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Study of the Physical and Mechanical Properties of Composite Boards Made of a Mixture of Poplar Chips and Recycled Tires

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Abstract

The present study focused on the possibility of using recycled tires in the production of composite boards. Variables included: Mixing ratio of rubber particles and wood chips at four levels, namely 0, 25, 50, and 75 percent (based on the weight of dry wood); resin content at three levels, namely 3, 4, and 5 percent; and density at two levels, namely 0.55 and 0.75 gr/cm^3. In total, 24 different treatments of bending strength, modulus of elasticity (MOE), and shear strength were examined according to DIN standards as well as impact strength in compliance with ASTM standard. The treatments were then compared with the control samples. Results showed that mixing ratio of rubber chips influences the mechanical and physical properties of the composite board produced. The increase in rubber chips content decreased bending strength, MOE, and shear strength; but it increased the specific gravity, MOR, MOE, and shear strength. Maximum MOR, MOE, and shear strength were at the mixing ratio of %25 rubber chips, using % 5 resin, and having 0.75 gr/cm^3 specific gravity. Maximum impact strength was at the mixing ratio containing 50 percent rubber chips, using a 5 % resin and having 0.75 gr/cm^3 specific gravity.

Keywords. composite board; mixing ratio; resin content; recycled tire; physical, mechanical properties.

بررسی چسبندگی داخلی تخته مرکب ساخته شده از مخلوط خرده چوب صنوبر و لاستیک بازیافتی از تایر اتومبیل

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چکیده

این تحقیق به منظور امکان استفاده، و جایگزینی لاستیک بازیافتی اتومبیل در ساخت تخته مرکب چوب/ لاستیک انجام گرفته است. عوامل متغیر شامل: نسبت اختلاط پودر لاستیک به خرده چوب، در چهار سطح صفر،۲۵، ۵۰، ۷۵ درصد(بر مبنای وزن چوب خشک)، درصد چسب در سه سطح ۳،۴،۵ درصد و وزن مخصوص در دوسطح cm/gr^3 ۰/۵۵، ۰/۷۵gr/cm^3 بوده است. ترکیب عوامل متغیر ۲۴ حالت (تیمار) و مقاومت چسبندگی داخلی مطابق استاندارد DIN در مقایسه با نمونه شاهد مورد آزمایش و بررسی قرار گرفت. نتایج نشان می دهد که درصد اختلاط پودر لاستیک بر روی خواص فیزیکی و مکانیکی تخته مرکب تأثیر دارد و افزایش درصد پودر لاستیک چسبندگی داخلی را کاهش می دهد. اما افزایش وزن مخصوص و مقدار چسب سبب افزایش چسبندگی داخلی می‌شود. بیشترین مقدار چسبندگی داخلی در درصد اختلاط صفر و ۲۵ درصد پودر لاستیک، ۵٪ مقدار چسب و وزن مخصوص ۰/۷۵ gr/cm^3 می باشد.

واژگان کلیدی: تخته مرکب، نسبت اختلاط، درصد رزین، تایر بازیافتی، خواص فیزیکی و مکانیکی

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Introduction

Recent progresses in the technology of new and efficient resins have made particleboard highly important. Population growth increases the need for wood products; therefore, careful use of the resources is a must.

The way and direction in which particles are located in composite boards can be regarded as a vital factor in determining their properties. The shape and size of the particles, as well as the kind of resin used in the board, also contribute to the properties of the board.

Limitations on forest resources as well as the increasingly recognition of the high value of trees by humans have led scientists to carry out vast studies for finding the economic ways to utilize wood efficiently. One of these is the production of composite boards made of wood particle, rubber, and resin. Two areas included in the present study: a study on mechanical specifications of the composite boards made of wood particles and recycled tire; production of an emerging product; and material recycling.

Lee (1998), Febriano (1999), and Yang (2004) reported that rubber decreases water absorption and water content substantially and also increases the board's flexibility. Shang *et al.* (2001) studied the properties of the composite board made of woody fibers from a TMP process and recycled rubber obtained from used automobile tires passed through grade 30 mesh and containing different resin and rubber contents. Results showed that an increase in the resin content would increase the internal bond, but decrease impact strength, bending and tensile strengths. Due to their greater flexibility, rubber and wood composite-boards are suitable for places where tolerating high impact or compression loads are essential. In addition, they can also be used in indoor structures, such as flooring of rooms and gymnasiums, kids' rooms, as well as outdoor structures such as park benches, playgrounds for children in parks and curbs alongside the roads.

Materials and Methods

Raw materials: Chips from poplar (*Populus nigra*) and worn-out automobile tires were used in the present study. Trees were collected from Shafa-rood district in Gilan province and delivered to the laboratory of the Faculty of Natural Resources at Karadj to be converted into chips with a Pallmann (pz8) chipper. Recycled automobile tire powder (grade 60 mesh) was obtained from Yazd tire manufacturing factory and delivered to Alborz Research Center. When the boards were made, a DarTec testing machine was used (Figure 1) to measure the mechanical strengths; this machine is equipped with drawing and graphing apparatus.

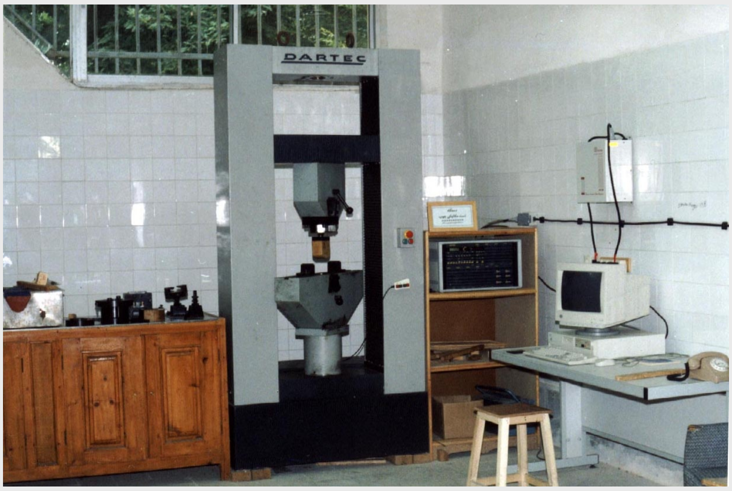

Figure 1- Testing machine used for the samples

For measuring wood chips slenderness (length/thickness ratio) 50gr was taken by random and with the precision of 0/01 mm determined. Dispersion of wood chips was examined according to Bison - Quality – 44011 standards Specifications of the chips are summarized in Table 1. The resin used in this study was polymeric methylene diisocyanate (PMDI) the specifications of which are in Table 2. Variables and constant factors in this study are as follows (Tables 3 and 4).

Table 1- Specifications of the chips used in this study

Specifications of the chips	Mean Value
Length of the chips (mm)	33.95
Thickness of the chips (mm)	0.66
Slenderness Ratio	51.43

Table 2- Specifications of the resin used in this study

Resin type	Appearance	Density (gr/cm^3)	Solid Particles (%)	Viscosity (CP)	NCO (%) N = C = O
PMDI	Liquid; dark brown	0.66	100	300	30.5 – 32.5

Table 3- Variables

Tire powder (%)	0 (control) 25 50 75
Resin (%)	3 4 5
Density (gr/cm^3)	0.55 0.75

Table 4- Pressing factors and Thickness of the board

Thickness of the board (mm)	15
Pressing time (min.)	10
Pressure (Kg/cm^3)	49
Pressing temperature (centigrade)	120

Results and Discussion

Bending Strength The slenderness ratio of the chips used in the present study was 51.43 while the slenderness ratio of the tire powder was nearly 1. An increase in tire powder content ranging from 0 to 75 percent would result in a 92 % decrease in the bending strength. Also, an increase in density ranging between 0.55-0.75 gr/cm^3 resulted in a decrease in the porosity of the boards. Increased density causes more material in volume and naturally promotes loading capacity. The control sample showed maximum bending strength, followed by the mixture ratio of 25% tire powders, 5% resin, and 0.75 gr/cm^3 density (Figure 2).

The modulus of elasticity was also highly influenced by the volumetric ratio of the mixed raw materials and the interactions among them. Results showed that the chips' content and density had significant effect on the physical and mechanical properties; the higher the ratio of chips, the higher a MOE will be achieved. Furthermore, powerful bonds, adequate and uniform pressing time or temperature on the composite board, and homogenous mat forming are some of the effective factors on MOE [10]. The control sample had the maximum MOE followed by treated wood with 25% tire powder, 3% resin, and 0.75 75 gr/cm^3. Figure 3 shows the interaction of different mixing ratios of tire powder, resin, and density with MOE.

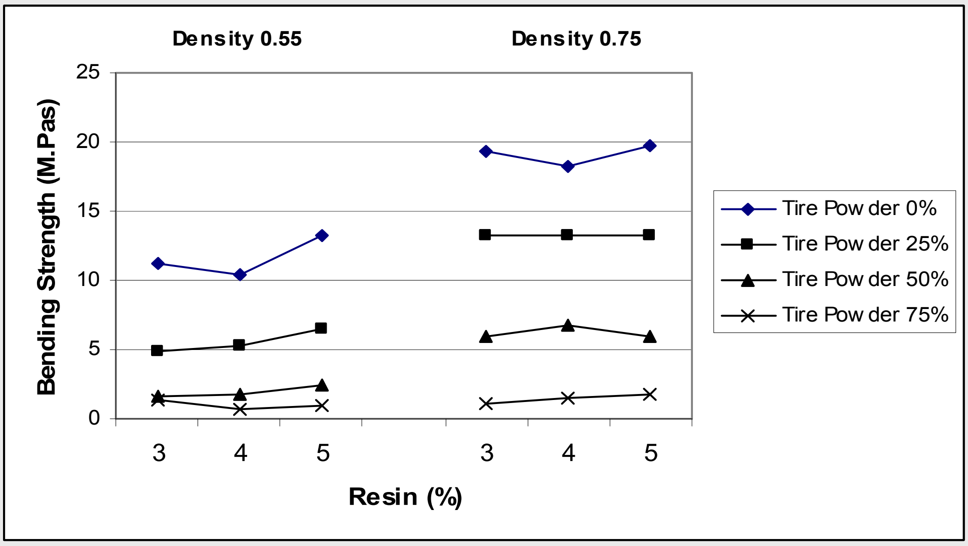

Figure 2- Interaction among the mixing ratios of tire powder, resin, and density with bending strength.

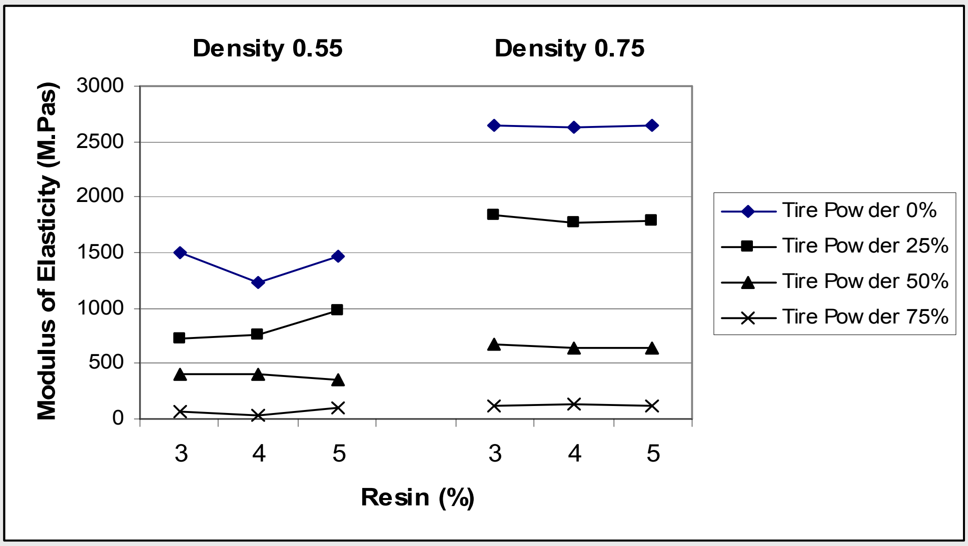

Figure 3- Interaction between the mixing ratios of tire powder, resin, and density with MOE.

Shearing strength

Shearing strength parallel to the surface of the board, specifically in the central layer of the board, is one of the basic properties that indicates the quality of adhesion and cohesion among the chips, tire powder, and resin. Shearing strength may be improved by adequate and uniform pressing, and complete polymerization of the resin in the internal layers of mat [10]. Boards with higher densities (0.75 gr/cm^3 in comparison to 0.50 gr/cm^3) show a higher MOE due to their better response to pressing. Increase in the volumetric ratio of tire powder up to 75% would decrease 85% of the shearing strength. The control sample (0% tire powder, 5% resin, and 0.75 gr/cm^3) showed maximum shearing strength of 2.87 MPa which was clearly higher than the standard limit of 2 MPa. Followed by the sample was board with 25% tire powder, 5% resin, and 0.75 gr/cm^3, resulting in 2.08 MPa; apparently it is higher than the standard limit (Figure 4).

Impact strength

Rubber is composed of many polymeric repeated units (mainly polybutadiene) chained together and having great flexibility due to their ability to stretch and rotate around their axes. Rubber has high elasticity and can absorb energy while changing its elastic form [1]. Once rubber particles are added to the chips and are linked to them, tensions and stresses will be accumulated in the rubber particles; this ability to absorb and accumulate a great deal of stresses leads the shear strength increase, allowing it to absorb a great deal of energy; this results in a subsequent increase of impact strength. Studies show that the greater the percentage of rubber powder, the less impact strength will be observed [1]. However, using more resin causes inflexible inter-molecular bonds to be formed, and also renders rubber particles more tightly fixed in their position at the time of impact [1]. Therefore, it will let energy absorption decrease; consequently the impact strength will decrease. Shang (2001) reported that an increase in resin will decrease impact strength and vice versa [1]. Figure 5 shows the interaction of rubber powder content, resin content, and density with impact strength. Table 5 also shows mechanical properties of 0.75 gr/cm^3 density composite board.

Furthermore, the flexibility and flexural properties

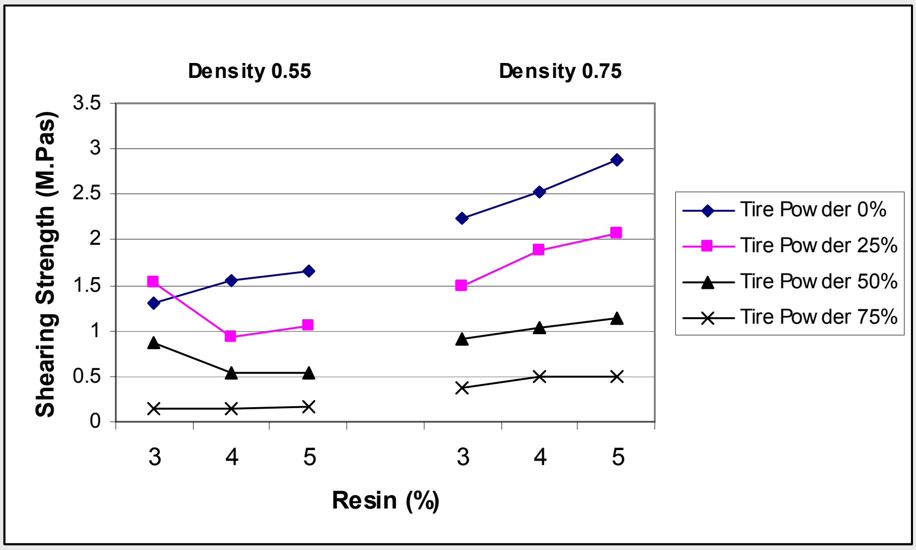

Figure 4- Interaction between the mixing ratios of tire powder, resin, and density on shearing. strength parallel to the surface of the board

of the wood chip/rubber powder composite boards with waste tire were superior to those of other wood-based panel products. The results of Yang *et al.* (2004) achieved in his study have a close correlation with those of the present study regarding decrease in water absorption as well as increase in impact strength.

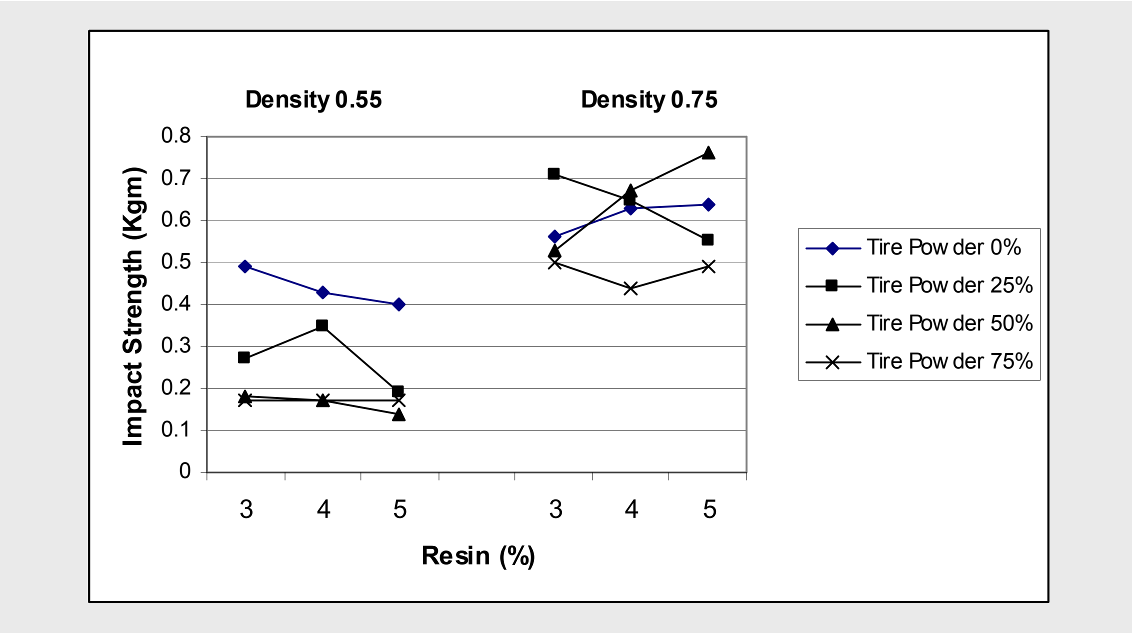

Figure 5- The interaction of rubber powder content, resin content, and density on impact strength.

Table 5- Mechanical properties of 0.75 gr/cm^3 density composite board.

PDMI (%)	Mixing Ratio Chips:Rubber	Modulus of Elasticity (M.Pas)	Modulus of Rupture (M.Pas)	Shearing Strength Parallel to the surface (M.Pas)	Impact Strength (Kgm)
3	25:75	121.96	1.11	0.37	0.5
	50:50	668.36	5.92	0.92	0.53
	75:25	1831.53	13.19	1.5	0.71
	100:00	2652.39	19.35	2.24	0.56
4	25:75	136.59	1.55	0.49	0.44
	50:50	632.14	6.80	1.03	0.67
	75:25	1772.54	13.28	1.88	0.65
	100:00	2631.60	18.31	2.53	0.63
5	25:75	120.47	1.69	0.5	0.49
	50:50	643.16	5.98	1.14	0.76
	75:25	1786.48	13.25	2.08	0.55
	100:00	2638.14	19.69	2.87	0.64

Discussion and Conclusion

High elasticity along with the ability to absorb a great deal of energy while elastically deforming make composite board (made of wood chips and up to 50% rubber powder) to have an increase in impact strength of up to 16%. Furthermore, increased resin content results in inflexible inter-molecular bonds being created; this will cause rubber particles to absorb less energy made by the impact and, consequently, the impact strength will decrease. On the other hand, the water-proof nature of rubber leads the composite to have less thickness swelling. In this case, using isocyanate resin improves this property. The slenderness ratio of the tire powder was nearly 1. An increase in the volumetric ratio of tire powder resulted in a decrease in shearing strength, bending strength and MOE. Also, an increase in density ranging from 0.55 to 0.75 gr/cm^3 resulted in a decrease in porosity and an increase in the mechanical properties of the boards.

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