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Full Length Research Paper

Effects of drying methods of lamellas used in multilayer parquet manufacturing on surface roughness and bonding strength

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The objective of this study is to determine surface roughness and bonding (tensile shear) strength of lamellas (top layer of multilayer parquet) which were cut away from green lumber and dried by different types of drying methods. Also, finding out the most convenient manufacturing method as surface roughness, bonding strength properties was aimed by comparing results with surface roughness and bonding strength of lamellas, which were cut away from dry lumber as seen in practice. Flat sawn green lamellas with 5 and 2 mm thicknesses, which were cut away from Iroko lumber by means of thin cutting frame saw, were dried with 3 different drying methods such as drying in lumber drying kiln, jet ventilated **automatic veneer roller** dryer **and veneer press dryer. Effect of drying temperature on surface roughness and bonding strength was also determined by applying 3 different drying temperatures as 60, 100 and 140°C in jet ventilated automatic veneer roller dryer. In addition, lamellas with the same thicknesses were manufactured from dry lumber by means of the same thin cutting frame saw mentioned above. As the result of analysis of variance showed, differences between test groups were determined as surface roughness. Consequently, effect of drying method on surface roughness was found. Also, surface roughness values were determined to be increasing as drying temperature increases when drying in veneer roller dryer. Surface roughness values of lamellas dried in lumber drying kiln were found to be higher than those cut away from the dry lumber as expected. Differences exist between test groups as bonding strength was determined by means of analysis of variance. The biggest bonding strength was found in lamella group which were cut away from dry lumber and mentioned as comparison group. It was found that no relation existed between bonding strength and temperature increase drying in veneer roller dryer. Also, it was determined that no significant relation was found between surface roughness and bonding strength as the result of correlation analysis. Conclusively, it was found that lamella manufacturing method, cutting away from dry lumber, was the most convenient method for obtaining the best bonding strength in multilayer parquet production.**

Key words: Drying method, multilayer parquet, surface roughness, bonding strength.

INTRODUCTION

Lamellas, define as top layer of multilayer parquet elements, are usually cut away from dry lumber; but drying lumber takes longer time. Drying time is the most important factor affecting drying economy. It has been known that as drying time shortens, drying expenses decreases. Many factors influence drying time (Kantay, 1993). Material thickness is the most important dimensional property influencing drying time, because thickness has an influence on evaporation surface per volume. As thickness decreases, evaporation surface of material increases. Lamellas are materials which have higher drying speeds due to their larger surfaces compared to volume. Higher air movement (ventilation) and temperatures can be

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applied for drying lamellas, which are similar to conditions of drying rotary peeled and sliced veneers. Drying time can be shortened and expressed as minutes by using higher ventilation quantities and temperatures (Kantay, 1983; Kantay et al., 1997).

Thickness of lamella is defined to be manufactured with at least 2, 5 mm according to TS EN 13489 (2004). Since top limit is not stated in the standard for lamella thickness, lamella thicknesses were determined to be between 2.5- 5mm, especially 3 -4 and 4 -5mm for three and two layer parquets in practice, respectively (Kantay and Gungor, 2009). According to the mentioned thicknesses, lamellas are also found to be manufactured conveniently to veneer definition stated in TS 1250 (1974). Veneer thickness is also stated to be up to 8 mm in standard (Kantay, 1983). Drying time of beech peeled veneers to be used in plywood manufacturing, with 3 mm thickness similar to lamellas, is 23 min at 100-140°C temperatures, drying in veneer roller dryer (Bozkurt and Goker, 1981). Lamellas are manufactured from dry lumber by means of thin cutting frame sawn at all multilayer parquet enterprises in Turkey. Manufacturers stated that chip quantity could be increased and rough surfaces would be obtained if lamellas were manufactured from green lumber, because bigger set of the teeth and larger tooth pitch had been used in the mentioned production. Bonding of lamella to the bottom layer is essentially important for multilayer parquet manufacturing. There are many factors influencing bonding (Aydın and Colakoglu, 2005a and 2005b; Aydın et al., 2001). Density, moisture content, extractive substances quantity, anatomical structure, surface roughness and temperature of wood are effective on bonding (Ors and Colakoglu, 1995). The most important factor, related to wood material, influencing bonding is the surface quality due to surface roughness. Surface roughness influences penetration quantity and distribution of glue on veneer surface. As a result, smooth surfaces give higher bonding strength values compared to rough surfaces. Faust et al. (1986) found that rough veneers decreased bonding strength of yellow pine plywood as 33% ratios compared to smooth veneers. Efe and Gurleyen (2001) determined that the biggest bonding strength was obtained with surfaces sanded with 120 numbered sandpaper among surfaces sanded with 40, 60 and 120 numbered sandpapers. Sönmez et al. (2001) aimed to determine the effect of surface roughness on bonding strength of acacia wood processed with knives planer (HSS) and found out that acacia wood processed with 4 knives planer (HSS) gave smoother surfaces and bigger bonding strength. Efe et al. (2007) also found similar results. Guler and Colakoglu (2000) determined the effect of surface roughness of calabrian pine (*Pinus brutia Ten.*) veneers on shear-tensile strength of plywood. They found that plywood made of smooth, steamed and naturally dried veneers showed higher shear-tensile strength values. Lamellas cut away from dry lumber can be considered to give better surface quality than those cut away from green lumber. However, drying methods of veneers have an influence on veneer quality and surface roughness is similar to plywood manufacturing. Veneers become smooth and surface quality is improved due to pressing effect, as a result of drying in veneer roller dryer and especially with veneer hot press dryer. Lutz et al. (1974) dried walnut sliced veneers in veneer roller and hot press dryers. Form and colour changes of veneers were determined. Form changes were found less on veneers dried in hot press dryer, but colour changes were determined to be darker when compared to veneers dried in other types of methods. Sernek (2001) found that wetting ability of Douglas fur veneers decreased according to heating plate temperature which increases in veneer press dryer with heating plate.

Excessive heating of wood is known to cause surface roughness (Bozkurt and Goker, 1981). Since higher temperatures are applied in veneer drying, surface roughness values increase. Starecki (1975) found that surface roughnesses of veneers increase above 120°C in the study where 100, 120, 150, 180 and 210°C drying temperatures were applied. In another study, Aydın and Colakoglu (2002) objected to determine effect of veneer drying temperature on wettability, surface roughness and some properties of plywood. As a result, they found that surface roughness increases due to temperature increase. Also, Kantay et al. (2003) determined that surface roughness increases, since veneer peeling temperature increases in both heating of log by steaming or by treating it in hot water on plywood manufacturing line. On the other hand, Unsal et al. (2005) and Dundar et al. (2008) determined that veneer drying temperature had no effect on surface roughness in their studies where 100,115,130°C and 120,140,160,180°C drying temperatures were applied, respectively. Drying temperature is known to influence surface quality and bonding strength. Many studies showed that applying higher temperatures in veneer drying influenced bonding strength and wettability of wood. Applying higher veneer drying temperatures is known to decrease hygroscopicity due to wettability of wood (Christiansen, 1990). Surface inactivation was defined as changes due to heat effect, causing loss in bonding ability when veneers are dried in higher temperatures (Troughton and Chow, 1971). Surface inactivation can cause decreases in wettability of glue, spreading to surfaces, penetration and hardening of glue (Vick, 1999). The objective of this study is to determine surface roughness and bonding strength of lamellas cut away from green lumber and dried by applying various drying methods. Also, by comparing these surface roughnesses and bonding strength values with those of lamellas cut away from dried lumber, especially taking part in practice, the most convenient production method was intended to be determined for obtaining the most appropriate in both surface roughness and bonding strength properties.

MATERIALS AND METHODS

One Iroko (*Milicia* spp.) log, with 70 cm central diameter, selected from a timber store of a lumber enterprise in which exotic tree species are sawn off among Iroko logs, were cut into planks with 10 cm thickness and various widths by using slash sawing method. First of all, pre-drying was applied to the planks and then lamella blocks with 32 mm thicknesses, which are convenient, were sawn off from these planks. Lamella blocks which have annual ring angle bigger than 60° were chosen for lamella manufacturing. Some of these blocks were put in classic drying kiln for drying. Others were transported to Bahar Forest Products in fresh wood conditions and sawn off to lamellas with 5.2 mm thickness by using "Wintersteiger" brand thin-cutting frame saw. Tooth depth, tooth pitch of saw blade, saw thickness, the set of the teeth, cutting speed and feed speed of the machine are 5, 14, 0. 8, 0. 2 mm, 3 m/sec and 0. 5 m/min, respectively. Obtained 150 fresh lamellas were divided into 5 groups and dried from 40% initial moisture content to 10% final moisture content by using different drying methods. These groups and drying methods are stated below:

Group (LDK-60): Drying in classic lumber drying kiln as lamella at 60℃
Group (VRD-60): Drying in jet ventilated automatic veneer roller dryer as lamella at 60℃
Group (VRD-100): Drying in jet ventilated automatic veneer roller dryer as lamella at 100℃
Group (VRD-140): Drying in jet ventilated automatic veneer roller dryer as lamella at 140℃
Group (VPD-100): Drying in veneer press dryer as lamella at 100℃.

Lamella group 6 (LBD-60), which were obtained by drying lamella blocks (lumber) at 60℃ and sawing them off to lamellas with 5.0 mm thickness by using thin-cutting frame saw is determined to be the sixth comparing group.

Drying in lumber drying kiln

Lamella blocks are stated as LBD-60 and fresh lamellas are expressed as 1. Group (LDK-60) was dried in lumber drying kiln by using classic drying method at 60℃. Lamellas were stowed with bunches, each containing 4 lamellas. In fact, lamellas can be dried in classic lumber drying kilns by applying higher temperatures above 60℃. However, 60℃ drying temperature was chosen for this study, because lamella blocks were dried at 60℃. These two groups would be compared as surface roughness and bonding strength properties.

Drying in veneer press dryer

Rotary peeled veneers were known to be dried in veneer press dryer with heating plate in plywood manufacturing. In these dryers, peeled veneer is dried by pressing and drying time shortens by using higher drying temperatures. Veneers that are mostly arranged as packages according to veneer thicknesses, each containing 5 veneers, are settled between heating plates of machine and then pressed. Drying occurs on the edges of veneers, but not on veneer surfaces. Veneers become smooth during pressing (Kantay, 1982a and 1982b).

Temperature can be adjusted in veneer press dryer and drying time changes according to tree specie, initial moisture content of veneer and temperature. Since temperature increases, drying time shortens but colour changes and crack formation could occur. Pressing pressure has influence on surface quality, surface finishing and bonding properties. On the other hand, increase in temperature cause colour changes (Lutz et al., 1974; Kantay, 1983; Aydın and Colakoglu, 2005a and 2005b).

Appropriate bonding of lamellas, top layers of multilayer parquet elements to bottom layer and no change of natural colour of lamellas are required in multilayer parquet production. A study on determining the convenient drying temperature and pressing pressure for lamella drying was not materialized so far. Drying was applied at 100℃ temperature and 5 kg/m^2 pressing pressure. Drying time was 22 min from 40% initial moisture content to 10% final moisture content. 0.2 mm thickness loss and colour change were observed by the naked eye and were determined in lamellas after drying. Since the veneer press dryer was not presented in firms near Istanbul, lamellas were dried in plywood press in Pelit Arslan plywood firm.

Drying in jet ventilated automatic veneer roller dryer

Veneer roller dryers are used in drying veneers thicker than 1 mm in plywood industry. Rotary peeled veneer thicknesses can be up to 3.6 mm (Bozkurt and Goker, 1981). Lamella thicknesses which vary between 2.5 - 4 mm can be dried in this machine. For this reason, drying in the jet ventilated (vertical ventilation applied) automatic roller veneer dryer was chosen as another type of lamella drying for this study. The objective of drying lamellas in veneer roller dryer, is applying short drying time. Drying time changes according to tree specie, initial moisture content, thickness of veneer and drying temperature applied in these machines. Drying temperature is the most effective factor. As temperature increases, drying time shortens; but as temperature increases, form changes take place and colour could get darkened (Kantay et al., 1997). Kollman et al. (1951) determined that the most significant colour changes occurring during drying took place with the effect of both temperature and moisture. Also, it was found that this group of colour changes was not important in veneer drying, because longer effective time was determined to be needed for getting colour changes occurring with the influence of temperature and moisture. On the other hand, Kantay (1983) conducted a study on drying sliced veneers. He found that colour changes occurred in drying sliced veneers at high drying temperatures by applying drying time as seconds (the longest drying time as 2 min). For this reason, drying temperatures above 150℃ was not recommended in drying. Many studies were conducted on colour changes in rotary peeled veneer drying (Lutz et al., 1974; Kantay et al., 1997; Aydın and Colakoglu, 2005a and 2005b). Drying temperatures as 60 - 100 - 140℃ were applied in drying tests and materialized at veneer roller dryer in Pelit Arslan Plywood Firm. The aim of using different drying temperatures is to determine the effect of various temperatures. The aim of applying low drying temperature such as 60℃ in veneer roller dryer is to compare the results with groups 1 (LDK-60) and 6 (LBD-60). Drying time took 25 min from 40% initial moisture content to 10% final moisture content in automatic veneer roller dryer at 100℃. Air-drying was not considered in lamella drying. Moisture content of lamella and top layer of multilayer parquet element is required to be between 5 - 9% according to TS EN 13489 (2004). It is not possible to descend to these mentioned moisture contents by applying air-drying.

Measurement of moisture content

Moisture contents of lamellas were measured in 3 points, such as 2 points 30 cm inner from lamella edges and 1 point from the middle of the specimen favorable to TS EN 13183-2 (2002). "Gann

Table 1. Statistical data of surface roughness values (Ra) of lamella groups according to drying methods.

Drying method	LDK-60	LBD-60	VRD-140	VRD-100	VRD-60	VPD-100
Arithmetic mean	10.832	10.606	10.208	10.126	9.484	6.287
Standard deviation	1.982	2.0151	1.9842	2.3709	1.648	1.603233
Variance	3.9282	4.0607	3.9369	5.621	2.715	2.570355
Coefficient of variation	18.297	19	19.437	23.415	17.37	25.50076
Maximum	15.64	14.67	14.98	17.41	13.64	12.62
Minimum	7.11	7.38	6.18	6.38	5.72	4.23

LDK-60, Drying as lamella in lumber drying kiln at 60℃; LBD-60, drying as lumber in lumber drying kiln at 60℃; VRD-140, drying as lamella in veneer roller dryer at 140℃; VRD-100, drying as lamella in veneer roller dryer at 100℃; VRD-60, drying as lamella in veneer roller dryer at 60℃; VPD-100, drying as lamella in veneer press dryer at 100℃.

Hydromette HT 85 T" electrical resistance type moisture content measurement device was used for measurement, in which tree specie and temperature adjustment can be applied.

Surface roughness test method

Surface roughness measurements were made on lamellas which were dried using the various methods mentioned above. At first, test pieces were conditioned at 20 ± 2℃ and 65 ± 2% relative humidity. A stylus method was employed to evaluate the surface characteristics of the samples (Faust and Rice, 1986). Mitutoyo SJ-301 Profilmeter was used for determining surface roughness. Tracing speed, stylus tip diameter and tip angle were chosen to be 10 mm/min, 4 µm and 90^0, respectively. Measurements were made perpendicular to the fiber direction of samples. Roughness values were measured with a sensitivity of 0.5 µm. A 15 mm tracing length (L_t) with a 2.5 mm cutoff was used for measurements. Surface roughness was determined on 3 points; such as 2 points, 20 cm inner from edges and 1 point at the middle of lamellas. Surface roughness values of lamellas (Ra, Ry, Rz and Rq) were measured.

Bonding of lamellas

After surface roughnesses were measured, lamellas were wrapped up to prevent moisture content changes; then, they were carried to İskandinav Parquet Firm, a multilayer parquet enterprise. Each of the lamellas were divided into two parts from the middle and then glued to each other. In this way, glued 15 pieces were obtained from each test group. Commercial named "Rakkoll GXL-3" was used as adhesive. Adhesive used for lamella bonding and method are same with the ones used in practice in this factory. Pressing temperature, pressure and time were applied as 80℃, 250 bar and 4 min, respectively in practice. Bonding strength test specimens were prepared according to TS EN 205 (2004) after gluing. Test specimens were put in conditioning room.

Tensile shear strength test

Tests were made according to TS 5430 EN 204 (2003) and TS EN 205 (2004). 2 mm/min loading speed was applied. Maximum load as Newton (N) was recorded from the machine. Tensile shear strength was calculated from the equation stated below.

$$\text{Tensile Shear Strength } \sigma = F_{max}/A \ (N/mm^2)$$

Where, F_{max}= Maximum load applied (N); A = glued surface area (A = a x b mm^2).

Evaluation method

Statistical data belonging to sample groups related to surface roughness (Ra, Ry, Rz and Rq) and tensile shear strength (arithmetic mean, standard deviation, variance, coefficient of variation and range of variation) were determined using the statistical package for the social sciences (SPSS).

One-way analysis of variance (ANOVA) was made to establish the existence of difference between groups for each surface roughness and tensile shear strength. Significant differences between test groups were determined using Duncan's multiple range tests. Also, statistical relations between surface roughness and tensile shear strength were tested by correlation analysis.

RESULTS

Surface roughness (Ra) values of lamella groups dried by various methods are given in Table 1. One-way analysis of variance (ANOVA) test used in establishing the existence of difference as lamella surface roughness values between groups according to applied drying methods are given in Table 2. The result of ANOVA proved that the difference between surface roughnesses of the lamellas was significant at 95 and 99% confidence level with respect to applied drying methods. DUNCAN test was used to show the difference determined with ANOVA. Test results are given in Table 3.

As can be seen from Table 3, it was shown that there was a statistical difference between surface roughness values of the lamella blocks dried at 60℃ in lumber drying kiln with surface roughness of the lamellas dried at 100℃ in veneer roller dryer and the lamellas dried at 60 and 100℃ in veneer roller and veneer press dryers, respectively. Also, there was a difference between surface roughness values of the lumber dried at 60℃ in lumber drying kiln with surface roughness of the lamellas dried at 140℃ in veneer roller dryer, the lamellas dried at 100 and 60℃ in veneer roller dryer and the lamellas dried at 100℃ in veneer press dryer. Lastly, there was a difference between surface roughness values of the lamellas dried

Table 2. One-way analysis of variance (ANOVA) test of surface roughness values (Ra).

Source of variation	Degree of freedom	Total variance	Variance	F-ratio 95%	F-ratio 99%	Confidence level
Between Groups	5	1133.2	226.6	59.55992	59.55992	(95%) S*
Within Groups	474	1803.8	3.805	>	>	(99%) S**
Total	479	2937		2.214	3.017	

Table 3. Duncan test results belonging to surface roughness values (Ra).

Parameter	LBD-60	VRD-140	VRD-100	VRD-60	VPD-100
LDK-60	0.226	0.62387	0.7065	1.3483	4.545125
Rp	0.61068	0.64274	0.66411	0.6796	0.69181239
LBD-60		0.39787	0.4805	1.1223	4.319125
Rp		0.61068	0.64274	0.6641	0.6795988
VRD-140			0.08262	0.7244	3.92125
Rp			0.61068	0.6427	0.66411372
VRD-100				0.6418	3.838625
Rp				0.6107	0.64273995
VRD-60					3.196875
Rp					0.61067928

LDK-60, Drying as lamella in lumber drying kiln at 60℃; LBD-60, drying as lumber in lumber drying kiln at 60℃; VRD-140, drying as lamella in veneer roller dryer at 140℃; VRD-100, drying as lamella in veneer roller dryer at 100℃; VRD-60, drying as lamella in veneer roller dryer at 60℃; VPD-100, drying as lamella in veneer press dryer at 100℃.

Table 4. Statistical data of tensile shear strength according to drying methods.

Statistical data	VRD-60	VRD-100	VRD-140	LBD-60	LDK-60	VPD-100
Arithmetic mean	5.023419	6.128679	5.672027	6.050745	6.520264	5.393853
Standard deviation	0.59198	0.732075	0.609323	0.691361	1.134397	0.723312
Variance	0.35044	0.535933	0.371274	0.477981	1.286857	0.52318
Coefficient of variation	11.7844	11.94506	10.74259	11.42606	17.39802	13.40993
Maximum	6.530326	7.18419	6.883629	7.402753	9.86071	7.077348
Minimum	4.01605	4.46368	4.24869	5.063903	4.77619	4.570515

LDK-60, Drying as lamella in lumber drying kiln at 60℃; LBD-60, drying as lumber in lumber drying kiln at 60℃; VRD-140, drying as lamella in veneer roller dryer at 140℃; VRD-100, drying as lamella in veneer roller dryer at 100℃; VRD-60, drying as lamella in veneer roller dryer at 60℃; VPD-100, drying as lamella in veneer press dryer at 100℃; Rp is value called the least significant studentized range.

at 60℃ in veneer roller dryer with the lamellas dried at 100℃ in veneer press dryer at 95 and 99% confidence level. Tensile shear strength values of lamella groups dried with various drying methods are given in Table 4. ANOVA test used in establishing the existence of difference as tensile shear strength values between groups according to drying method types applied are given in Table 5. The result of ANOVA proved that the difference between tensile shear strength was significant at 95 and 99% confidence level with respect to lamella drying methods. DUNCAN test was used to show the difference determined with ANOVA. Test results are given in Table 6.

As can be seen from Table 6, it was shown that there was a statistical difference between bonding strength values of the lamella blocks dried at 60℃ in lumber drying kiln with bonding strength values of the lamellas dried at 140℃ in veneer roller dryer and the lamellas dried at 100℃ in veneer press dryer. Also, there was a difference between bonding strength values of the lamellas dried at 100℃ in veneer press dryer and the lumber dried at 60℃ in lumber drying kiln with bonding strength values of the lamellas dried at 100℃ in veneer roller dryer and the lamellas dried at 60℃ in veneer roller dryer. Lastly, there was a difference between bonding strength values of the lamellas dried at 140℃ in veneer roller dryer with the lamellas dried at 60℃ in veneer roller

Table 5. One-way analysis of variance (ANOVA) test of tensile shear strength values.

Source of variation	Degree of freedom	Total variance	Variance	F-ratio 95%	F-ratio 99%	Confidence level
Between groups	5	29.481	5.896	8.314	8.314	(95%) S*
Within groups	95	67.367	0.709	>	>	(99%) S**
Total	99	96.849		2.214	3.017	

Table 6. Duncan test results belonging to tensile shear strength values.

Parameter	VRD-100	LBD-60	VRD-140	VPD-100	VRD-60
LDK-60	0.391585	0.4695194	0.8482374	1.1264108	1.4968446
Rp	0.5272382	0.5549182	0.5733716	0.5867408	0.5972856
VRD-100		0.0779344	0.4566524	0.7348258	1.1052596
Rp		0.5272382	0.5549182	0.5733716	0.5867408
LBD-60			0.3787179	0.6568914	1.0273252
Rp			0.5272382	0.5549182	0.5733716
VRD-140				0.2781735	0.6486072
Rp				0.5272382	0.5549182
VPD-100					0.3704337
Rp					0.5272382

LDK-60, Drying as lamella in lumber drying kiln at 60℃; LBD-60, drying as lumber in lumber drying kiln at 60℃; VRD-140, drying as lamella in veneer roller dryer at 140℃; VRD-100, drying as lamella in veneer roller dryer at 100℃; VRD-60, drying as lamella in veneer roller dryer at 60℃; VPD-100, drying as lamella in veneer press dryer at 100℃; Rp is value called the least significant studentized range.

Table 7. Correlation analysis for determining relation between surface roughness values (Ra) and tensile shear strength at different temperature.

Parameter	Sample size	Correlation	Significant level
RVRD and TSSVRD at 60℃	20	0.255	0.259
RVRD and TSSVRD at 100℃	20	-0.089	.710
RVRD and TSSVRD at 140℃	20	-0.244	0.300
RLBD and TSSLBD at 60℃	20	0.238	0.312
RLDK and TSSLDDK at 60℃	20	-0.117	0.623
RVPD and TSSVPD100℃	20	0.221	0.349

RVRD, Roughness veneer roller dryer; TSSVRD, tensile shear strength veneer roller dryer; RLBD, roughness lamella block drying; TSSLBD, tensile shear strength lamella block drying; RLDK, roughness lamellas in drying kilns; TSSLDDK, tensile shear strength lamellas dried in drying kilns; RVPD, roughness veneer press dryer; TSSVPD, tensile shear strength veneer press dryer.

dryer at 95 and 99% confidence level.

Correlation analysis was made for determining the effect of surface roughness on tensile shear strength and results are given in Table 7. As can be seen from Table 7, there was no significant relationship between surface roughness of lamellas and tensile shear strength at 95% significant level. Correlation analysis was also made for determining the effect of drying temperature (60, 100 and 140℃) used in veneer roller dryer on tensile shear strength and results are given in Table 8. As can be seen from Table 8, there was no significant relationship between drying temperature (60,100, and 140℃) in veneer roller dryer and tensile shear strength at 95% significant level. Surface roughness (Ry) values of lamella groups dried with various drying methods are given in Table 9. Surface roughness (Rz) values of lamella groups dried with various drying methods are given in Table 10. Surface roughness (Rq) values of lamella groups dried with various drying methods are given in Table 11.

DISCUSSION

Lamellas, top layers of multilayer parquet elements are

Table 8. Correlation analysis for determining relation between drying temperature and tensile shear strength.

Temperature and tensile shear strenght	Sample size	Correlation	Significant level
Drying at 60℃ in VRD and TSS at 100℃ in VRD	20	0.141	0.553
Drying at 60℃ in VRD and TSS at 140℃ in VRD	20	0.166	0.484

VRD, Veneer roller dryer; TSS, tensile shear strength.

Table 9. Statistical data of surface roughness (Ry) of lamellas according to drying methods.

Statistical data	LDK-60	LBD-60	VRD-140	VRD-100	VRD-60	VPD-100
Arithmetic mean	121.235	119.967	118.864	115.767	114.624	76.806
Standard deviation	27.103	25.7781	34.3557	36.7396	25.8452	25.334
Variance	734.574	664.512	1180.32	1349.8	667.975	641.79
Coefficient of variation	22.3559	21.4877	28.9033	31.7358	22.5478	32.984
Maximum	191.9	198.9	248.2	219.4	186.2	132.3
Minimum	74.61	64.93	62.01	50.72	70.62	39.9

CV, Coefficient of variation; SD, standard deviation, AT, arithmetic mean; Max, maximum; Min, minimum; LDK-60, drying as lamella in lumber drying kiln at 60℃; LBD-60, drying as lumber in lumber drying kiln at 60℃; VRD-140, drying as lamella in veneer roller dryer at 140℃; VRD-100, drying as lamella in veneer roller dryer at 100℃; VRD-60, drying as lamella in veneer roller dryer at 60℃; VPD-100, drying as lamella in veneer press dryer at 100℃.

Table 10. Statistical data of surface roughness (Rz) of lamellas according to drying methods.

	LDK-60	LBD-60	VRD-140	VRD-100	VRD-60	VPD-100
Arithmetic mean	86.33713	83.19338	78.77063	76.57775	75.15088	56.876
Standard deviation	15.53696	14.46356	16.24784	16.7676	13.87356	19.65201
Variance	241.3972	209.1945	263.9924	281.1523	192.4756	386.2015
Coefficient of variation	17.99569	17.38547	20.62678	21.89617	18.46094	34.55238
Maximum	124	121.9	141.2	114.1	119.3	121.9
Minimum	57.77	51.8	45.22	42.99	45.11	29.52

CV, Coefficient of variation; SD, standard deviation, AT, arithmetic mean; Max, maximum; Min, minimum; LDK-60, drying as lamella in lumber drying kiln at 60℃; LBD-60, drying as lumber in lumber drying kiln at 60℃; VRD-140, drying as lamella in veneer roller dryer at 140℃; VRD-100, drying as lamella in veneer roller dryer at 100℃; VRD-60, drying as lamella in veneer roller dryer at 60℃; VPD-100, drying as lamella in veneer press dryer at 100℃.

sawn off usually from dried lumber. Drying time of lumber is long and this increases production expenses. For shortening drying time, lamellas can be cut away from green lumber and dried by using various drying methods. On the other hand, appropriate bonding of lamellas to bottom layers is important besides shortening drying time in multilayer parquet production. Many factors affect tensile shear strength. The most important ones are drying method, drying temperature and surface roughness.

In this study, lamellas manufactured from green lumber were dried by using four different methods. Three different temperatures as 60,100 and 140℃ were applied in drying with jet ventilated veneer roller dryer. The determination of drying temperature effect on surface roughness and tensile shear strength were tried. Also, for making comparisons, lamellas were manufactured from dried lumber usually seen in practice, in Turkey. In this way, lamellas manufactured from both green and dried lumber were researched according to surface roughness and tensile shear strength, and the most convenient lamella production method and drying method were determined.

Using analysis of variance, surface roughness differences were determined between test groups. In this way, drying method effect on surface roughness was revealed. As was expected, the least surface roughness was obtained by drying in veneer press dryer. Drying in veneer press dryer has made known the effect of pressing on surface smoothness. This effect was emphasized in Lutz et al. (1974). Surface roughness values of lamellas dried in veneer roller dryer at 3 different temperatures were found to be bigger than those dried in press dryer and less than those dried in lumber drying kilns. Surface roughness

Table 11. Statistical data of surface roughness (Rq) of lamellas according to drying methods.

Statistical data	LDK-60	LBD-60	VRD-140	VRD-100	VRD-60	VPD-100
Arithmetic mean	15.568	15.2861	14.787	14.652	13.765	9.285
Standard deviation	2.9377	2.75769	3.7968	3.7649	2.6291	2.4644
Variance	8.6301	7.60488	14.416	14.175	6.912	6.0733
Coefficient of variation	18.87	18.0405	25.676	25.695	19.1	26.542
Maximum	21.73	21.91	26.92	22.71	19.95	18.12
Minimum	10.76	9.49	9.12	7.12	8.22	6.03

CV, Coefficient of variation; SD, standard deviation, AT, arithmetic mean; Max, maximum; Min, minimum; LDK-60, drying as lamella in lumber drying kiln at 60℃; LBD-60, drying as lumber in lumber drying kiln at 60℃; VRD-140, drying as lamella in veneer roller dryer at 140℃; VRD-100, drying as lamella in veneer roller dryer at 100℃; VRD-60, drying as lamella in veneer roller dryer at 60℃; VPD-100, drying as lamella in veneer press dryer at 100℃.

values were stated to have increased by using higher drying temperatures in veneer roller dryer. This result is similar to other research results conducted by Starecki (1975), Aydın and Colakoglu (2002) and Kantay et al. (2003). Surface roughness difference was found between test groups (drying lamellas in drying kilns at 60℃, (LDK-60) and drying lamella blocks in lumber drying kiln at 60℃ (LBD-60)). Lamellas mentioned in these two test groups were manufactured in the same machine and dried in the same temperature. Lamellas, which were manufactured from green lumber and dried in drying kiln were found to have rougher surfaces. This result was expected and expressed by parquet manufacturers. According to these results, surface roughness of lamella group, which was manufactured from dried lumber and also mentioned as comparison group was higher than those dried in veneer roller and press dryers and smaller than those dried in lumber drying kiln. These results were found to be as expected and agreeable to literature; but as tensile shear strength, the results were found different.

Tensile shear strength differences were determined between 6 test groups dried with various drying types by applying analysis of variance. Tensile shear strength tests were applied according to TS EN 205 (2004). The biggest tensile shear strength value was determined in lamella group 6 and drying lamella blocks in lumber drying kiln at 60℃ (LBD-60) and was stated as comparison group. The smallest tensile shear strength value was found in lamella test group 2 (VRD-60), explained as drying lamellas in veneer roller dryer at 60℃. Tensile shear strength value of lamella test group, dried in veneer press dryer and having the smallest surface roughness values, was not expected to be bigger. The reason for this could be the surface inactivation effect. It was stated that surface inactivation occurrence could take place in drying at veneer press dryer in literature (Sernek, 2001). Tensile shear strength value of test group 1, LDK-60, drying lamellas in drying kilns at 60℃, having the biggest surface roughness was found to be higher than expected among other test groups. Tensile shear strength of test group 1, LDK-60 was found to be higher than the one dried in veneer press and roller dryers at 60 and 140℃. Relation between surface roughness and tensile shear strength was examined by applying correlation analysis in this study and no significant relation was found. However, it was stated that tensile shear strength increased, as surface roughness decreased in the literature (Faust and Rice, 1986; Efe and Gurleyen, 2001; Sonmez et al., 2001; Efe et al., 2007). Tensile shear strength and drying temperatures relations were determined in lamella test groups dried at 60, 100 and 140℃ temperatures respectively in veneer roller dryer by applying correlation analysis. As a result of correlation analysis, no relation was determined. Tensile shear strength of test group, dried by veneer roller dryer at 100℃ was found higher than that dried at 140℃. This result cannot state that bonding quality decreased, as drying temperature increased. This is because tensile shear strength of test group dried in veneer roller dryer at 60℃ was found smaller than that dried at 140℃.

Conclusively, tensile shear strength of lamella test group manufactured from dried lumber was found higher than other test groups dried in various conditions. Although surface roughness of test group dried in veneer press dryer at 100℃ was very small, tensile shear strength was found smaller than other test groups, while drying in veneer roller dryer, surface roughness increase was determined to materialize as drying temperature increases; but this case can not be generalized. Tensile shear strength of 3 test groups dried in veneer roller dryer was found smaller than that dried as lamella block. These results indicated that lamella manufactured from dried lumber, which has been usually applied in multilayer parquet production, is convenient for multilayer parquet manufacturing in obtaining adequate tensile shear strength as compared to other drying methods tested in this study.

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REFERENCES

Aydin I, Çolakoğlu G (2002). The effects of veneer drying temperature on wettability, surface roughness and some properties of plywood, p. 60-70. Proceedings of the Sixty Panel Products Symposium, 9-11 October 2002, Llandugno, Wales, UK.

Aydin I, Çolakoğlu G (2005a). Formaldehyde emission, surface roughness, and some properties of plywood as function of veneer drying temperature, Drying technology, 23(5): 1107-1117.

Aydin, I, Çolakoğlu G (2005b). Effects of surface inactivation, high temperature drying and preservative treatment on surface roughness and colour of alder and beech wood. Appl. Surface Sci. 252: 30-440.

Aydin I, Çolakoğlu G, Akbulut T (2001). Adhesion theory in bonding wood material, Faculty of Forestry Publication, Istanbul University, Serie: B, 51(2): 91-99, Istanbul.

Bozkurt Y, Göker Y (1981). Utilization of Forest Products, Faculty of Forestry Publication, Istanbul University, Number: 297, Bahcekoy/Istanbul.

Christiansen AW (1990). How overdrying wood reduces its bonding to phenol formaldehyde adhesives: A critical review of the literature, Part 1. Physical Responses, Wood Fiber Sci. 22(4): 441-459.

Efe H, Gürleyen L (2007). The determination of bonding strength of various wood surfaces on the sanded with different numbered sandpapers, Kastamonu University, Faculty of Forestry Journal, 7(2): 110-123, Kastamonu.

Efe H, Gürleyen L, Budakçi M (2007). Effect of the cutting direction and number of knives on surface smoothness and bonding strength for Acacia, Kastamonu University, Faculty of Forestry Journal, 7(1): 13-23, Kastamonu.

Faust TD, Rice JT (1986). Effect of veneer surface roughness on the bond quality of southern pine plywood. Forest Prod. J. 36(4): s. 57-62.

Guler C, Çolakoğlu G (2001). The effect of surface roughness of calabrian pine (*Pinus brutia Ten.*) veneers produced in different conditions on the shear-tensile strength of plywood, Sütçü İmam.University, Sci. Eng. J. 4(1): 92-98.

Kantay R (1982a). Veneer drying, Faculty of Forestry Publication, Istanbul University, Serie: B, 32(2): 94-125, Istanbul.

Kantay R (1982b). Veneer Drying Machines, Istanbul University, Serie: B, 32(2): 126-146, Istanbul.

Kantay R (1983). Studies on drying properties of Walnut, Quercus and Fagus veneers, Faculty of Forestry Publication, Istanbul University, Number: 269, Bahcekoy/Istanbul.

Kantay R (1993). Drying and Steaming of Lumber, Forestry Education and Culture Foundation, Publication Number: 6, Istanbul.

Kantay R, Korkut S, Sancakli M (1997). Effect of drying temperature on drying time and quality in drying veneer, 1. National Furniture Congress Journal Book, pp. 281-289, Hacettepe University, Beytepe/Ankara.

Kantay R, Akbulut T, Korkut S (2003). The effect of peeling temperature on surface roughness in peeled beech veneer production, Faculty of Forestry Publication, Istanbul University, Serie: A, 53(2): 1-11, Istanbul.

Kantay R, Güngör NM (2009). Lamella production for multi-layer parquet elements, Faculty of Forestry Publication, Istanbul University, Serie: B, 59(1): 43-58, Istanbul.

Lutz JF, Habermann H, Panzer HR (1974). Press-drying green, flats sliced Walnut Veneer to reduce buckling and waviness, Forest Prod. J. 24(9): s. 29-34.

Ors Y, Colakoglu G (1995). Effect of some production factors on Bonding Strength of Alder and Poplar Plywood, Agriculture and Forestry, Tubitak, 19: 451-456.

Sernek M (2001). Inactivation of wood surfaces: A literature review, Virginia Tech University, Wood-based Composites Center, Technical Report No: 103, p. 14.

Sonmez A, Budakci M, Gurleyen L (2001). The effect of surface smoothness on bonding strength for acacia wood that processed with knives planer (HSS), Gazi University, J. Ind. Arts Education Faculty, Year: 9, No. 9: 29-40.

Starecki A (1975). Effect of drying temperature on the shrinkage and surface roughness of veneer. Przemyel-Drzewny, Poland, 40(4): 18-24.

TS EN 1250 (1974). Veneers, Turkish Standardization Institute, Necatibey Avenue, No. 112, Ankara.

TS EN 13183-2 (2002). Moisture content of a piece of sawn timber - Part 2: Estimation by electrical resistance method; Part 2: Turkish Standardization Institute, Necatibey Avenue, No.112, Ankara.

TS EN 205 (2004). Adhesives-Wood adhesives for non-structural applications- determinationof tensile shear strength of lap joints, Turkish Standardization Institute, Necatibey Avenue, No.112, Ankara.

TS EN 13489 (2004). Wood Flooring, Multilayer parquet elements, Turkish Standardization Institute, Necatibey Avenue, No. 112, Ankara.

TS 5430 EN 204 (2003). Classification of thermoplastic wood adhesives for non-structural applications, Turkish Standardization Institute, Necatibey Avenue, No. 112, Ankara.

Vick CB (1999). Adhesive bonding of wood materials, Forest Products Laboratory, Wood Handbook-Wood as an Engineering Material, Gen. Tech. Rep. FPL-GTR-113, Madison, WI, U.S. Department of Agriculture, Forest Service, p. 463.