EFFECT OF ADHESIVE TYPE ON THE QUALITY PROPERTIES OF PARTICLEBOARD

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Abstract: *The objective of the present study was to investigate the effect of adhesive type on physical and mechanical properties of particleboard. Three types of adhesives, urea-formaldehyde, melamine-urea formaldehyde adhesive, and acrylic adhesive, were used in the production of lab scale particleboards with three layers. The particleboards produced with the acrylic adhesive had the best physical and mechanical properties, followed by MUF adhesive, and UF adhesive, respectively. The lowest formaldehyde emission was observed for the acrylic bonded particleboards, followed by MUF, and UF adhesive bonded particleboards, respectively. Based on the findings obtained from the present study, the acrylic adhesive can be efficiently used in the production of particleboard.*

Keywords: PARTICLEBIARD, ADHESIVE, SURFACE QUALITY, TECHNOLOGICAL PROPERTIES

1. Introduction

The demand for particleboard representing 57% of the total volume of wood-based panels has recently increased dramatically throughout the world, especially for housing construction and furniture manufacturing. Worldwide demand for particleboard has been steadily growing since then at a rate between 2 and 5% per annum [1].

As known, one of the most successful ways to improve dimensional stability and mechanical properties of wood-based panels is to increase adhesive content. Particleboard industry mainly use urea formaldehyde (UF) adhesives as binding agents due its low price, easy supply, low curing temperature and duration, colorless, and good mechanical properties in dry environment. However, UF adhesives have significant amount of formaldehyde emission emitted from particleboard as compared to the melamine-formaldehyde and phenol-formaldehyde.

A new kind of adhesive for wood based panels is acrylic based adhesive. These adhesives differ from the standard acrylics which are final polymers in that they are mixtures of acrylic monomers usually with a synthetic rubber. They are catalyzed during the bond formation by means of a peroxide or amine using a free radical mechanism. They can be produced either as an emulsion or solvent soluble form. They are used as pressure sensitive adhesives, and for flooring, paper lamination, textiles, flocking adhesives etc. These adhesives structurally similar to the vinyls but have very different properties. Advantages are very fast bond time, accurate metering of the catalyst is unnecessary, and their ability to bond a wide variety of substances [2]. The objective was the present study was to investigate the effect of adhesive type on physical and mechanical properties of particleboard.

2. Materials and method

Pinus sylvestries L. trees were harvested in Trabzon, Black Sea Region of Turkey. The bark was removed before chipping. After the foliage was trimmed, all the trees were chipped using a ring type flaker before the chips were reduced into smaller particles using a hammermill. The particles were dried to 3% moisture content in a dryer. The dried particles were classified into two sizes using a 3.0-1.5-0.5 mm openings vibrating screen for the core and face layers. In the next process, adhesives were applied with a pneumatic spray gun. Based on oven dry weights of particle weight, 9% and 11% urea formaldehyde (UF), melamine urea formaldehyde (MUF) and acrylic adhesives (AR) with a solid content of 55% were applied for core and surface particles, respectively. The ratio of the face thickness to the total thickness of a panel known as the shelling ratio was 0.40 for all samples. Ammonium chloride (concentration: 25%) and dibenzoylperoxide were used as adhesive hardeners for UF and MUF, and AR, respectively, and during the blending process by about 1% based on the solid amount of adhesives. No wax or any other additives were used for the panel manufacture. Mats formed manually in a frame with a size of 55 x 55 cm were pressed in a hot press at a temperature of 150 °C using a pressure of 25 kg/cm^2 for 6 min. All panels were pressed to a nominal thickness of 12.0 mm and an average target density of 0.65 g/cm^3. The four different panel compositions are outlined in Table 1. Two panels were made for each group.

Table 1. The experimental design of the study.

Panel Type	Adhesive Type
1	Urea Formaldehyde* (UF_1)
2	Urea Formaldehyde ** (UF_2)
3	Melamine Urea Formaldehyde (MUF)
4	Acrylic adhesive (AR)

* formaldehyde / urea mole ratio :1.09
** formaldehyde / urea mole ratio: 1.20

The panels were kept in a conditioned room with a relative humidity of 65% and a temperature of °20 C until they reached equilibrium moisture content. Physical; thickness swelling (TS) and water absorption (WA) (EN 317, 1993), and mechanical; modulus of rupture (MOR), modulus of elasticity (MOE) (EN 310, 1993) and internal bond strength (IB) (EN 319, 1993), formaldehyde emission (EN 120-1) of particleboards were determined for the produced particleboards. 20 specimens were tested for each test property.

One-way analysis of variance, ANOVA, was conducted ($p \leq 0.05$) to evaluate the effect of adhesive type on the quality properties of the panels. Significant differences between the mean values of the panel types were determined using Newman-Keuls's test.

3. Results and discussion

The physical and mechanical properties of the particleboards are presented in Table 2. The physical and, mechanical properties of the particleboards produced with the melamine formaldehyde adhesive were found to be higher than those of the particleboard produced with urea-formaldehyde adhesive. The melamin provides the crosslinking and thus the heat resistance, strength properties and water stability compared to urea. The incorporation of the formaldehyde into the melamine is easier than urea. Amino groups in the melamine adhesive can bond with more than two formaldehyde molecules, which causes in a decrease in the formaldehyde emission from particleboard. Melamin solves lower than urea in water. There are ether bridges apart from *methylol* bridges in the cured melamine formaldehyde. This improves the mechanical properties and water resistance and decreases the formaldehyde emission from the particleboard. Melamine is a formaldehyde scavenger because melamine is more reactive than urea. The difference in the kinetic behavior of melamine and urea is caused by the effects of nitrogen atoms in two compounds. The nitrogen of amino methylol group in the methylol urea is less nucleophilic. MUF adhesives dissolve lower in water, thus they have higher bond strength and lower formaldehyde emission [3]. In addition, the MUF has a higher thermal stability at high temperatures than the UF adhesive.

Table 2. The physical and mechanical properties of particleboards.

Panel Type	MOR (N/mm^2)	MOE (N/mm^2)	IB (N/mm^2)
1	12.64 (0.34) (a)	1684. 52 (37.33) (a)	0.301 (0.14) (a)
2	13.78 (0.22) (b)	1845.27 (54.62) (b)	0.417 (0.28) (b)
3	14.85 (0.48) (c)	2007.74 (65.33) (c)	0.503 (0.18) (c)
4	16.01(0.56) (d)	2489.96 (44.78) (d)	0.586 (0.22) (d)

Note: Numbers in the parenthesis are standard deviations. Different letters in the same line represent statistical differences at 95% confidence level.

Based on EN 312 standard, 12.5 and 13N/mm^2 are the minimum requirements for MOR of particleboard general uses and interior fitments (including furniture), respectively, while the minimum MOE for interior fitment is 1800 N/mm^2. The panel types 2, 3 and 4 had higher MOR and MOE for general purposes and furniture manufacturing requirements. The panel type 1 satisfied the required level of MOR only for general purposes. The IB data ranged from 0.301 to 0.586 N/mm^2. The minimal requirements of internal bond strength for general purpose and furniture manufacturing are 0.28 and 0.40 N/mm^2, respectively. According to the test results, while panel type 1 had the required level of IB for general purposes, 2, 3 and 4 type panels met the required level of IB for interior fitments. The results showed that test panels did not have the required level of TS according to EN 312 standard due to no usage of wax or other water-repellent agents in the manufacturing of test panels. Average formaldehyde emission values of the test panels are given in Table 2.

Table 2. The formaldehyde emission of particleboards.

Panel Type	Thickness swelling	Water absorption	Formaldehyde emission
1	27.35 (1.12) (a)	82.33 (1.85) (a)	11.12 (0.03) (a)
2	25.13 (1.08) (b)	79.64 (1.02) (b)	7.71 (0.05) (b)
3	22.45 (0.87) (c)	74.28 (1.93) (c)	7.58 (0.04) (c)
4	18.04 (1.32) (d)	68.45(1.22) (d)	0.03 (0.01) (d)

Note: Numbers in the parenthesis are standard deviations. Different letters in the same line represent statistical differences at 95% confidence level.

The maximum permissible formaldehyde content for E_1 quality particleboard is 8 mg CHOH/100 g dry particleboard sample according to EN 312. Particleboard types 2, 3 and 4 met the required level of FE for indoor applications. Adhesive type was found to be effective on the surface roughness of the panels. The superior physical and mechanical properties, and formaldehyde emission values obtained from particleboard panels manufactured with acrylic adhesive. The acrylic provides the flexibility, coverage (fullness), filling and water resistance. Acrylics are used because of their excellent strength, stability and uniformity. Acrylic shows the lowest levels of formaldehyde emission. The proposed acrylic adhesive can be considered as a zero formaldehyde emission binder. Acrylic adhesive fills the cavities among the particles in particleboard. This prevents that water penetrate among the chips, which increase the water resistance of the particleboard [4].

Urea-formaldehyde had the lowest quality in terms of physical and mechanical properties. UF adhesives have drawbacks in terms of low water resistance and bonding and formaldehyde release. Urea in the cured UF adhesive is easily solved in water. In particular, this phenomenon is ascribed to the reversibility of the amino-methylene bond, which also explains the low resistance of UF against the influence of water and moisture, especially at high temperatures.

Formaldehyde/urea molar ratio significantly affects the physical and mechanical properties of particleboard. As the molar ratio of formaldehyde was increased in the adhesive, all the properties of the particleboards improved while the formaldehyde emission increased. The formaldehyde-urea molar ratio significantly affects the bond performance between the particles in the particleboard. The main differences between the panels produced with urea formaldehyde adhesives with high and low contents of formaldehyde are due to their reactivity as a consequence of the different free formaldehyde content and their degree of crosslinking in the cured network. The increased reactivity and crosslinking of the adhesive and the rate of hardening in adhesives of higher formaldehyde/urea mole ratio causes tighter and more compact board structure. For this reason, mechanical properties increase, thickness swelling and water absorption decrease and surface roughness improves due to high degree of crosslinking and of the water into the particleboard is restricted. There are no ether bridges, no unreacted branch- site methylol groups and no other free formaldehyde in the adhesive at low mole ratio [5]. Increasing the formaldehyde /urea mole ratio negatively affected the formaldehyde emission of the test panels. This is due to higher content of free formaldehyde in adhesive.

4. Conclusions

This study showed the adhesive type significantly affected the physical and mechanical properties of particleboard. The particleboards produced with the acrylic adhesive had the highest physical and mechanical properties, followed by MUF adhesive, and UF adhesive, respectively. The lowest formaldehyde emission was observed for the acrylic bonded particleboards, followed by MUF, and UF adhesive bonded particleboards, respectively. Based on the findings obtained from the present study, the acrylic adhesive can be efficiently used in the production of particleboard.

6. References

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