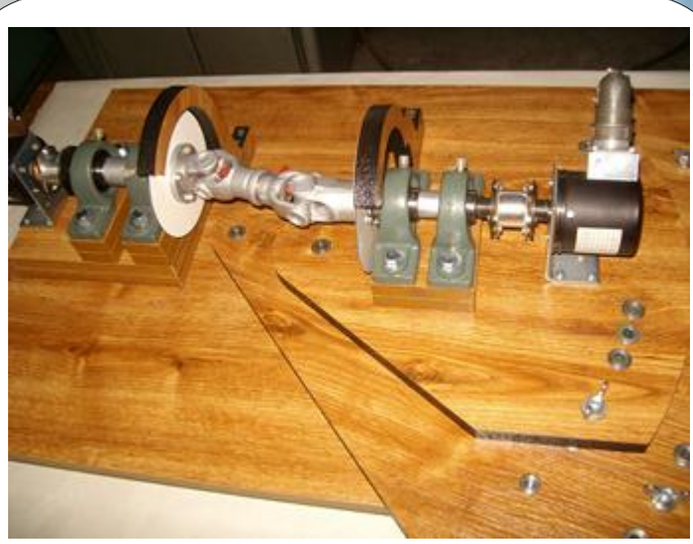
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EFFECT OF THE MARBLE POWDER AND WOOD POWDER CONTENT ON THE TECHNOLOGICAL PROPERTIES OF THERMOPLASTIC COMPOSITES

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Abstract: The waste powder produced during the manufacture of marble, which is presently mostly discarded in landfills, has the potential for higher-valued usage. Recycling marble waste powder will contribute to the protection of nature as well as economic gain. The goal of this study is to investigate the potential use of marble waste powder as filler in the thermoplastic composites with wood. Thermoplastic composites were manufactured by adding marble factory waste powder and wood powder in different ratios to polypropylene (PP). Maleic anhydride grafted polypropylene (MAPP) were used as coupling agent to improve interfacial adhesion between hydrophilic wood–fibers and hydrophobic polypropylene. The waste marble powder and wood powder were mixed by weight of with polypropylene in the percentage of 0%, 10%, 20%, 30%, 40%, and 50%. Physical and mechanical tests were performed on the specimens prepared from the thermoplastic composites. Although mechanical properties of the composites decreased with increasing content of the marble powder, the water absorption of the composites significantly decreased with increasing content of the marble powder.

KEYWORDS: THERMOPLASTIC COMPOSITES, TECHNOLOGICAL PROPERTIES, WOOD POWDER, MARBLE POWDER,

1. Introduction

Studies of polymer composites mixing with organic or inorganic fillers have steadily increased due to the advantages of the fillers in economic and environmental aspects. Organic wood fibers have characteristics of low density, biodegradability, and sustainable productivity [1, 2], and inorganic fillers have attracted great attention because of their cost efficiency, abundance [3]. The fillers (organic or inorganic materials) generally increase stiffness, strength, and hardness of polymer composites by hybridization [4, 5, 6]. Inorganic and organic fillers have long been considered as a future candidate to replace glass fiber or carbon fiber in thermoplastic composites, and thus, it can help resolving environmental issues and taking economic advantage over those artificial fibers [7].

Marble, used frequently in construction applications, is utilized by an industry that produces a significant amount of solid waste during the cutting process. Recycling the marble powder produced during cutting is an important issue because of the current development of environmental awareness and costs for filler [8]. It is estimated that approximately 2.2 million tons of marble blocks are processed in Turkey annually, of which 660,000 tons of marble powder is thrown out without being recycled. If that potential material is evaluated in industry, it is provided significant gains to the economy [9]. The unused marble powders have significant effects, not only economically, but environmentally as well. The large number of marble processing facilities in the world is the cause of the intensification of marble waste areas, which negatively affect the environment and natural beauty, especially in the regions where these facilities are located [10].

When studies on the economic use of marble wastes were examined, it was observed that they reported on the construction sector in general, such as using marble powder wastes in filler processes, the manufacture of light construction blocks, improving floors with marble powder, and as an additive substance in the manufacture of cement [9, 11, 12, 13, 14, 15, 16, 17]. Excluding the use of wastes from marble processing facilities as construction materials, it was observed that they are used as powder wastes reduced to different dimensions as a raw material decoration in architecture, a filler material, and as an additive substance for agricultural purposes [18, 19].

The use of organic wastes of wood industry and agricultural industry as an additive substance in the manufacture of thermoplastic composites has drawn a lot of attention in recent years. In previous studies, in addition to waste wood fibers, some other natural fibers such as kenaf [20], jute [21], sisal [22], flax [23], hemp [24], coir [25], pine cones [26], walnut shell [27], and sunflower stalk [28] have been investigated, and positive results have been obtained. Altough some inorganic fillers such as talc [29], kaolin [7], clay [30], boron-nitride [31], and zinc-borate [32] have widely been adopted in thermoplastic composites with wood fiber, to our knowledge, there are no reports on the utilization of marble waste powders as a filler in thermoplastic composites.

The objective of this study was the manufacture of thermoplastic composites by adding marble powder and wood powder in different ratios to polypropylene and studying their physical and mechanical properties. We aimed to investigate the effect of marble powder content on the density, water resistance and mechanical properties of the thermoplastic composites.

2. Materials and methods

2.1. Materials

The waste marble powder were obtained from the collected liquid precipitation ponds at a factory manufacturing travertine marble powders in Denizli, Turkey. The technical compositions of the travertine marble are given in Table 1. The marble powders were passed through a mesh screen and retained on a 0.25-mm mesh screen (Fig.1). The marble powders were then oven-dried to a moisture content of 0 to 1% using a laboratory oven at 100 °C for 48 h, and then stored in a sealed container.

Wood particles were obtained from beech (*(Pinus nigra* Arnold var. *pallasiana*, oven-dryρ = 0.490 g/cm^3) lumbers by using laboratory type disc chipper with three knives. The moisture content of the wood particles, as determined by oven-dry weight, was found to be 40–50% prior to the treatment. The wood particles were ground in a laboratory *Wiley*grinder. The wood powder passing through a US 35-mesh screen was retained by a US 80-mesh size. The wood powder was dried in a laboratory oven at 102 °C for 24-h to a moisture content of 0–1% based on the oven-dry weight of wood ant then stored in a polyethylene bag.

Polypropylene (PP) (melting temperature = 160°C, density = 0.9 g/cm^3, melt flow index at 230°C and 2.16 kg = 6.5 g/10 min) produced by Petkim Petrochemical Co. (Izmir, Turkey) was used as the polymeric material. MAH-grafted PP [MAPP-OPTIM-415 with the reactive modifier MAH (MAH content = 1 wt %)] was supplied by Pluss Polymers Pvt., Ltd. (New Delhi, India).

Table 1. *Technical Properties of the Marble (Test report of Demirkayalar Marble Company, Denizli, Turkey, 2009).*

Property	Unit	Travertine Marble
Hardness	Mohs	3 to 3.5
Unit Weight	g/cm^3	2.44
Density	g/cm^3	2.66
Particle Size	µm	<250
Water Absorption in Atmospheric Pressure	By weight (%)	1.62
Water Absorption Under Pressure	By weight (%)	3.94
Porosity	%	3.94
Compressive Strength	N/mm^2	54.4
Compressive Strength After Freezing	N/mm^2	50.8
Degree of Pores	%	3.94
SiO_2	%	1.91
F_2O_3	%	79.10
MgO	%	1.15
CaO	%	2.43

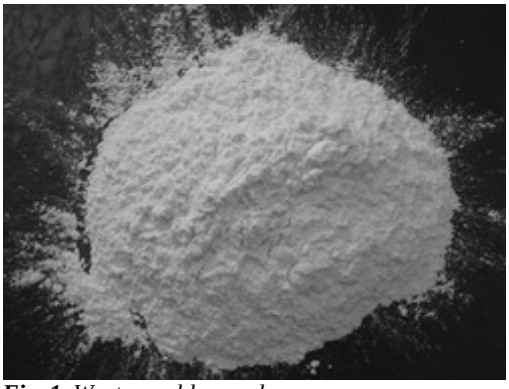


Fig. 1. *Waste marble powder*

2.2. Composite Manufacturing

The marble powder, wood powder, PP, and MAPP granulates were pre-blended in a mixer and then processed in a 30- mm conical, co-rotating, twin-screw extruder (Aysa Instrument Com., Istanbul, Turkey) with a length to diameter ratio of 30 : 1. The raw materials were fed into the main feed throat with a gravimetric feed system. The barrel temperatures of the extruder were controlled at 170, 180, 190, and 190°C for zones 1, 2, 3, and 4, respectively. The temperature of the extruder die was held at 200°C. The extruded strand passed through a water bath and was subsequently pelletized. These pellets were stored in a sealed container and then dried for about 3–4 h before they were injection-molded. The temperature used for the injection-molded samples was 170–190°C from the feed zone to the die zone. The WPC samples were injected at an injection pressure between 45 and 50 kg/m² with a cooling time of about 30 s. Finally, the samples were conditioned at a temperature of 23 ± 2°C and a relative humidity of 50 ± 5% according to ASTM D 618-08.12. The formulations of the composites are given in Table 2.

2.3. Mechanical properties

The flexural properties, modulus of rupture (MOR), and modulus of elasticity (MOE) were measured in three-point bending tests with a standard material testing system at a crosshead speed of 1.3 mm/min in accordance with ASTM D 790-03. The MOR and MOE values of the samples with dimensions of 127 × 12.7 × 3.2 (thickness) mm^3 were determined at ambient conditions of 23 ± 2°C and 50 ± 5% relative humidity according to ASTM D 618-08. The tensile tests were conducted according to the ASTM D 638. Tensile specimens [dogbone shape (Type III)] were tested with a crosshead speed of 5 mm/min in accordance with ASTM D 638. Seven specimens were tested for the tensile and flexural properties of each composite formulation.

Table 2: *The raw material formulations of the WPCs.*

WPC code	Wood powder (%wt)	Marbel powder (%wt)	Polypropylene (PP) (wt%)	MAPP (wt%)
A	50	0	47	3
B	40	10	47	3
C	30	20	47	3
D	20	30	47	3
E	10	40	47	3
F	0	50	47	3

2.4. Water resistance

Thickness swelling (TS) and water absorption (WA) tests were carried out according to ASTM D 570-05 specifications. The test samples were in the form of disks 50.8 mm in diameter and 3.2 mm in thickness. Ten replicate samples were tested for each WPC formulation. The conditioned samples were placed in a container of distilled water maintained at a temperature of 23 ±1°C. The weights and thicknesses of the samples were measured at different time intervals during the long period of immersion. At the end of 24, 168 (7 days), and 672 (28 days) h of submersion, the samples were removed from the water one at a time, all surface water was wiped off with a dry cloth, and the samples were weighed to the nearest 0.001 g and measured to the nearest 0.001 mm immediately. The value of WA as a percentage was calculated as follows:

$$WA\ (t) = \frac{W(t) - W_0}{W_0} \times 100$$

The value of the TS as a percentage was calculated as follows:

$$TS\ (t) = \frac{T(t) - T_0}{T_0} \times 100$$

where TS(t) is the thickness swelling at time t (%), T_0 is the initial thickness of the sample, and T(t) is the thickness at time t. The density of the sample was measured on the TS sample.

3. Result and discussion

3.1. Mechanical properties

The mechanical properties of the WPCs are presented in Table 3. The MOR of the WPCs decreased with increasing content of the marble powder. In particulare, the MOR more decreased as the amount of marble powder was above 30 wt% (Figure 2). The addition of 10 wt% marble powder improved the MOE considerably. Further incerement in the marble content up to 50 wt% decreased the MOE of the composites but still it was higher than that of the control group without marble powder (Table 3, Figure 3).

Table 3: *The results of the mechanical properties of the composites.*

WPC code	MOR (N/mm²)	MOE (N/mm²)	Tensile Strength (N/mm²)	Tensile Modulus (N/mm²)
A	55,3 (3,49)*	3616,0 (648,16)	31,0 (3,39)	3842,3 (159,08)
B	55,0 (0,93)	4843,2 (514,06)	29,4 (1,34)	3800,3 (87,38)
C	54,0	4763,3	28,9	3622,8

	(2,36)	(645,10)	(0,95)	(241,24)
D	52,0	4549,1	22,8	3218,0
	(0,76)	(743,09)	(2,26)	(193,52)
E	45,2	3965,1	21,2	2863,9
	(2,44)	(610,99)	(1,52)	(247,95)
F	44,8	3813,5	20,0	2755,0
	(1,18)	(743,82)	(1,81)	(220,00)

* Standard deviations

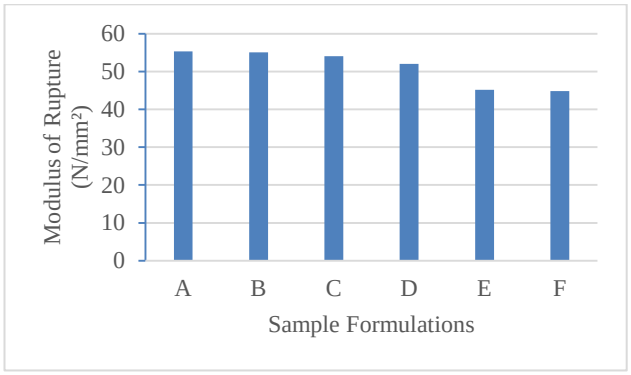


Fig. 2: *The MOR of the composites*

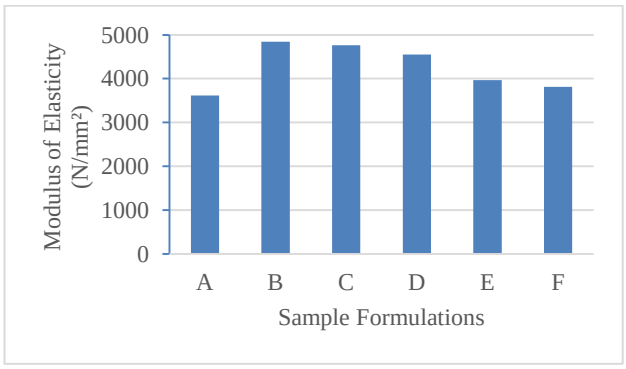


Fig. 3: *The MOE of the composites*

The tensile strength and tensile modulus of the composites are shown in Figures 4 and 5, respectively. As increased the marble content of composites, both the tensile strength and the tensile modulus decreased. Specifically, as the amount of marble content was above 20 wt%, the tensile strength and modulus decreased remarkable when compared to the composites having 20 wt% and below. The decreament ratio in the tensile strength was more pronounced than the decreament ratio in the tensile modulus.

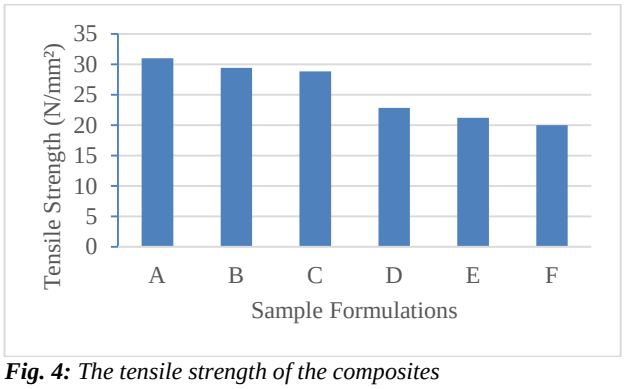


Fig. 4: *The tensile strength of the composites*

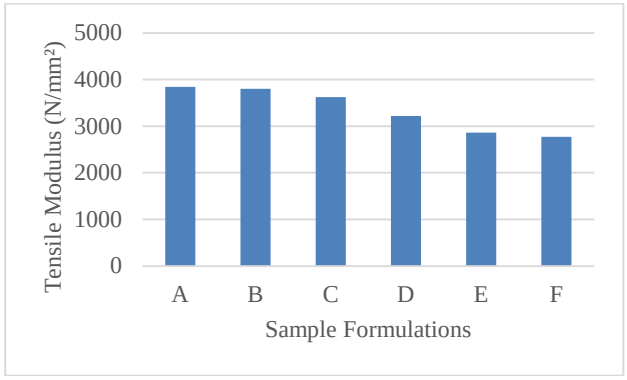


Fig. 5: *The tensile modulus of the composites*

3.2. Water resistance

The results of water resistance are presented in Table 4. In general, the water absorption and thickness swelling decreased with increasing amount of the marbel powder and decreasing amount of wood powder (Table 4, Figures 6 and 7). The water absorption and thickness swelling of composites sharply decreased when the amount of marble content reached to 30 wt%. The highest water absorption and thickness swelling values were found in the specimens produced with 50 wt% wood powder while the lowest values were found in the specimens produced with 50 wt% marble powder as seen Figures 6 and 7.

Table 4: *The results of water reistance of the composites.*

WPC code	Water Absorption (%)			Thickness Swelling (%)		
	One day	One week	Four week	One day	One week	Four week
A	0,21 (0,08)*	0,56 (0,08)	1,30 (0,15)	0,40 (0,18)	0,85 (0,25)	1,53 (0,35)
B	0,19 (0,03)	0,47 (0,08)	1,24 (0,16)	0,30 (0,12)	0,66 (0,17)	1,45 (0,23)
C	0,17 (0,07)	0,47 (0,08)	1,10 (0,14)	0,26 (0,08)	0,63 (0,14)	1,43 (0,18)
D	0,12 (0,05)	0,32 (0,14)	0,65 (0,16)	0,24 (0,10)	0,58 (0,14)	0,93 (0,22)
E	0,11 (0,09)	0,18 (0,06)	0,25 (0,08)	0,19 (0,06)	0,35 (0,13)	0,64 (0,23)
F	0,09 (0,06)	0,09 (0,05)	0,14 (0,05)	0,13 (0,07)	0,22 (0,13)	0,42 (0,22)

* Standard deviations

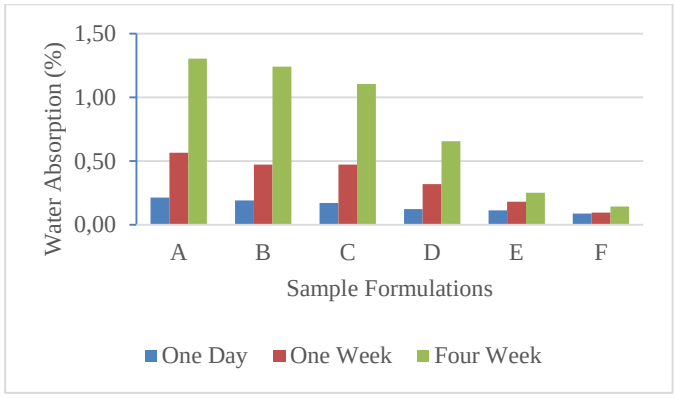


Fig. 6: *The water absorption ratios of the composites*

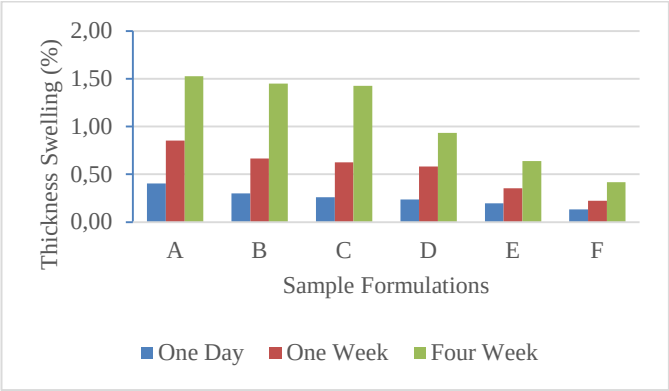


Fig. 7: *The thickness swelling ratios of the composites*

4. Conclusions

The results of the research revealed that the increase in the amount of the marble powder in the composites had a negative effect on the mechanical properties of the composites while the increase in the amount of the wood powder had a positve effect. One exception of this was observed in the MOE values where the MOE of composites improved considerably with the addition of 10 wt% marble powder and then decreased again with the further incerement in the marble content up to 50 wt%. The decrease in the mechanical properties of composites was more remarkable when the marble content in the composites was over than 20 wt%. The water absorption and thickness swelling decreased with increasing amount of the marbel powder and decreasing amount of wood powder.

5. Acknowledgement

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