\ \ell^3}{4.b.h^3.\ \Delta a} \tag{2}$$

Here:

E = Modulus of elasticity in bending (N/mm^2)

2.3.2. Cleavage Test

The specimens that were used for the cleavage test were prepared in conformance with the ASTM D 143 standard as can be observed in Figure 3. The test pieces prepared were kept in a climatization chamber at a temperature of 20±2ºC and a relative humidity of 65±5% until they reached an equivalent moisture of content of 12±2% and tests were made in the universal test machine.

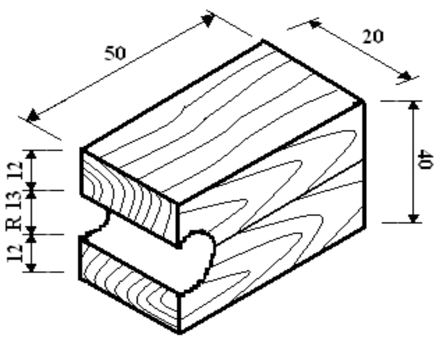

Figure 3. Test piece for the cleavage test (measurements in mm)

The cleavage resistance was calculated by using Equation 3.

$$\sigma_{C} = \frac{P_{max}}{A} \qquad (3)$$

Here:

σ_C = Cleavage resistance (N/mm²),

P_{max} = Largest force determined at moment of breaking (N)

A = Cross-section of split area (mm²)

2.4. Evaluation of the data

First of all, the analysis of normality was implemented on the values obtained in the tests in the SPSS program and the values that distorted the group were removed and 10 each values were examined for each comparison group. The Analysis of Variance (ANOVA) was used for the data obtained. When there was a significant difference among the groups at the conclusion of the analysis, Duncan test was implemented and a comparison of differences among the average values was made.

3. Results and Discussion

The average bending strength values across grains and the results of the analysis of variance have been given in Table 1.

Table 1. Bending strength across grains and analysis of variance (N=10)

	$\bar{X}$ (N/mm^2)	Standard Deviation	Standard Error	Degree of Freedom	Total of the Squares	Average of the Squares	F	p
MP30	4.3840	0.1576	0.0498	2	7,021	3,511	5,582	0.009*
MP45	5.3560	1.2279	0.3882					
MP90	4.2830	0.5952	0.1882					
Total	4.6743	0. 098	0.1661	29	24,002			

* A difference of $p < 0.05$ is significant.

According to the analysis of variance a statistically significant difference was found among the EWPs produced in different angles. According to this result, the Duncan test implemented among the different cutting angles and the test results have been given in Table 2.

Table 2. Duncan test analysis of the bending strength across grains

	Cutting Angle		Average Difference	p
Duncan	MP30	MP45	- 0.9720	0.011*
		MP90	0.1010	0.778
	MP45	MP30	0.9720	0.011*
		MP90	1.07 0	0.005*
	MP90	MP30	- 0.1010	0.778
		MP45	- 1.0730	0.005*

* A difference of $p < 0.05$ is significant.

According to the Duncan test results, a statistically significant difference was observed between the MP30 and MP45 and the MP45 and MP90. However, a statistically significant difference was not observed between the MP30 and MP90. According to the average values, the best result for bending strength across grains was shown in the EWP coded MP45 at 5.3560 N/mm^2.

The analysis of variance test results made for the modulus of elasticity for bending across grains have been given in Table 3.

Table 3. Analysis of variance for determining the modulus of elasticity of bending across grains (N=10)

	$\overline{X}$ (N/mm^2)	Standard Deviation	Standard Error	Degree of Freedom	Total of Squares	Average of Squares	F	p
MP30	6.1610	0.4333	0.1370	2	86,991	43,495	23,327	0.000*
MP45	10.3320	2.2147	0.7004					
MP90	8.2 00	0.7078	0.2238					
Total	8.2377	2.1762	0.3973	29	137,335			

* A difference of $p < 0.05$ is significant.

According to the analysis of variance a statistically significant difference was found among the various cutting angles.

Accordingly, the results of the Duncan test made have been given in Table 4.

Table 4. The Duncan test analysis for determining the modulus of elasticity of bending across grains

	Cutting Angle		Average Difference	p
Duncan	MP30	MP45	- 4.1710	0.000*
		MP90	- 2.0590	0.002*
	MP45	MP30	4.1710	0.000*
		MP90	2.1120	0.002*
	MP90	MP30	2.0 90	0.002*
		MP45	- 2.1120	0.002*

* A difference of $p < 0.05$ is significant.

According to the Duncan test results for the modulus of elasticity, a statistically significant difference was found between the MP45 and MP90, the MP30 and MP45, and the MP30 and MP90. According to the average values, the best result for the modulus of elasticity for bending across grains was seen in the EWP coded MP45 at 10.3320 N/mm^2. The lowest of the modulus of elasticity results appeared in the EWP specimens coded MP30 at 6.1610 N/mm^2 and is a situation that should be taken into consideration. Despite the fact that a difference was not observed between the MP30 and MP90 according to the bending strength values, the MP90 produced better results in the modulus of elasticity and it can be stated that in the plastic deformation phase prior to breaking at the ends of the MP30 long, narrow strips of wood produced with a 30º angle, were the cause of an increase in the compression tension.

The results of the analysis of variance for the cleavage test across grains have been given in Table 5.

Table 5. Analysis of variance of the cleavage test (N=10)

	$\overline{X}$ (N/mm^2)	Standard Deviation	Standard Error	Degree of Freedom	Total of Squares	Average of Squares	F	p
MP30	0.6810	0.0619	0.0196	2	0.138	0.069	12,141	0.000*
MP45	0.8330	0.0769	0.0243					
MP90	0.6990	0.0854	0.0270					
Total	0.7377	0.1002	0.0183	29	0.291			

* A difference of $p < 0.05$ is significant.

According to Table 5, a statistically significant difference emerged among the three different model panels. Accordingly, the results of the Duncan test made among the models have been given in Table 6.

Table 6. The Duncan test analysis of the cleavage test across grains

	Cutting Angle		Average Difference	p
Duncan	MP30	MP45	- 0.1520	0.000*
		MP90	- 0.0180	0.598
	MP45	MP30	0.1520	0.000*
		MP90	0.1340	0.000*
	MP90	MP30	0.0180	0.598
		MP45	- 0.1340	0.000*

* A difference of $p < 0.05$ is significant.

According to the results of the Duncan test, while there was a statistically significant difference observed between the MP30 and MP45, and the MP45 and MP90, a statistically significant difference did not emerge between the MP30 and MP90. According to the average values, the best cleavage resistance were shown in the EWP coded MP45 at 0.8330 N/mm^2. The fact that a statistically significant difference did not emerge between the MP30 and MP90 is a result that should be dwelled upon.

4. Conclusion

According to the study results, the EWP specimens coded MP45, which were produced with long, narrow strips of wood cut at a 45º angle showed the best resistance in the bending strength across grains at 5.3560 N/mm^2, in the determination of the modulus of elasticity at 10.3320 N/mm^2 and in the cleavage resistance at 0.8330 N/mm^2. These results are in conformance with the studies in the literature [9]. Nevertheless, while it was expected that the MP30 specimens produced with the long, narrow strips of wood at a 30º cutting angle would produce a better result in all the tests made compared to the MP90 specimens produced with the long, narrow strips of wood at a 90º cutting angle, the fact that a statistically significant difference did not emerge is an important result of this study, which should be dwelled upon. This situation can be explained by not being able to show sufficient resistance against tensions due to a decrease in the thicknesses of the long, narrow strips of wood at the end parts of the cut, despite the fact that as the angle value decreases, the area of the adhesive surface increases.

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