Influence of Planer Shavings and Waste Particleboards Usage in Core layer on Physical and Mechanical Properties of Three-layer Particleboards

***Hüsnü YEL[1], Ayfer DÖNMEZ ÇAVDAR[2], Hülya KALAYCIOĞLU[3], Uğur ARAS**
[1]Dept. of Forest Industrial Engineering, Artvin Çoruh University, Artvin 08000, Turkey
[2]Dept. of Interior Architecture, Karadeniz Technical University, Trabzon 61080, Turkey
[3]Dept. of Forest Industrial Engineering, Karadeniz Technical University, Trabzon, Turkey
*Corresponding author: yel33@artvin.edu.tr

Geliş Tarihi: 12.05.2014

Abstract

The objective of this study is to investigate utilization of waste particleboards and planer shavings in manufacturing three-layer particleboard panels. For this purpose, waste particleboards and planer shavings were used in core layer of particleboard at different shelling ratios. Nine groups of three-layer experimental boards with a target density of 0.65 g/cm3 were manufactured. Physical (thickness swelling and water absorption) and mechanical properties (modulus of rupture, modulus of elasticity and internal bonding strength) of the particleboards produced were determined according to EN standards. The results have showed the mechanical properties of all the particleboards (excepted for B board group produced from 100% waste particleboard) produced have satisfied the minimum requirements of mechanical properties of particleboard defined in EN standards. Thickness swelling values of the experimental particleboard for 24h water immersion were found lower than the maximum thickness swelling value of particleboard in defined in EN standards.

Keywords: Particleboard, Waste particleboard, Planer shavings, Mechanical properties, Physical properties

Orta Tabakada Atık Yongalevha ve Planya Artıkları Kullanımının Yongalevhanın Fiziksel ve Mekanik Özellikleri Üzerine Etkisi

Özet

Bu çalışmada, üç tabakalı yongalevha panellerinin üretiminde atık yongalevha ve planya artıklarının kullanılabilirliliğinin araştırılması amaçlanmıştır. Bu amaçla, atık yongalevhalar ve planya artıkları farklı oranlarda yongalevhanın orta tabakasında kullanılmıştır. 0.65g/cm^3 hedef yoğunluğa sahip 9 farklı grupta deneme levhası üretilmiştir. Üretilen levhaların fiziksel (su alma ve kalınlık artımı) ve mekanik (eğilme direnci, eğilmede elastikiyet modülü ve yüzeye dik çekme direnci) özellikleri, ilgili EN standartlarına uygun olarak belirlenmiştir. Elde edilen sonuçlara göre, %100 atık yongalevhadan üretilen levha grubu (B) hariç tüm levha gruplarının mekanik özellikleri, EN standartlarında belirtilen minimum şartları sağladığı görülmüştür. Deneme levhalarının 24 saatlik kalınlık artımı değerleri ise standartta belirtilen maksimum değerden daha düşük bulunmuştur.

Anahtar Kelimeler: Yongalevha, Atık, Planya artığı, Mekanik özellikler, Fiziksel özellikler

Introduction

Because of an increase in the demand for forest products due to the growth of the world population, forest products industries are faced with a shortage of raw materials. This situation leads to the better and efficient utilization of available resources. The re-utilization of wood waste, used wood and annually non-wood materials in manufacturing particleboards can play a vital role both in economic development and in forest resources conservation of any country.

Many researchers have investigated the properties of particleboards made from wide variety of wood and non-wood residues: hazelnut husk (Güler et al. 2009), eggplant stalks (Güntekin and Karakuş 2008), pepper stalks (Güntekin et al. 2008), sunflower stalks (Bektaş et al. 2005), coffee husk and hulls (Bekalo and Reinhardt 2010), pine needle litter (Nemli and Aydın 2007), almond shells (Gürü et al. 2006), branch wood, decayed wood and bark (Nemli et al. 2004), cotton carpel (Alma et al. 2005), recycled paper sludge (Lykidis and Grigoriou 2008), wood prunings and waste porcelain stone (Hermawan et al. 2009).

Particleboard produced from wood or other lingo-cellulosic materials is used widely in the manufacture of furniture, floor underlayment, cabinets, home constructions, tabletops, vanities, sliding doors, lock blocks, interior signs, pool tables, electronic game consoles, kitchen worktops, work surfaces in offices, educational establishments, laboratories, and other industrial products (Url 1 1996). Therefore, particleboard has a very important place in forest products industry and, its using ratio and importance are increasing day by day.

In a panel under load, the forces of compressive and tensile decrease towards the center (neutral zone) and become zero in the center (Zerkert 1997). Therefore, there is no need for core layer to resist to the forces of compressive and tensile as well as surface layers. This means low-quality materials can be used in core layer without a significant decrease in strength values of the panel.

The objective of this study is to manufacture qualified particleboards using planer shavings and waste particleboards in core layer and poplar in surface layer and to determine their optimal usage ratios. Our secondary objective is to find an alternative raw material and contribute to the recycle of some wood based wastes for the particleboard industry in the world.

Materials and Methods

Poplar (*Populus euroamericana cv*.) shavings and waste particleboards used in this study were obtained from Sözenler Forest Products Co. in Trabzon. Urea formaldehyde used as a binder was obtained from Kastamonu Integrated Wood Industry and Trade Co., Turkey. Waste particleboard and poplar wood had been chipped using a hacker before the chips were reduced into smaller particles using a laboratory-scale knife ring flaker. Planer shavings were obtained from some poplar wood using a plane machine. And then, these planer shavings (waste) were reduced into smaller particles by using the flaker. All the particles were classified into four size categories by means of a screening machine through meshes with 3, 1 and 0.5mm apertures to remove oversize and undersize and separate the core and surface layer particles. The classified particles were dried to 1-3% moisture content in a laboratory hot air dryer. The particles were blended with urea formaldehyde (UF) resin with a solid content of 60%. The amount of resin and hardener (NH_4CI) required for a particleboard was determined by its resin solid weight and it was calculated as proportionate to the oven dry weight of the wood particles required. UF resin was used 9% in core layer and 11% in surface layers. Ammonium chloride was used as a catalyst (hardener) in 1%. The target density of experimental particleboards produced with lengths of 56 cm, widths of 50 cm, and thicknesses of 1.8 cm, was 0.65g/cm^3. Experimental design was shown in Table 1.

Table 1. Experimental design

Board type	Shelling ratio	Surface layer Raw materials	Core layer Raw materials
A	40:60	Poplar	Poplar
B	40:60	Waste PB	Waste PB
C	40:60	Planer shavings	Planer shavings
D	50:50	Poplar	Waste PB
E	50:50	Poplar	Planer shavings
F	40:60	Poplar	Waste PB
G	40:60	Poplar	Planer shavings
H	30:70	Poplar	Waste PB
J	30:70	Poplar	Planer shavings

Hand-formed mats were pressed at a temperature of 150^{o}C and a pressure of 25 kg/cm^2 for 6 min. After pressing, the particleboards were conditioned at a temperature of 20 ^{o}C and relative humidity of 65% for seven days.

Test samples were cut from the particleboards by means of a circle saw, and all the samples were conditioned to equilibrium at the temperature of 20^{o}C and the relative humidity of 65% prior to the test. The values for internal bonding strength (IB), modulus of rupture (MOR), modulus of elasticity in bending (MOE), thickness swelling (TS) and water absorption (WA) after 2 hours and 24 hours water immersion were then determined according to procedures defined in the European Union Standards EN 310, EN 317, EN 319 and ASTM D1037. The data obtained was statistically analyzed by using the analysis of variance (ANOVA) and Duncan's mean separation tests.

Results and Discussion

The mean, standard deviation and Duncan test results for water absorption (WA) and thickness swelling (TS) of particleboards made from poplar chips (control), waste particleboard and planer shavings for 2-h and 24-h water immersion times were shown in Table 2. The best (the lowest) water absorption and thickness swelling values of the board groups for both 2 and 24 hours water immersion were obtained from B-board group (made of waste particleboards). This is why B-board group contains more urea formaldehyde adhesive than the other board groups because B board group was produced from waste urea formaldehyde-bonded particleboard. Previous cured UF maybe resist water absorption.

Since planer shavings consist of lighter and thinner particles, especially in core layer, than waste particleboard, the difference between water absorption values of B and C board groups after 2-hours water immersion was not statistically significant, while the difference after 24-hours water immersion was statistically significant.

The maximum thickness swelling requirements are 15%, and 14% for load-bearing and heavy-duty load-bearing boards respectively after 24-h immersion, according to EN 312-4 and EN 312-6. Accordingly, B, C, D, F and H board types has satisfied the minimum requirements of the above standards. However, thickness swelling values of A, E, G and J groups were found higher than 15% for 24-h water immersion. These high values may be related to the fact that no wax or other hydrophobic substance was used during particleboard manufacture. Adding water-repellent chemicals such as paraffin, coating of the particleboard surfaces and acetylating of particles can improve the water repellency of the panels (Rowell and Norimoto 1998; Nemli 2000; Güntekin et al. 2008).

Table 2. Means, standard deviation and Duncan test results for thickness swelling (TS) and water absorption (WA) of the boards after 2 h and 24 h water-immersion

Board Type	Water Absorption (%)		Thickness Swelling (%)	
	2h	24h	2h	24h
A	62.31 (3.85) b	73.23 (3.32) bc	16.21 (0.95) d	18.35 (0.83) e
B	56.73 (2.03) a	68.67 (4.75) a	11.29 (0.69) ab	13.47 (0.57) ab
C	56.14 (4.28) a	77.33 (3.86) d	10.82 (0.66) a	13.93 (0.63) bc
D	62.00 (5.15) b	69.97 (3.77) ab	11.01 (0.47) a	13.08 (0.54) a
E	62.00 (4.25) b	75.24 (4.58) cd	13.93 (0.59) c	16.12 (0.54) d
F	59.93 (5.01) ab	66.75 (2.39) a	10.84 (0.61) a	13.73 (0.62) b
G	60.72 (3.46) b	76.06 (3.82) cd	13.71 (0.55) c	16.55 (0.74) d
H	59.36 (4.54) ab	69.13 (4.39) a	11.63 (0.51) b	14.37 (0.59) c
J	67.92 (4.12) c	81.55 (3.65) e	16.87 (0.64) e	19.48 (0.77) f

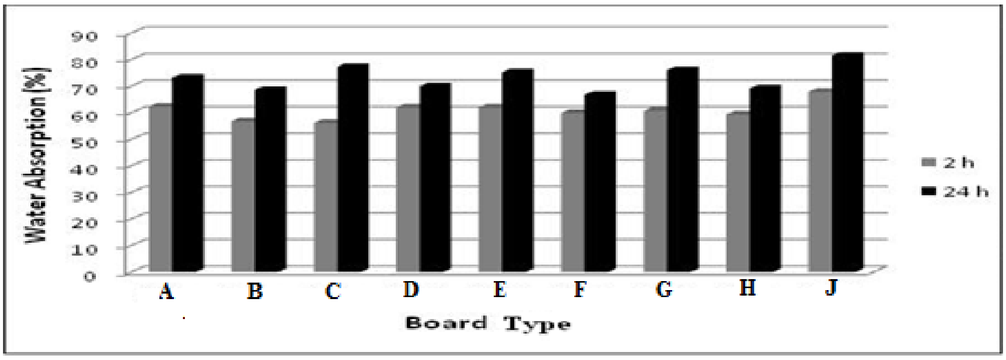
**Numbers in parenthesis are standard deviation. Means within a column followed by the same capital letter are not significantly different at 5% level of significance.*

Thickness swelling values of the particleboards generally were found lower than the thickness swelling values of the particleboard made from particles impregnated with *Pinus brutia* bark extractives reported by Nemli et al (2006) and those of the particleboard made from saline Athel wood reported by Zheng et al (2006).

On the other hand, water absorption values of the particleboards were found higher than those of the particleboard made from saline Athel wood reported by Zheng et al (2006). In addition, both thickness swelling and water absorption values of the particleboards were found lower than those of the particleboards made from saline eucalyptus reported by Pan et al (2007).

Figure 1 shows average values of water absorption and thickness swelling of the particleboards for 2-h and 24-h water immersion. As shown in figure 1, planer shavings have generally increased water absorption ratio of the particleboard with increasing the usage ratio of planer shavings ratio, while the waste particleboard have decreased water absorption ratio of the particleboard with increasing the usage ratio of the waste particleboard**.** Both planer shavings and waste particleboards have decreased thickness swelling values of the particleboards. In addition, it can be seen that waste particleboard is more effective on decreasing thickness swelling values of the particleboards than the planer shavings.

Table 3 shows average values of modulus of rupture (MOR), modulus of elasticity (MOE) and internal bonding strength (IB) and statistical test results of the particleboard produced from poplar, planer shavings and waste particleboard. The highest values were obtained from G-board group for MOR and MOE, and H-board group for IB, while the lowest values were obtained from B board group for MOR, MOE and IB. This is why bonding among the particles is weak because the particles produced from waste particleboard were more coarse and dense than normal poplar chips and planer shavings.



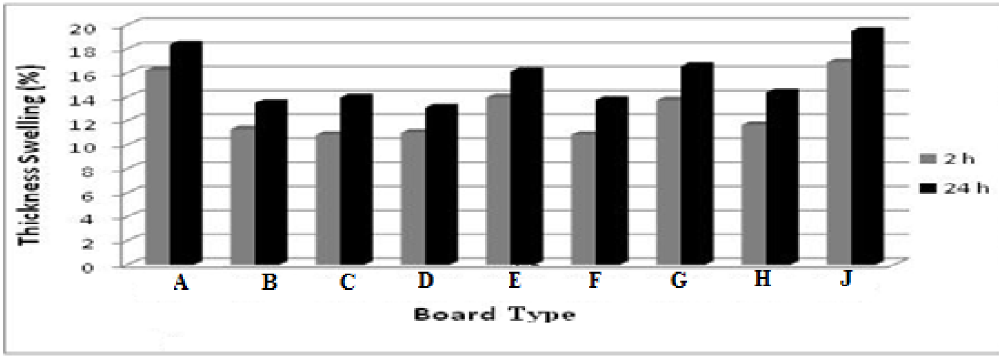


Figure 1. Average values of water absorption and thickness swelling of the particleboards for 2 h and 24 h immersion

Table 3. Means, standard deviation and Duncan test results of modulus of rupture (MOR), modulus of elasticity (MOE) and internal bonding strength (IB) of the board groups

Board Type	MOR	MOE	IB
		N/mm^2	
A	17.76 (0.95) C	2702 (126) C	0.74 (0.01) B
B	9.12 (0.65) A	1649 (102) A	0.63 (0.02) A
C	17.81 (0.88) C	2639 (163) C	0.84 (0.02) DE
D	15.03 (0.67) B	2226 (167) B	0.83 (0.03) DE
E	18.14 (0.91) C	2635 (172) C	0.77 (0.04) BC
F	17.14 (0.84) C	2666 (156) C	0.80 (0.03) CD
G	20.63 (0.79) D	2935(163) D	0.65 (0.01) A
H	14.81 (0.57) B	2353 (139) B	0.87 (0.01) E
J	17.26 (0.76) C	2594 (143) C	0.62 (0.02) A

**Numbers in parenthesis are standard deviation. Means within a column followed by the same capital letter are not significantly different at 5% level of significance.*

As shown in Table 3, the differences between MOR and MOE values of A, C, E, F and J board groups were not statistically significant. In addition, the difference between IB values of B, G and J boards was not statistically significant. However, the differences between MOR and MOE values of B, D and G board groups were statistically found significant.

According to EN 312-2 and EN 312-3 standards, 11.5, 13, and 1600 N/mm^2 are the minimum requirements for modulus of rupture, and modulus of elasticity of particleboard panels for general uses and furniture manufacturing, respectively. All the board groups, except for B board group, have satisfied the minimum requirements for the modules of rupture and modules of elasticity of particleboards defined in EN 312-2 and EN 312-3 standards for both general uses and furniture manufacturing. IB values of the particleboards produced, ranged from 0.62 to 0.87 N/mm^2. Based on the test results, internal bonding strength values of all the board groups were much higher than the minimum internal bonding strength requirements of particleboards for general uses, which is 0.24 N/mm^2 for general purpose uses and 0.35 N/mm^2 for interior fitments as stated in EN 312-2 and EN 312-3, respectively.

Mechanical properties (MOR, MOE and IB) of all the board groups were generally found higher than MOE (ranged from 371 to 2088 N/mm^2), MOR (ranged from 3.73 to 16.59 N/mm^2) and IB strength (ranged from 0.0176 to 0.639 N/mm^2) values of the particleboards produced from hardwood sawmill waste reported by S. Setunge et al (2009). In addition, the mechanical properties were also found higher than MOE (ranged from 1121 to 1722 N/mm^2), MOR (ranged from 8.10 to 13.35 N/mm^2) and IB strength (ranged from 0.204 to 0.382 N/mm^2) values of the particleboards produced from alder wood (*Alnus glutinosa* subsp. *barbata*) with *Pinus brutia* bark extractives reported by Nemli et al (2006). On the other hand, mechanical properties of all the boards were found much higher than those of composite board produced using wood prunings and waste porcelain stone reported by Harmawan et al (2009).

Figure 2 shows average values of modules of rupture (MOR), modules of elasticity (MOE) and internal bonding strength (IB) of the particleboards produced. As shown in figure 2, the mechanical properties decrease with the increment of the usage ratio of waste particleboard in particleboard manufacturing. In addition, it can be seen that if particles obtained from waste particleboards are used only in core layer, the mechanical properties of the particleboard will satisfy the minimum requirements of the EN standards.

Both MOR and MOE values of A (control) and C board groups were similar to each other, while the IB strength value of C was higher than A group. The reason for this situation may be that planer shavings in the core layer were finer than the normal poplar chips (A). Nevertheless, IB strength value of J was lower than those of A and C, while IB strength value of E was shown between IB strength values of A and C. This means E had the best suitable shelling ratio in particleboards produced from planer shavings and poplar chips.

Conclusions

Mechanical and physical properties of the particleboards produced generally satisfied the requirements for particleboard defined in EN standards. The lowest mechanical properties were obtained from the boards made of 100 % waste particleboard. This is why bonding between the particles is weak because the particles produced from waste particleboard were more coarse and dense than normal poplar chips and planer shavings. However, it was shown that using waste particleboards in core layer have increased mechanical properties of the boards. Therefore, it was shown that high qualified particleboards could be manufactured by using waste particleboards in core layer. In addition, the lowest (best values) of thickness swelling and water absorption values were obtained from the boards made of 100% waste particleboard. This is why this board group contained more urea formaldehyde adhesive than the other board groups because it was produced from urea formaldehyde-bonded waste particleboard.

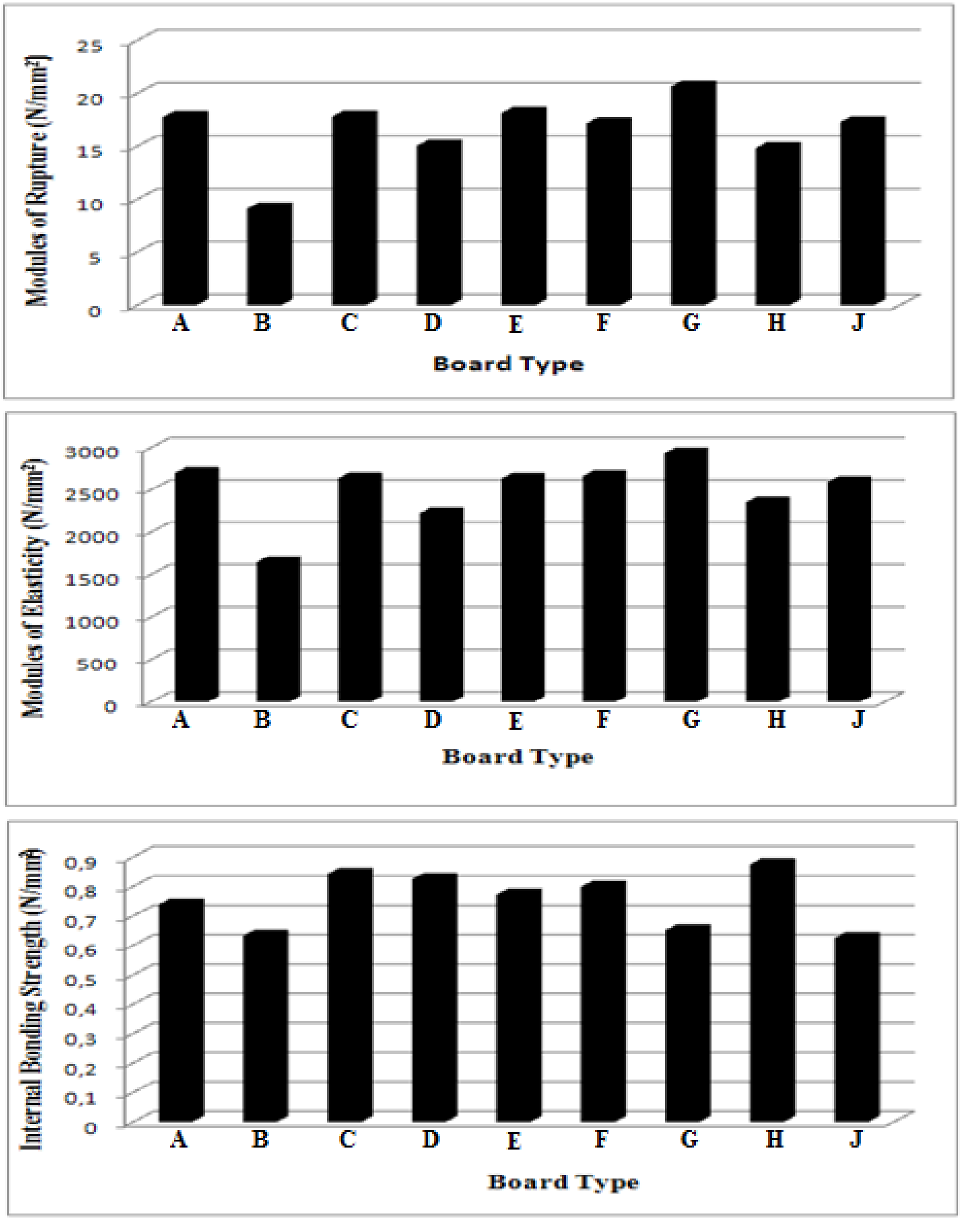


Figure 2. Average values of modules of rupture (MOR), modules of elasticity (MOE) and internal bonding strength (IB) of the particleboards produced

According to the test results, the best mechanical properties of the particleboard were obtained from G and F board groups, whose core layers were consisted of planer shavings and waste particleboards, respectively. This means the best suitable shelling ratio is 0.4:0.6 (surface layer / core layer) when using planer shaving and waste particleboards in core layer.

Particleboard industries should take account of the test results above when waste particleboard and planer shaving are used. Therefore, it can be produced the particleboards having the lower cost and higher quality.

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