Comparative Analysis of the Nail and Screw Withdrawal Resistances of Fir (*Abies Mill.*), Cherry (*Prunus Avium L.*), Walnut (*Juglans Regia L.*) and Oak (*Quercus L.*) Wood

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ABSTRACT

In this study, the nail and screw withdrawal resistance (NWR and SWR) of wooden materials obtained from Fir (*Abies Mill.*), Cherry (*Prunus avium L.*), Walnut (*Juglans regia L.*) and Oak (*Quercus L.*) on the tangential, radial and transverse cut surfaces were researched. A total of 480 each samples were prepared in conformance with ASTM 1761 in order to determine the effect of the species of wood and type of cut surface on the NWR and SWR and the NWR and SWR of these samples were measured on the universal test machine. The data obtained was analyzed statistically and the findings obtained were interpreted. According to this, the highest NWR and SWR was on the radial cut surfaces in oak. As the specific gravity increases, the NWR and SWR increases. In general, the radial cut surfaces have a higher NWR and SWR compared to the tangential and transverse cut surfaces and the tangential cut surfaces have a higher NWR and SWR compared to the transverse cut surfaces.

Keywords: Wood, Nail, Screw, Withdrawal Resistance

Göknar *(Abies Mill.)*, Kiraz *(Prunus Avium L.)*, Ceviz *(Junglans Regia L.)* ve Meşe *(Quercus L.)*'nin Çivi ve Vida Tutma Dayanımlarının Karşılaştırmalı Analizi

ÖZET

Bu çalışmada Göknar *(Abies Mill.)*, Kiraz *(Prunus avium L.)*, Ceviz *(Junglans regia L.)* ve Meşe *(Quercus L.)'* den elde edilen ahşap malzemenin teğet, radyal ve enine kesit yüzeylerindeki çivi ve vida tutma dayanımları araştırılmıştır. Ağaç ve kesit yüzey türünün çivi ve vida tutma dayanımına etkisinin belirlenmesi için ASTM D 1761'e uygun olarak 480 adet numune hazırlanmış ve üniversal test makinesinde bu numunelerin çivi ve vida tutma dayanımları ölçülmüştür. Elde edilen veriler istatistiksel olarak analiz edilmiş elde edilen bulgular yorumlanmıştır. Buna göre en yüksek çivi ve vida tutma dayanımı Meşe'de radyal kesit yüzeylerde ortaya çıkmaktadır. Özgül ağırlık arttıkça çivi ve vida tutma dayanımı artmakta, genelde radyal kesit yüzeyler teğet ve enine kesit yüzeylere kıyasla ve teğet kesit yüzeyler de enine kesit yüzeylere kıyasla daha yüksek çivi ve vida tutma dayanımı vermektedir.

Anahtar kelimeler: Ahşap Malzeme, Çivi tutma dayanımı, Vida tutma dayanımı

INTRODUCTION

Mechanical fastenings (nails, screws, bolts, etc.) are in the forefront as the assembly elements used the most, along with glues, in the production of products, such as furniture and furnishing elements, wooden houses, roofs, sea vessels, and gift items for which wood and wood-base materials are used and in

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the assembly of components and accessories, which form the system of the products. Especially the use of screws is becoming even more widespread in joints and in fitting elements related to joints due to the fact that modularity has come into the forefront, especially in the manufacture of furniture and furnishing elements. Furthermore, solid wooden panel production with the methods of edge joints and the use of these panels in the production of panel furniture is one of the constructive practices frequently used. In this situation, the strength characteristics according to the species of wood of these fastenings acquire importance.

Nails or screws in use resist either withdrawal loads or lateral loads, or a combination of the two. Both withdrawal and lateral resistance are affected by the wood, the nail and screw, and condition of use. The resistance of a nail or screw shank to direct withdrawal from a piece of wood depends on the density and fiber direction of the wood, moisture content changes in the wood, the diameter of the nail or screw, type of shank, nail point, time the nail or screw remains in the wood, surface coatings, and the depth of penetration.

It was determined that the sessile oak has the highest SWR in the study for determining the effect of the structural characteristics, depending on the species of wood and wood-base materials, on the NWR and SWR, and this was followed by the eastern beech, Calabrian pine, Crimean pine, cedar of Lebanan, Scotch pine and Uludağ fir, respectively. The highest value was obtained in sessile oak for NWR and it was followed by eastern beech, cedar of Lebanon, Calabrian pine, Crimean pine, Scotch pine and Uludağ fir, respectively (Ferah, 1991). It was determined that the NWR of Oak (*Quercus crupula*) is approximately twice as much as that of spruce (*Picea jezonesis*) and willow (*Larix leptolepis*) (Kanaomori et al, 1978). In the study made related to the vertical and parallel SWR to the surface of four materials, it was determined that eastern beach was the most effective material in both directions and that this was followed by molded fiberboard (Werzalit), Medium Density Fiberboard (MDF) and particleboard (Doğanay, 1995). In another study, it was stated that in wood materials of beech and spruce, the highest SWR was in beech in a vertical direction with 20x30 screws and that the highest NWR was in spruce in a parallel direction to the fibers (Özçiftçi and Doğanay, 1999). Related to the NWR and SWR in five types of wood, it was determined that eastern beech had the highest NWR and that it was followed by Anatolian chestnut, bearded alder, eastern beech and Scotch pine, respectively. Also, in the same study, the highest SWR was obtained in eastern beech and it was followed by bearded alder, Anatolian chestnut, Scotch pine and eastern spruce, respectively (Akyıldız, 1999). It was determined that the covering of the particleboard surface with Continuous Pressure Laminate (CPL) increased its SWR (Altınok and Kılıç, 2003). It was found that in case the moisture content of the wood drops below the fiber saturation point, then a definite decrease in the NWR was found (Bacher, 1964). It was found that the NWR in eastern beech, Anatolian chestnut, bearded alder, eastern spruce and Scotch pine was higher at the 30% moisture content compared to the 12% moisture content and that the SWR was higher at the 12% moisture content compared to the 30% moisture content. Also, in the same study, it was determined that the NWR of the green Scotch pine wood was approximately 30% less than that of the heartwood in a vertical direction to the fibers and approximately 10% less in a parallel direction to the fibers. It was stated that there is a direct relationship between the NWR and the specific gravity (Helinska, 1993). In another study, it was determined that the NWR was high in a tangential direction (Noguchi and Sugihara, 1961). It was stated that existing yield models used for design of nailed connections can predict nominal design values for nailed connections of OSB sheathing and Douglas-fir framing members with various levels of decay damage, provided that the dowel bearing capacity of the wood materials can be assessed (Kent et al., 2004). The effect of incising and preservative treatment on resistance to nail withdrawal was investigated using Douglas-fir and hem-fir lumber. Incising has no significant negative effects on resistance to nail withdrawal for either wood species. Treatment with chromated copper arsenate also had no significant negative effects on nail withdrawal resistance, and ammoniacal copper zinc arsenate treatment was associated with significant improvements in resistance (Kang et al., 1999). Screw withdrawal, nail withdrawal, and nail head pull-through capacity are relatively unaffected by wood flour content in wood flour-thermoplastic composite panels. However, wood flour content affected lateral nail resistance. The use of pilot holes (predrilling) was found to have little effect on fastener capacity. The screw withdrawal capacity of the tested wood flour-thermoplastic composite panels was found to be equal to or greater than that of conventional wood panel products (Falk et al., 2001). OSB and MDF had clearly greater shear moduli in comparison with Lauan plywood and Douglas fir plywood. Contrary to that, neither remarkable differences in the slip moduli nor the ductilities of nailed joints in all panels was found. Specimens with MDF had relatively low maximum lateral resistance in air-dry conditions, and a part of the specimens with OSB was degraded remarkably due to the accelerated aging treatment. Ductilities of the nailed joints clearly were affected by the arrangement of grain directions of the timber main-members, parallel or perpendicular to the loading direction. Estimated allowable shear wall resistance was relatively low for the shear walls with Douglas-fir plywood or some OSB. Obvious differences in degradation of shear wall resistance due to the accelerated aging treatment among the panels except for a part of the OSB were not found (Hirai et al., 1999). Experimental results indicated that the joints constructed of beech with 7-mm diameter screws yielded the highest strength in both withdrawal and bending tests, and the joints constructed of scotch pine with 5-mm diameter screws had the lowest withdrawal strength and bending moment resistance. It was concluded that the general formula that is used to predict the two-pin bending moment resistance of a dowel joint as a function of a single dowel could also be used to predict the moment resistance of the same type of screwed joint. In other words, the bending moment resistance of the joints could be predicted as a function of ultimate withdrawal strength of a single screw (Efe et al., 2004). The influence of reinforced nailing on the static and dynamic performance of full-size wood frame shear walls with large openings, sheathed with OSB panels, was evaluated experimentally. Combinations of parameters were studied, such as the number of hold-downs, the panel shapes, the nail distribution, and the bracing systems. Comparisons of the dissipated energy per cycle revealed a higher capacity for walls using nails with washer reinforcement than without. Results from numerical simulations of the monotonic and cyclic tests performed on the walls are presented (Richard et al., 2001) The properties evaluated included bending strength and stiffness, swelling, surface hardness, and screw holding capacity as a function of processing variables (i.e., density, chip type, and board construction). Two types of chips (whole tree and pure wood), two types of mat constructions (single- and three-layer), and four different density levels (0.4, 0.5, 0.65, and 0.75 g/cm^3) were used in manufacturing the test panels. Board density and mat construction type were found to have major influences on board properties while chip type had no significant effect on the properties. The results showed that with some improvements in process parameters and processing techniques, low-grade eastern redcedar has a future as a particleboard furnish in the manufacture of marketable products (Cai et al., 2004). In addition to ultimate capacity, statistical distributions of the deformations at ultimate capacity were determined to evaluate the reliability of wood shearwalls designed using AF and PA/ASCE 16. The resistance of each wall was determined from a monotonie pushover analysis, which uses existing load-slip fastener data to determine the monotonie behavior of a wood shearwall. The wind load statistics were determined as a function of the nominal (code-specified) values using existing load models. Reliability indices for wood shearwalls built using 8d common nails [3.3 mm (0.131 in.) diameter] and subject to the 50 year design wind load ranged from β = 3 to 3.5. The percent drift at ultimate (neglecting uplift) ranged from 1.6 to 2% (Van De Lindt et al., 2005)

In studies made to determine effects of the structural characteristics of the fastenings on the withdrawal resistance (WR) it was found that the WR of sharp pointed nails in wooden constructions were higher compared to common nails. It was stated that sharp pointed nails decreased splitting strength and for this reason, it would be more suitable to use common wire nails in types of woods, which are sensitive to splitting (Scholten, 1953). It was determined that WR of threaded nails are higher compared to those without threads (Mack, 1960; Reardon et al. 1984). It was found that the annularly and helically threaded nails had a much higher WR compared to common wire nails. It was stated that there is a direct relationship in a positive direction between the diameter of the nail and the WR and that as the length of the nail increases, the WR of nail increases (Stern and Price, 1949). It was determined that the WR of nails coated with epoxy is higher in dried wood compared to undried wood (Laxe, 1968). It was stated that the WR of annularly threaded nails decreased when there is a shrinkage emerging with water loss when there is drying in wood, but that the WR of helically threaded nails did not change (Kanaomori et al., 1978). It was determined that the WR of screw was related to the screw length and that it has a direct relationship in a positive direction with the screw diameter (Kjucukov and Encev 1977a,b; Broker and Krause 1991). The test results show that there is no significant difference in strengths between plywood and oriented strand board. Head pull-through strength appears to increase with fastener diameter. The major conclusion reached is that, except for small size nails (less than 2 in. long), fastener head pull-through in sheathing prevails over shank withdrawal from timber in sheathing-to-timber joints when loaded axially (Craft and Chui, 2002). A study was realized in a research programme investigating the mechanical properties of self-tapping screws and nails in wood. The programme consisted of deformation-controlled tests to determine embedment strength, withdrawal strength, pull-through strength, bending capacity of individual screws, shear strength of screwed and nailed wood-wood connections, and shear strength of screwed wood-steel connections. All test specimens showed ductile behaviour. Based on the results from the first four types of tests, a simple calculation model for the shear strength of screwed wood-wood and wood-steel connections was set up and compared with the test results from the last two types of tests. The calculation model took dowel action and friction (wood-wood and wood-steel) into account and showed excellent agreement with the test results (Hansen, 2002).

As it can be seen from the information given related to the available literature, the species and the type of cut surface of the wood material related to the structural characteristics of the wood are influential on the NWR and SWR. With this study, it was targeted to determine the NWR and SWR on tangential, radial and transverse cut surfaces of wood materials obtained from Fir (*Abies Mill.*), Cherry (*Prunus avium L.*), Walnut (*Junglans regia L.*) and Oak (*Quercus L.*). In this manner, more appropriate decisions could be made in the joints with screws in furniture and furnishing production and in the assembly of fitting elements

MATERIALS and METHODS

Materials

Fir (*Abies Mill.*), Cherry (*Prunus avium L.*), Walnut (*Juglans regia L.*) and Oak (*Quercus L.*) were obtained by the random selection method from the Siteler in Ankara/Turkey under air-drying conditions with the objective of determining their NWR and SWR. The materials brought to the study location were dried to the 10% moisture content with the kiln drying and were stacked and left under the influence of the environmental conditions. A total of 480 each samples (4 wood species x 3 cutting surface types x 2 types of fastenings x 20 repeat numbers = 480) were prepared with the net measurements of 50 x 50 x 150 mm (thickness x width x length) by providing that the annual rings of these materials were at a maximum perpendicular level to the surface. For the NWR tests, 2.5x50 mm common wire nails were driven into 240 each samples, 5x50 mm (22x50) flathead screws were driven into 240 samples in a manner in which 35 mm portions of the screws were entering the wood, with the placement model given in Figure 1. Later, the samples were taken into the climatization room having a temperature of 20 ± 2ºC and a relative humidity value of 65±3% and were kept waiting until their weights were unchanged (up until a 12% moisture content). After this point, the samples were insulated to prevent a change in moisture content and were kept waiting for the tests. The general principles specified in ASTM D 1761 were complied with in the preparation of the samples.

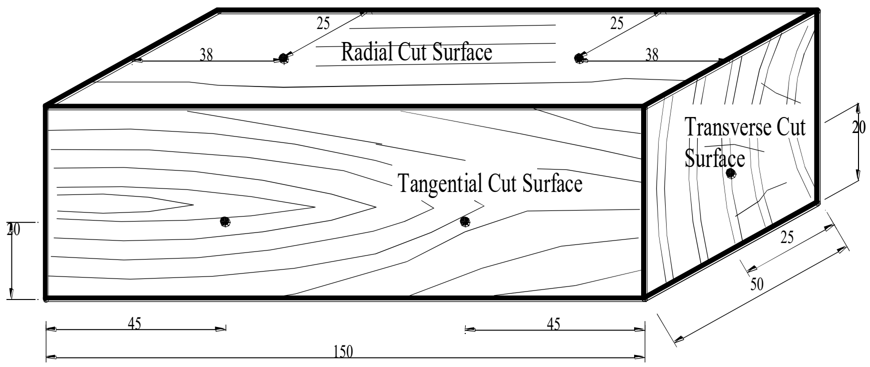

Figure 1. The measurement of the samples to be used in the tests and the placement plan of the nails and screws

Furthermore, 20 each samples with the dimensions of 20x20x20 mm from each species of wood were taken and the air-dried specific gravities of the woods were found. The principles in the ISO 3131 were complied with in the determination of the air-dried specific gravities.

Methods

The universal test machine was used in finding the NWR and SWR of the samples having air-dried moisture content and the general principles given in ASTM D 1761 were complied with in the realization of the tests. The samples were attached to the machine and withdrawal was applied with a speed of 2.5 mm/min. until the screws and nails were completely removed. The maximum load read on the machine indicator was recorded as the NWR and SWR belonging to the related surface of the experimental sample. Subsequently, in the calculation of the NWR or SWR belonging to the related surface, the arithmetic average of the two values belonging to that surface were taken and this value was accepted as the NWR or SWR belonging to the related surface. This process was repeated on all of the samples.

The analysis of variance (F test) was used in the determination of whether or not there was a difference between the NWR or SWR values dependent on the variables. In case a significant difference emerged among the groups, then a comparison was made with the Duncan's multiple range test at a $\alpha=0.05$. The SPPS 11.5 computer package program was used in the calculation of the Analysis of Variance (ANOVA), arithmetic average, standard deviation, and minimum and maximum values.

RESULTS AND DISCUSSION

Specific Gravities

The air-dried specific gravities of the woods from which the samples were obtained for determining the NWR and SWR were determined within the principles given in ISO 3131 and the specific gravity values obtained are given in Table 1.

Table 1. The air-dried specific gravity values of the woods from which the samples were obtained.

SPECIES OF WOOD	AIR-DRIED SPECIFIC GRAVITY (g/cm³)	VALUES IN THE LITERATURE
Fir ***(Abies Mill.)***	0.460	0.430-0.454 (Aslan, 1994)
Cherry ***(Prunus avium L.)*****,**	0.559	0.600 (Örs and Keskin 2002;. Gökmen 1963)
Walnut ***(Junglans regia L.)***	0.560	0.680 (Tengiz, 1984)
Oak ***(Quercus L.)***	0.701	0.690-0.750 (Örs and Keskin, 2002)

The analysis of variance (F-Test) was used to determine whether or not there was a significant difference between the air-dried specific gravity values obtained according to the species of wood (Table 2). Since $p<0.05$, the difference among the magnitude of the values is significant.

Table 2. The analysis of variance of the specific gravity values according to the species of wood.

Source	Sum of Squares	Degrees of Freedom	Mean Square.	F	Significance P
Type of wood	0.61	3.00	0.20	292.42	0.00*
Error	0.05	76.00	0.00		
Total	26.91	80.00			

*P<0.05

The Duncan’s multiple range test was applied for determining the homogeneous groups of the air-dried specific gravity values of the species of wood (Table 3). As cherry and walnut fell into the same homogeneous group with 0.56 g/cm^3 air-dried specific gravity values, there was no difference between them. Oak, within the existing species of wood, had the highest air-dried specific gravity value and this was followed by cherry and walnut at 0.56 g/cm^3 and fir at 0.46 g/cm^3 (Table 3).

Table 3. The analysis of difference (Duncan’s Multiple Range test) among the specific gravity values according to the species of wood.

GROUPS	*N*	α=0,05		
		1	**2**	**3**
Fir *(Abies Mill.)*	*20*	0.46		
Cherry *(Prunus avium L.)*	*20*		0.56	
Walnut *(Junglans regia L.)*	*20*		0.56	
Oak *(Quercus L.)*	*20*			0.71

The Effect on NWR of the Species of Wood and Type of Cut Surface

The NWR obtained according to the species of wood and the cut surface types according to the principles specified in the method section are given in Table 4.

Table 4. The NWR values according to the cut surfaces of the wooden materials.

Species of Wood	Cut Surface	Nail Withdrawal Resistance (kgf)
Fir	Radial	62.75
	Tangential	60.40
	Transverse	30.15
Cherry	Radial	90.40
	Tangential	93.55
	Transverse	68.25
Walnut	Radial	102.15
	Tangential	101.80
	Transverse	78.30
Oak	Radial	148.85
	Tangential	121.15
	Transverse	96.25

The analysis of variance (F-test) was used to determine whether or not test variables were effective on the NWR values obtained according to the species of wood and cut surfaces and the values obtained are given in Table 5.

According to this, since p<0.05, the species of wood and the cut surfaces on which the nail was driven were influential on the NWR.

Table 5. The analysis of variance of the NWR according to the types of wood and types of cut surfaces.

SOURCE	Sum of Squares	Degrees of Freedom	Mean Square	F	Significance P
Wood Species	155035.90	3	51678.63	382.86	0.00*
Cut Surface	48551.14	2	24275.57	179.84	0.00*
Wood Species- Cut Surface	8808.33	6	1468.06	10.88	0.00*
Error	31045.54	230	134.98		
Total	2091935.00	240			

*P<0.05

The homogeneous groups obtained with the Duncan's multiple range test made to determine between which groups there was a difference according to the species of wood and the types of cut surfaces are given in Table 6.

Table 6. The Duncan's Multiple Range Test for the NWR homogeneous groups according to the types of cut surfaces and the species of wood.

	Species of wood	***N***	**α=0,05**			
			1	**2**	**3**	**4**
Transverse Cut Surface	**Fir**	20	30.15			
	Cherry	20		68.25		
	Walnut	20			78.30	
	Oak	20				96.25
Radial Cut Surface	Fir	20	62.75			
	Cherry	20		90.40		
	Walnut	20			102.15	
	Oak	20				148.85
Tangential Cut Surface	Fir	20	60.40			
	Cherry	20		93.55		
	Walnut	20			101.80	
	Oak	20				121.15

As it can be observed from the table, since none of the dual interactions of the species of wood - transverse cut surface, species of wood - radial cut surface and species of wood - tangential cut surface NWR fell into the same homogeneous group, the difference was significant among all of the values. In this situation, the highest NWR in the radial cut surfaces according to the species of wood was 148.85 kgf in oak and this was followed by 102.15 kgf in walnut, 90.40 kgf in cherry and 62.75 kgf in fir. This listing related to the magnitude of NWR values did not change on the tangential and transverse cut surfaces. The NWR values on the tangential cut surfaces were determined to be 121.15 kgf in oak, 101.80 kgf in walnut, 93.55 kgf in cherry and 60.40 kgf in fir. The NWR values on the transverse cut surfaces were determined to be 96.25 kgf in oak, 78.30 kgf in walnut, 68.25 kgf in cherry and 30.15 kgf in fir.

As it can be seen from an examination of these values, the highest NWR was 148.85 kgf in the radial cut surfaces in oak and this was followed by 102.15 kgf in the radial cut surfaces in walnut, 93.55 kgf in the tangential cut surfaces in cherry and 52.75 kgf in the radial cut surfaces in fir. According to the cut surface types depending on the species of wood the highest NWR was found to be 93.55 kgf in the tangential cut surfaces in cherry and on the radial cuts surfaces in all of the other types. The lowest NWR were found to be on the transverse cut surfaces in all of the species.

As it can be observed in Table 1 a statistically significant difference was not observed between the specific gravity values of cherry and walnut. The NWR values on all types of the cut surfaces of walnut were approximately 10% higher compared to cherry. This result could stem from the differences in structural characteristics of these two species of wood.

As the specific gravity increases within the existing species of wood, the NWR also increases. This result is also in conformity with the results of studies made with this objective (Ferah, 1991; Helinska, 1993; Noguchi and Sugihara, 1961; Broker and Krause, 1991). According to this, it is necessary to prefer species of wood, which have a high specific gravity, for higher NWR.

Another important variable related to the NWR is the condition of the cut surfaces. According to the results obtained, the radial cut surface, other than the exceptional situation in cherry, has a higher NWR compared to the tangential and transverse cut surfaces and the tangential cut surfaces have a higher NWR compared to the transverse cut surfaces. This result is also in conformance with the existing literature (Noguchi and Sugihara, 1961; Aslan, 1994). The highest NWR in cherry is obtained on the tangential cut surfaces. This result could stem from the structural characteristics of this type of wood.

Accordingly, if a higher WR is sought in the joints with nails driven in different spacing dependent on the purpose of use, then the selection of the species of wood and the cut surface in the driving of nails acquires importance. It is necessary to prefer species of wood, such as oak and walnut within the existing species as suitable for the purpose for higher NWR.

The Effect on SWR of the Species of Wood and Types of Cut Surfaces

The SWR values obtained according to species of wood and types of cut surfaces, within the principles specified in the methods section, are given in Table 7.

Table 7. The SWR values according to the species of wood and the types of cut surfaces

Wood Species	Cut Surface	Screw Withdrawal Resistance (kgf)
Fir	Radial	216.90
	Tangential	251.55
	Transverse	145.80
Cherry	Radial	499.20
	Tangential	479.90
	Transverse	314.65
Walnut	Radial	587.35
	Tangential	586.20
	Transverse	433.45
Oak	Radial	653.10
	Tangential	632.90
	Transverse	488.15

The analysis of variance was applied in order to determine whether or not test variables were effective on the SWR and the values obtained are given in Table 8. According to this, since $p<0.05$, the species of wood and types of cut surfaces on which the screw was driven are influential on the SWR.

Table 8. Analysis of variance of the SWR according to the species of wood, cut surfaces and the dual interaction of the species of wood - cut surfaces.

SOURCE	Sum of Squares	Degrees of Freedom	Mean Square.	F	Significance P
Wood Species	4757430.03	3	1585810.01	611.74	0.00*
Cut Surface	1149802.30	2	574901.15	221.77	0.00*
Wood Species-Cut Surface	43312.07	6	7218.68	2.78	0.00*
Error	591041.00	228	2592.29		
Total	54592346.00	240			

*P<0,05

The homogeneous groups obtained with the Duncan's Multiple Range Test made for determining among which groups there are differences according to the species of wood and types of cut surfaces are given in Table 9.

Table 9. Duncan's multiple range test for the homogeneous groups for SWR according to the types of cut surfaces and the species of wood.

CUT SURFACE	WOOD SPECIES	N	α=0,05			
			1	2	3	4
Transverse Cut Surface	*Fir*	20	145.80			
	Cherry	20		314.65		
	Walnut	20			433.45	
	Oak	20				488.15
Radial Cut Surface	Fir	20	261.90			
	Cherry	20		499.20		
	Walnut	20			587.35	
	Oak	20				653.10
Tangential Cut Surface	Fir	20	251.55			
	Cherry	20		479.90		
	Walnut	20			586.20	

As it can be observed from the table, since none of the dual interactions of the species of wood – transverse cut surface, species of wood - radial cut surface and species of wood - tangential cut surface SWRs fell into the same homogeneous group, the difference is significant among all of the values. In this situation, the highest WR in the radial cut surfaces according to the species of wood was 653.10 kgf in oak and this was followed by 587.35 kgf in walnut, 499.20 kgf in cherry and 261.90 kgf in fir. This listing related to the magnitude of SWR values did not change on the tangential and transverse cut surfaces. The SWR values on the tangential cut surfaces were determined to be 632.90 kgf in oak, 586.20 kgf in walnut, 479.90 kgf in cherry and 251.55 kgf in fir. The SWR values on the transverse cut surfaces were determined to be 488.15 kgf in oak, 433.45 kgf in walnut, 314.65 kgf in cherry and 145.80 kgf in fir.

According to these values, the highest SWR was 653.10 kgf in the radial cut surfaces in oak and the lowest SWR was 145.80 kgf in the transverse cut surfaces in fir. The highest SWR in all of the species of wood were found in the radial cut surfaces and this was followed by the tangential and transverse cut surfaces.

As can be observed from Table 1 no statistical difference was seen between the specific gravity values of cherry and walnut. The SWR values of walnut were approximately 20% higher in the tangential and radial cut surfaces compared to cherry and approximately 30% higher in the transverse cut surfaces compared to cherry. This result could stem from the differences in structural characteristics of these two species of wood.

As the specific gravity increases within the existing species of wood, the SWR also increases. This result is also in conformity with the results of studies made with this objective (Broker and Krause, 1991). According to this, it is necessary to prefer species of wood, which have a high specific gravity, for higher SWR.

From the aspect of the effect of the condition of the cut surface on SWR, the radial cut surfaces have a higher SWR compared to the tangential and transverse cut surfaces and the tangential cut surfaces have a higher SWR compared to the transverse cut surfaces. According to this, it would be suitable to put the screws on the radial cut surfaces of the elements in the joints with screws.

Accordingly, if a higher SWR is sought in the joints with screws applied in different places dependent on the purpose of use, then the selection of the species of wood and the direction of the cut in putting the screws acquire importance. It is necessary to prefer species of wood, such as oak and walnut within the existing species as suitable for the purpose for higher WR.

In conclusion, if we were to make a generalization, in case a higher WR is sought in the assembling products with nails and screws, then it would be beneficial to prefer species of wood that have a high specific gravity and in bringing together face to face and side to side the surfaces for joining purposes, it would be beneficial for the radial cut surfaces to be in contact with each other and for the fastenings to be applied to this surface.

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