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Research article

INVESTIGATION ON WATER ABSORPTION PROPERTY OF WOOD PLASTIC COMPOSITE

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ABSTRACT: In this research, the effect of wood species & particle size water absorption property of composite made of four species Fir, Beech, poplar and Alder sawdust and high density polyethylene were investigated. Wood plastic composite was made from dried Fir sawdust as filler at 70% ratio by weight and high density Polyethylene in batch process at 185 ˚C temperatures, at two particle sizes mesh 40 and mesh 80. MAPP was as coupling agent then were determined and compared their water absorption property according to ASTM D570 after 2 & 24 hour immersion at distilled water. Water absorption percent decreased in 3-12% range with increasing particle size. There were differences between different species water absorption property, but this difference did not significantly affect.
Keywords: Wood-plastic Composite, water absorption, Particle size, Wood species, High density Polyethylene.

INTRODUCTION

There have been considerable increases in recent years on the production and application of wood–plastic composites (WPCs). Their properties and environmental advantages have made them a good choice for many applications [1, 2]. WPCs are made by combining wood and thermoplastic polymer, which results in a composite that combines the best properties of both components [3]. Wood often imparts strength and stiffness and is biodegradable, while the plastics afford ease of formation and moisture resistance [4, 5]. Effective use of wood-based particles and fibers as fillers or reinforcements in thermoplastic composites requires a fundamental understanding of the structural and chemical characteristics of wood [6]. The various wood species have different anatomies. These structural differences impact the use of these materials in WPC. For example, fiber dimensions, strength, variability and structure are important considerations [7]. Using diverse wood species and also sawdust from these species is regarded as a good opportunity to produce wood compounds with demanded properties and to supply compressed wood panels. It is essential to determine the properties of this new product. The moisture percent of this product influence in its other properties such as dimensional stability, mechanical properties, resistance to decay and etc. [8, 9]. The wood hydroxyl content affect on its water absorption. But in wood-plastic compound, physical and mechanical properties depend on the mutual effects between wood and thermoplastic material within the compound. Physical and mechanical properties of wood plastic composites (WPCs) generally depend on the properties of their components and the ratio of these components. One of the factors affecting properties of a wood component is wood particle size. The effect of this factor on WPC mechanical properties was mainly evaluated for typical WPCs containing small wood particles (wood flour) or short wood fibers [10].
Multi construct water resistance is improved by higher polymer rate [11]. Two distinctive parameters of wood are species and particle size. When fill is increased, water absorption elevates due to higher hydroxyl group [12]. They concluded that higher particle size leads to increasing of water absorption.

In this study the effect of particle size and species on water absorption of reinforced polyethylene constructs with sawdust of Fir, Beech, Poplar and Alder are investigated. It seems essential to evaluate the effectiveness of species and particle size for determining particle mesh size for wood-plastic compound production since this production is competitive and the cost must be decreased, sawdust is abundant in wood workshops and it can be used for the wood plastic compound production and Fir, Beech, Poplar and Alder woods are typically used in this workshops. The purpose of this study is investigation of particle size and wood species effects on rate of water absorption in wood plastic composite.

MATERIALS AND METHODS

Sample preparation:

Polyethylene polymer granule (specific gravity 960kg/m³ and MFI= 18 g/10 min from Arak Petrochemical Plant) as substrate was used in form of powder. The reinforcement material was sawdust from Fir, Beech, Poplar and Alder woods. Maleic anhydride conjugated with polypropylene was as adjusting material between two phases. Pure sawdust of Fir, Beech, Poplar and Alder woods were supplied from wood workshops in Shirvan, Gorgan and Kordkoy and it was screened using mesh 40 and mesh 80. The screened sawdust was placed inside an autoclave with 103±2 ˚C for 24hours until its moisture reached to near zero (<2%). The sawdust, polyethylene and conjugating material (MAPP) proportion rates in the mix were 68.7%, 29.3% and 2% respectively. The mix was compressed in form of a board using OTT press and based on table1 with following properties: 20x15 size, 1 g/cm³ gravity and 0.65cm thickness.

Table-1. Compression condition

Condition	Stage 1	Stage 2	Stage 3	Stage 4
Pressure	30-35	---	30-35	30-35
Temperature (˚C)	185	185	185	---
Time (min)	1	4	10	5

$$\rho = \frac{m}{V} \Rightarrow 1 = \frac{m}{195} \Rightarrow m = 195 \ g$$

$$195 + 10 = 205 \ g$$

$$\frac{68.7}{100} = \frac{x}{205} \Rightarrow x = 140.84 \ g \qquad (1)$$

$$\frac{29.3}{100} = \frac{W}{205} \Rightarrow w = 60.7 \ g$$

$$\frac{2}{100} = \frac{Y}{205} \Rightarrow Y = 4.1 \ g$$

M= mix mass for 195cm³ board
X= 68.7% sawdust weight rate
W= 29.3% polyethylene weight rate
Y=2% MAPP weight rate

The mix was poured into a cast and it was compressed initially (185˚C, 30-35 bar for 1 minute)(step1) and it was interrupted for 4 minutes with constant temperature(step2) and then the final compression was executed (185˚C, 30-35 bar for 10 minutes)(step 3). The board was removed out of autoclave and compressed for 5 minutes with 30-35 bars without heating (step4).

The produced boards were placed in room temperature for two weeks. The samples were dissected and their water absorption rates were tested. The tests were executed for wood-plastic mix using 70% sawdust of Fir, Beech, Poplar and Alder woods in two meshes (40 and 80) on 8 treatments with 3 iterations based on table 2.

Figure-1. The boards produced from A. Fir wood B. Beech wood C. Poplar wood E. Alder wood with polyethylene using 1. Mesh 40 2. Mesh 80

Table-2. The mix components rates and percentages used in the treatments.

No. of Treatment	Name of Treatment	Wood Species	Particle size (Meshes)	Amount of sawdust (%)	Amount of PE (%)	Amount of MAPE (%)
1	A_1B_1	Fir	40	68.7	29.3	2
2	A_1B_2	Fir	80	68.7	29.3	2
3	A_2B_1	Beech	40	68.7	29.3	2
4	A_2B_2	Beech	80	68.7	29.3	2
5	A_3B_1	Poplar	40	68.7	29.3	2
6	A_3B_2	Poplar	80	68.7	29.3	2
7	A_4B_1	Alder	40	68.7	29.3	2
8	A_4B_2	Alder	80	68.7	29.3	2

Test procedure

The water absorption test for wood plastic composite was performed according to ASTM D570. The samples were weighted and then they were suspended in distilled water in two treatment (for 2 hours and for 24 hours) with3 iterations. At last they were removed, reweighted and water absorption rate was measured.

$$W_a=100\times \frac{W_1 - W_0}{W_0} \quad (2)$$

W_a = water absorption rate (%)
W_1= sample weight after immersion (gr)
W_0= sample rate before immersion (gr)
Finally the results of tests were analyzed full randomly as factorial test using $SPSS_{13}$ and the averages were categorized using Duncan Test.

RESULTS

Table 3 shows all test data. This table was assessed and analyzed using General Linear Model and table 4 shows the result of this analysis.

Table-3. Average results for water absorption test

Wood Species	Particle size (Meshes)	Water absorption after 2 hours (%)	Water absorption after 24 hours (%)
Fir	40	27	47.66
Fir	80	30.66	50.66
Beech	40	25.33	46.33
Beech	80	34.33	54.66
Poplar	40	27	43.33
Poplar	80	33	55.66
Alder	40	27.66	40
Alder	80	29	46.33

Table-4. Duncan Test results for similar subsets of species

Species	Number of Iterations	Subsets	
		a	b
Alder	6	43.1667	
Beech	6	48.1667	48.1667
Fir	6	49.5000	49.5000
Poplar	6		51.1667
Significant		0.104	0.428

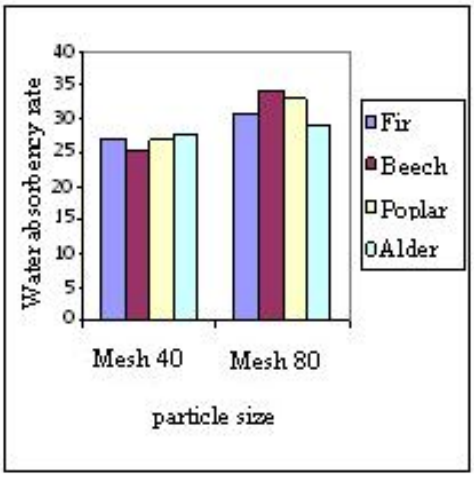

Figure-2. The impact of particle size on water absorption rate after immersion for two hours

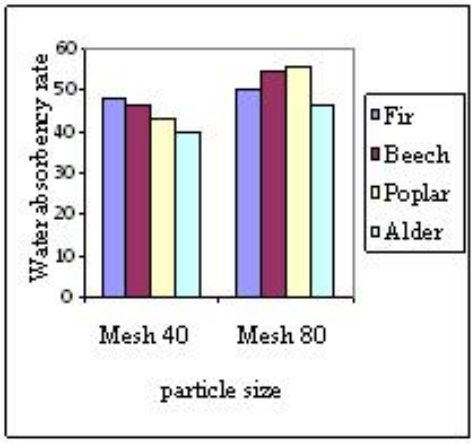

Figure-3. The impact of particle size on water absorption rate after immersion for 24 hours

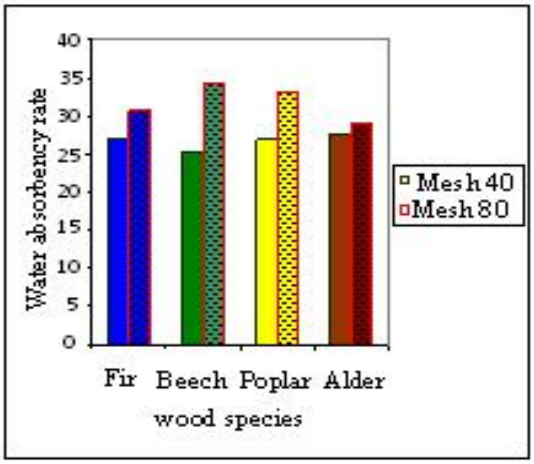

Figure-4. The impact of species type on water absorption rate after immersion for two hours

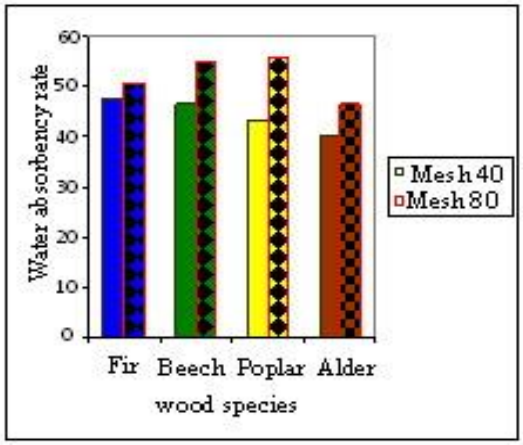

Figure-5. The impact of species type on water absorption rate after immersion for 24 hours

Table-5. Variance analysis for water absorption rate after immersion for two hours

Source Of Variations (S.O.V)	Sum of Squares (S.S)	Degrees of Freedom (df)	Mean-Square (M.S)	Test Statistic (F)	Level of Significant (p)	Significant
Factor A	73.500	1	73.500	5.234	0.036	*
Factor B	31.000	3	10.333	0.736	0.546	ns
Interaction Effect (A*B)	16.833	3	5.611	0.400	0.755	ns
Error	224.667	16	14.042			
Total	19840.000	24				

(**) Significant at the 0.01 level, (*) Significant at the 0.05 level, (ns) No significant

Table-6. Variance analysis for water absorption rate after immersion for 24 hours

Source Of Variations (S.O.V)	Sum of Squares (S.S)	Degrees of Freedom (df)	Mean-Square (M.S)	Test Statistic (F)	Level of Significant (p)	Significant
Factor A	352.667	1	73.500	9.629	0.007	**
Factor B	214.000	3	71.333	1.948	0.163	ns
Interaction Effect (A*B)	5.333	3	1.778	0.049	0.985	ns
Error	586.000	16	36.625			
Total	56454.000	24				

(**) Significant at the 0.01 level, (*) Significant at the 0.05 level, (ns) No significant

When mesh 40 instead of mesh 80 is used the water absorption rate (%) for 2 hours and 24 hours would differ. Smaller particles absorb more water. Water absorption percent decreased in 3-9% range after immersion for 2 hours and 3-12% range after immersion for 24 hours with increasing particle size. Table 4 shows water absorption rates for 2 and 24 hours immersion periods in Duncan Test that species there are tow groups. There were differences between different species water absorption property, but this difference did not significantly affect.

DISCUSSION

With increasing particle size, decreases homogeneity of wood composite, and decreases material coverage in some parts of matrix thus particles have many possibility to contact water. Since substrate rate was lower in this study, the results are not consistence with what predicted before because particle size is decreased and surface/volume ratio is therefore increased and substrate rate is not sufficient for particle coverage. Then, water absorption is decreased significantly in this study due to higher particle size. This is in contrast to the results of Khalil (2006). Although absorption rate for species type differ in 2 and 24 hours treatments, the difference is not significant.

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