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Bonding quality of plywood made from Polypropylene as an adhesive

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Abstract

In this study, Shear strength and wood failure percent of plywood made from poplar veneers and polypropylene as an adhesive have been investigated. The variables were polypropylene (PP) in three levels of 80, 120 and 160 g/m^2 and maleic anhydride polypropylene (MAPP) in 0 and 4 percent based on PP weight as coupling agent. Control samples were prepared by mixing 120 g/m^2 UF resin, 35% wheat flour and 4% Ammonium chloride based on UF dried weight. The results showed that polypropylene and MAPP had a positive significant effect on shear strength and Wood failure percent. Plywoods made from 4 percent MAPP added to 160 g/m^2 PP showed the best shear strength and wood failure percent. The control samples had the lowest shear strength. The minimum wood failure percent related to the uncoupled boards made from 80 and 120 g/m^2 PP. Shear strength and wood failure percent improved as the polypropylene increased by 35 and 70 percent, respectively. In addition, Shear strength and wood failure percent increased with applying MAPP by 13 and 69 percent, respectively. All samples met the minimum requirements for bonding quality of plywood as specified in the EN 314-1, 2 standards.

Keywords Plywood, Polypropylene, Maleic anhydride polypropylene, Shear strength, Wood failure percent

Introduction

Among wood-based panels that can be used as structural materials, plywood is one of the main products that has traditionally played an important role in light frame construction. Plywood is typically composed of an uneven number of thin layers of wood veneers, called plies, bonded together with an adhesive and with the grain direction of adjacent layers perpendicular to one another. In the past, the important criteria for assessing a wood adhesive for a specific application were its technical properties, gluing behavior and cost. During recent decades, a new set of criteria has attained more and more importance for instance the environmental and health aspects of the adhesive itself [11]. Although UF resin is one of the most widely used adhesives for bonding wood products, the lack of resistance to outdoor conditions, especially moisture, and its tendency to emit formaldehyde vapors are significant limitations [9]. The use of hydrophobic and non-formaldehyde adhesive can be a solution for this problem. Polypropylene (PP) is a thermoplastic polymer which is used in a wide variety of applications, including wood polymer composite, packaging, ropes, textiles, laboratory equipment and automotive components. Pentti et al (1999) reported a method for the surfacing of wood sheets, such as plywood with melt processable thermoplastic using extrusion coating. In their work, the method was applied to coat plywood with a copolymer of polypropylene. The adhesion between the wood and the polypropylene was improved by blending the polypropylene with maleated polypropylene wax. The experiments showed that the method produced sound and smooth polypropylene coated plywood and use of coupling agent improves the adhesion between the polypropylene and the wood [9]. Rasouli et al (2008) studied on plywood manufacture by using polypropylene as a binder. The results showed that MAPP has a significant effect on MOR parallel to grain. With the increase of MAPP, MOR improved. Polypropylene has a positive effect on thickness swelling after 2 and 24 hours. Water absorption was positively affected by polypropylene and MAPP [11].
In this study, we focused on the effect of using polypropylene as an adhesive and MAPP as a coupling agent on shear strength and wood failure percent of plywood.

Materials and methods

Experimental design and raw material

The experimental design was a factorial arrangement of treatments conducted in a completely randomized design. Duncan design was used to group means with a 95% confidence level. Rotary cut veneer sheets of *Populus Alba* with nominal thickness of 2mm were obtained from Nema Chob co. (Zanjan, Iran). First, the veneers were cut to 45×45 cm, and dried to 3% MC in a dryer at 70ºC. The base resin was a polypropylene V30S, with a melt flow index of 18 gr/10 min and maleic anhydride grafted polypropylene (MAPP) coupling agent (G101) was prepared from Kimia Javid Sepahan Co. (Esfahan, Iran). Since it is necessary to improve interfacial compatibility between wood and Polypropylene by a surface modification [5], MAPP coupling agent was used in this study.

Manufacturing plywood panels

Plywood panels with three plies and 6mm thickness were manufactured from veneers using polypropylene (in the three levels of 80, 120 and 160 g/m^2) mixed with MAPP in 0 and 4 percent based on PP weight. The glue mix was applied on the single surfaces of veneers

by using a brush. The assembled layers were then heat-pressed using a Burkle Hydraulic press (Model L-100) into a target thickness of 6mm guided by two rect-angular steel stops. The boards were pressed at 180ºC and the maximum pressure of 8kg/cm^2 for 5 minutes. After hot pressing, all boards made from polypropylene were cold-pressed at 8kg/cm^2 for 15 minutes followed by trimming the rough edges of the boards. Control samples were prepared by mixing 120 g/m^2 UF resin, 35% wheat flour (as a filler extender) and 4% Ammonium chloride (as a hardener) based on UF dried weight.

Plywood evaluation

The boards were cut into shear specimens without any visible defect, according to the standard of EN 314-1, 2 (Fig. 1). The shear strength and wood failure percent were evaluated after 20±3°C water soaking for 24h. Shear strength test of samples was performed on Instron 4486 machine (Instron Inc. UK).

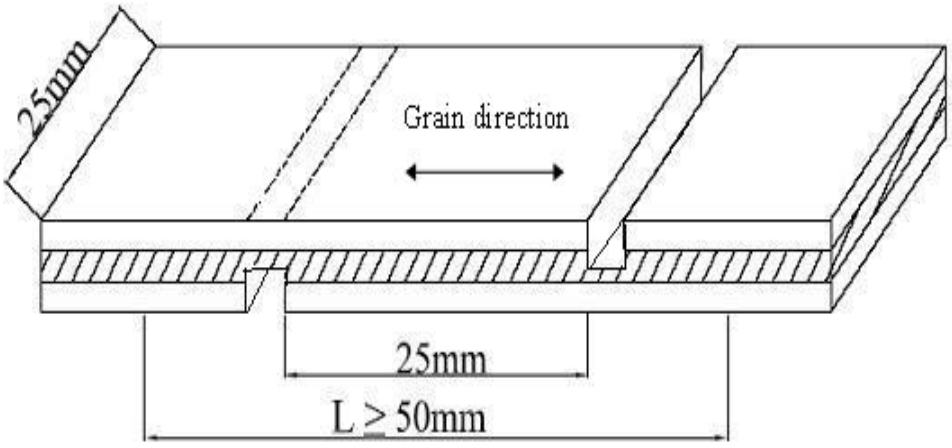

Figure 1. Plywood Shear Test Specimen

Results

Shear strength

The mean values of shear strength of plywood panels are showed in Figure2. The results reshowed that polypropylene had a significant effect on shear strength. By the increase of PP from 80 to 160 g/m^2, the mechanical interblocking between wood surface and PP increased and plywood property improved. With use of MAPP, shear strength increased significantly. It seems that MAPP migrates to the interface between the non-polar PP and polar fiber surfaces which results in a more efficient stress transfer from the glue line to the plies [12]. As a result, strength properties of plywood can be improved with addition of MAPP.

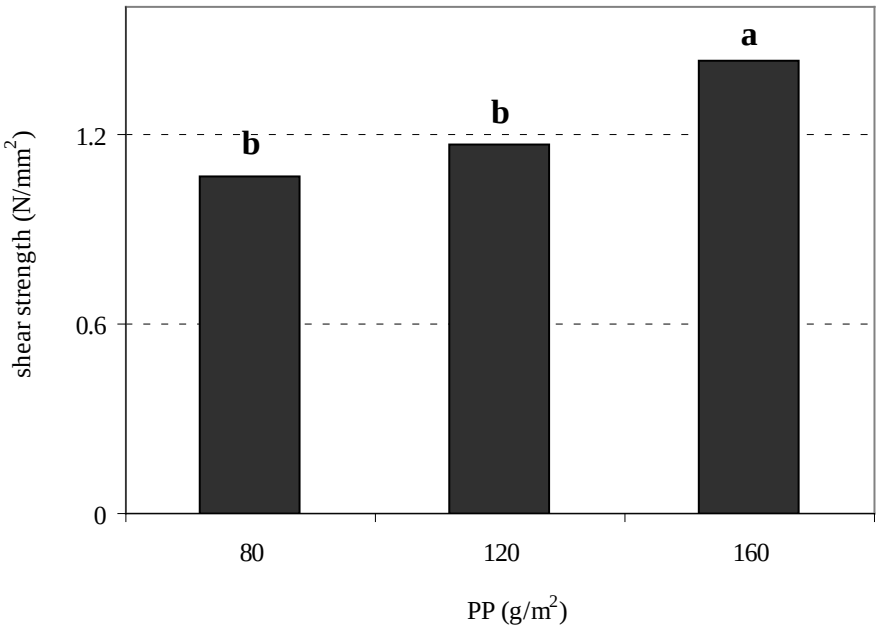

Fig.2. Effect of PP on shaer strength

Wood failure percent

Figure 4 demonstrates that wood failure percent was positively affected by polypropylene Figure 5 shows that a very significant Wood failure percent improvement due to the addition of MAPP can easily be seen. Wood failure percent ranged from 32 to 56%.

The mean values of properties for the 6 treatments with control sample were summarized in table 1 to allow a quick comparison of the effects of variables on the plywood properties. The plywoods made from 4 percent MAPP added to 160 g/m^2 PP showed the best shear strength and wood failure percent. Control samples had the lowest shear strength. The uncoupled (without applying MAPP) boards made from 80 and 120 g/m^2 PP showed the minimum wood failure percent. Based on table 1 the shear strength of plywood made from polypropylene was more than 1N/mm^2 but the Standard of EN 314-1, 2 (table 2) does not involve the limit values of wood failure percent for this range of shear strength. All cases as well as control sample met the minimum requirements for shear strength and wood failure percent of plywood as specified in the EN 314-1, 2 standards. In general, by increasing polypropylene, shear strength and wood failure percent values improved by 35 and 70 percent, respectively (Figures 2 and 4). Additionally, with use of MAPP, shear strength and wood failure percent increased by 13 and 69 percent, respectively (Figures 3 and 5).

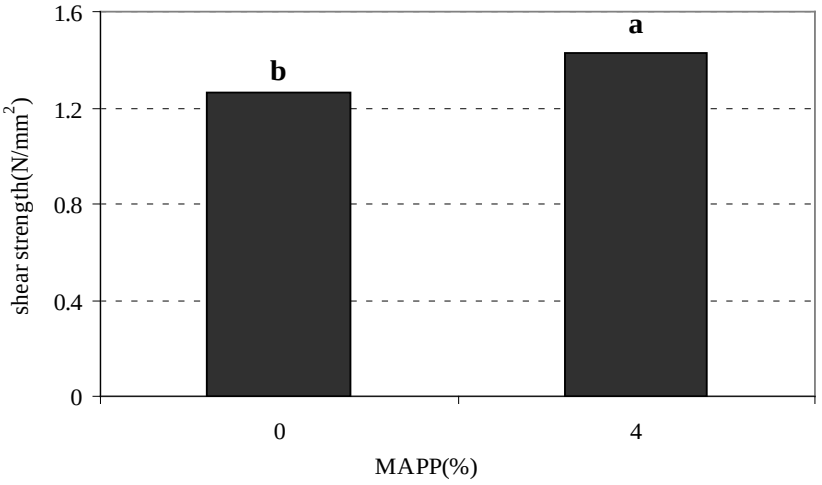

Fig.3. Effect of MAPP on shear strength

Table 1. Effect of PP and MAPP on shear strength and wood failure percentage

PP g/m^2	MAPP %	Shear strength(N/mm^2)	Wood failure (%)
80	0	1.056 ^{b}	27 ^{c}
	4	1.075 ^{b}	40 ^{bc}
120	0	1.097 ^{b}	27 ^{c}
	4	1.265 ^{ab}	55 ^{ab}
160	0	1.313 ^{ab}	44 ^{abc}
	4	1.474 ^{a}	64.5 ^{a}
Control sample		0.961 ^{b}	41 ^{bc}

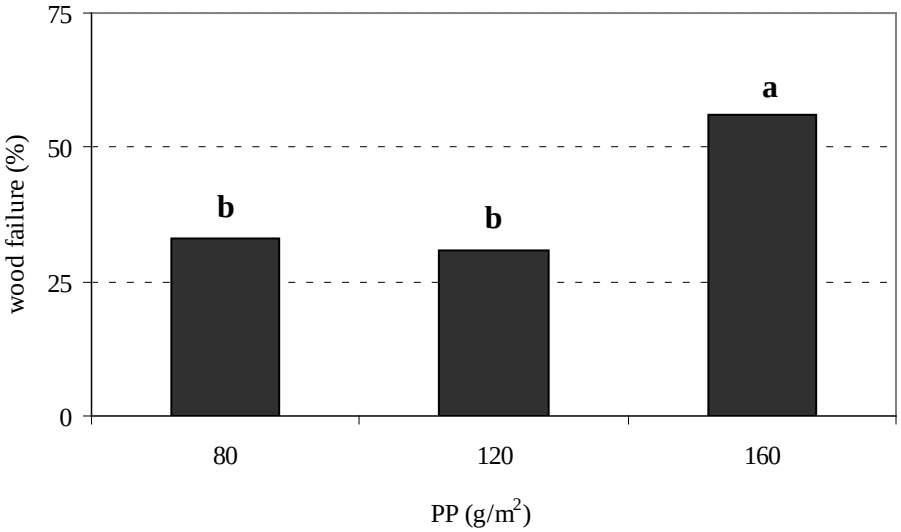

Fig.4. Effect of PP on wood failure percentage

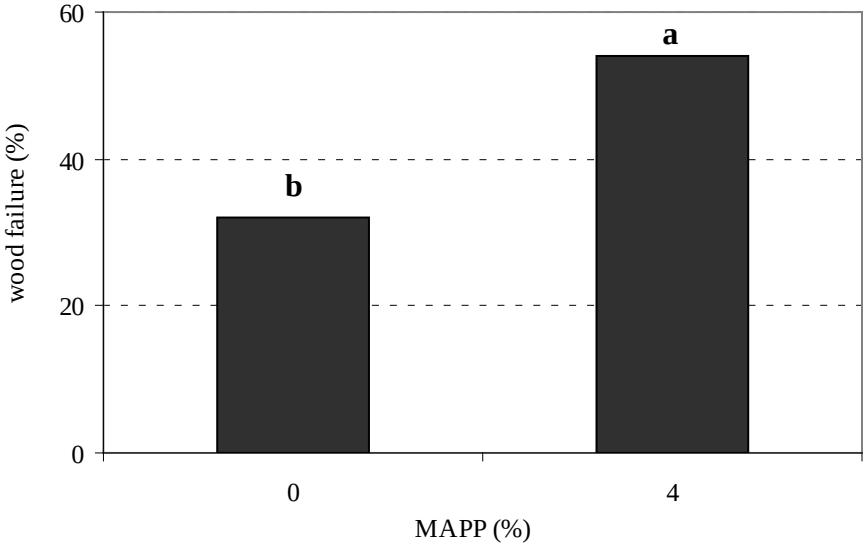

Fig. 5. Effect of MAPP on wood failure percentage

In uncoupled boards, weak adhesion may result from poor incompatibility between the hydrophilic wood surface and the hydrophobic polymer. Poor strength of composite is resulted from the lack of stress transfer from the polymer matrix to the load bearing natural fibers [1–5]. This stress transfer efficiency plays a dominant role in determining mechanical

properties of the composite and also in the material's ability to withstand environmentally severe conditions [3]. Interactions between the anhydride groups of maleated coupling agents and the hydroxyl groups of natural fibers can overcome the incompatibility problem to increase shear strength and wood failure [6]. This may be attributed primarily to the enhanced interfacial adhesion resulting from the presence of a matrix with increased polarity and wettability that may react or interact favorably with the hydroxyl group on the fiber surface [7, 8]. Figure 6 shows the proposed mechanism behind such bond formation [1]. It was estimated that the interaction between the coupler and wood may be of a covalent nature [2, 10]. Lu et al. (2001) have suggested a broader interfacial bonding, consisting of covalent bonds, secondary bonding (such as hydrogen bonding and Vander Wales's forces) and mechanical interblocking [6].
Based on the results, the combination including 160 g/m^2 PP and 4 percent MAPP introduced as the best condition which showed the best shear strength and wood failure percent.

CONCLUSIONS

The shear strength and wood failure percent values of plywood made from polypropylene met the minimum requirement specified in EN 314-1, 2 standards. Bonding quality of plywood was technically and environmentally superior to the control samples. Since PP is more expensive than UF, further researches on plywood properties made from recycled PP and the other thermoplastic wastes needs to be investigated.

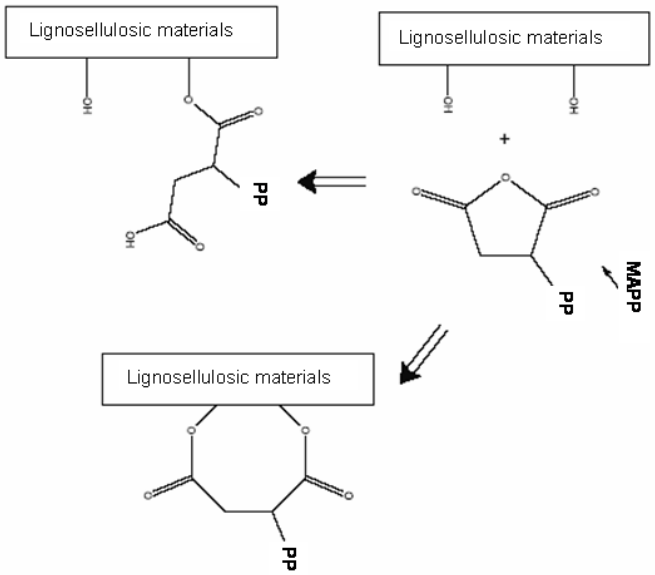

Figure 6. The proposed mechanism

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