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Stabilization of Waste Pet Bottles with Gypsum

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Abstract: The aims of this study were to determine the physical and mechanical features of gypsum composite material added waste PET bottles and investigate possible use of this material in agricultural constructions. Samples were prepared by mixing gypsum with waste PET bottles 0-2, 2-4 and 0-4 mm diameter. Density, water absorption, heat conduction, bending and compressive strengths of composite materials were determined. The results indicated that increasing the proportion of waste PET bottles added in gypsum influences density and heat insulation feature positively, but it decreases bending and mechanical resistance. It is possible to build more economical and better insulated constructions by using this composite material for coating walls and ceilings and flooring roofs.

Key words: Waste PET bottles, gypsum, composite materials, physical and mechanical features

INTRODUCTION

The concept of composite material refers to the material with high performance whose imperfect features are developed to be effective against outside factors or it is used for material which is obtained by physically mixing or composing it with other ingredients to produce material with desired performances (Ragsdale and Raynham, 1972; Guozhong *et al.*, 2003). Use of composite material is in question, especially in agricultural buildings as heat insulation material is important that it decreases air and environment pollution, saves energy and helps build lighter structures (Lindley and Whitaker, 1996). They can be produced as open or closed components of prefabricated system. These elements can also be produced in work sites.

Polyethylene terephthalate (PET) is a polymer in widespread use in the production of bottles and containers of water and carbonated drinks. PET bottles have replaced glass bottles as storing vessel of beverage due to its lightweight and ease of handling and storing (Choi *et al.*, 2005; Barriocanal *et al.*, 2004). As the beverage consumption increases drastically, the production of PET bottles increased exponentially. It was reported that PET bottles were produced about 120.000 tons at the end of 2004 in Turkey. However, the usage of polyethylene and PET products, as things stand right now, constitutes a relevant environmentally unsustainable problem.

Recycling PET waste is increasingly demanded for both ecological and technological reasons. In addition, stricter regulation concerning the recovery of waste is currently coming in force (Parra *et al.*, 2004). Various processes have been developed for recycling plastic waste, including mechanical, energy recovery and chemical processes (Barriocanal *et al.*, 2005). Waste PET bottles were reworked for drinking bottles by melting fusion, which turned out to be costly (Parra *et al.*, 2004). Then waste PET bottles were insured to recycle as lightweight aggregates to reduce the rework cost. However results have been very satisfactory. If waste PET bottles are reused as lightweight aggregates for concrete, positive effects on the recycling of waste resources and the protection of environmental containment are going to be possible (Choi *et al.*, 2005).

Mechanical and physical properties of composite materials produced with waste PET bottles added into gypsum were investigated in this study. Vast quantities of waste PET bottles are available in rural areas and obtaining the grinded punice which is a light material and has a binding feature, was easy and cheap. Gypsum was usually recommended as a binding material, because it gives physically superior quality to the buildings, is easily applied and lowers the cost. The objectives of this study are to; utilize the waste PET bottles as components of composite materials and asses the mechanical and physical properties of composite materials produced by waste PET bottles in varying rates.

MATERIALS AND METHODS

Light weight aggregates were made prepared by mixing gypsum with waste PET bottles 0-2, 2-4 and 0-4 mm diameter. The experiments were conducted in Ataturk University, Mechanics Laboratory, Erzurum, Turkey. Gypsum produced by ABS Company was used as binder; and waste PET bottles were used as additive materials. Some of the properties of gypsum used were; desiccation starting time is 8 to 12 min, desiccation lasting time is 25 to 30 min, minimum mechanical strength is 9,86 MPa, water absorption is 42% and surface hardness is 50 shore.

Waste PET bottles were added into gypsum at the rate of 5, 10, 15 and 20%. Two types of samples were prepared which were six pieces of 25*5*2 cm diameter (for bending strength and heat conductivity testing) and three pieces of 5*5*5 cm diameter samples (for mechanical strength testing) for each proportion. Totally 45 samples were produced. The samples taken out of the moulds were held in steam cure under 45°C and 95% relative moisture for 24 h (Arikan and Sobolev, 2002).

To determine their physical qualities, the samples were held in water for 2-24 h. Then water absorption and unit weight experiments and heat conduction coefficient measurements were done. Bending and mechanical resistance experiments were done using universal experimenting tool with 14 N mm⁻² min⁻¹ loading speed. Heat conduction coefficient was determined using KYOTO 500 model device with hot wire method. The principles reported in Anonymous (1982), Arikan and Sobolev (2002) and Guozhong *et al.* (2003) were taken into account when the samples were prepared and the experiments were done.

RESULTS AND DISCUSSION

Table 1 presents some of physical and mechanical properties of composite materials produced by adding waste PET bottles into gypsum.

Density: Composite material must have a low unit weight because of its body structure. The values obtained in this study are not different from the values recommended for gypsum by Anonymous (1982). Figure 1 clearly indicates that a negative relationship ($R^2 = 0.65$ and $p < 0.001$) occurred between amount of PET and density of the composite materials. As the ratio of waste PET bottles in the mixture increased, the density of the composite material decreased. Being light is a positive feature for the material as it enables easy transportation, easy application and easy processing.

Water absorption: Porous material absorbs some water when it is held in water or contacts water. Absorption of too much water causes altering the features of a material negatively. Therefore, it is useful to know the absorption feature of a material. It was found that, as the proportion of waste PET bottles in mixture increased, water absorption increased as well (Fig. 2). A linear regression equation adequately described the relationship occurred ($R^2 = 0.65$ and $p < 0.001$)

As gypsum elements are porous, they have little resistance to rain leakages. The solubility of gypsum in water is higher than any other construction material. Therefore, constructive measures are required to prevent gypsum from contacting water so that water absorption feature of a material can be decreased. The surface of the gypsum must be protected using silicate or sodium fluo-silicate when it is exposed to atmosphere conditions. In this way, the problems likely to arise from water exposure can be abolished or, at least, diminished. The size of the pores in the material can be decreased and this can provides slower and less water absorption.

Heat conduction: Heat conduction of gypsum varies depending on the amount of pores in gypsum and its unit weight. The hardened gypsum body involves pores in different diameters depending on body density and these pores contain motionless air. Thus, gypsum provides heat

Table 1: Some physical and mechanical properties

Waste PET bottles (%)	Sieve (mm)	Density (kg m ⁻³)	Water absorption (%)	Heat conduction (W mK ⁻¹)	Bending compressive (MPa)	Strength compressive (MPa)
5	0-2	1254	13	0.288	2.45	3.53
	2-4	1277	15	0.291	2.75	3.73
	0-4	1330	19	0.310	3.92	4.32
10	0-2	1232	19	0.232	2.16	3.43
	2-4	1246	24	0.285	2.56	3.64
	0-4	1303	32	0.301	3.53	3.92
15	0-2	1215	20	0.215	2.05	3.14
	2-4	1217	26	0.273	2.26	3.29
	0-4	1279	36	0.292	2.94	3.43
20	0-2	1201	24	0.201	1.67	2.75
	2-4	1192	28	0.268	1.96	2.79
	0-4	1240	39	0.283	2.65	3.24

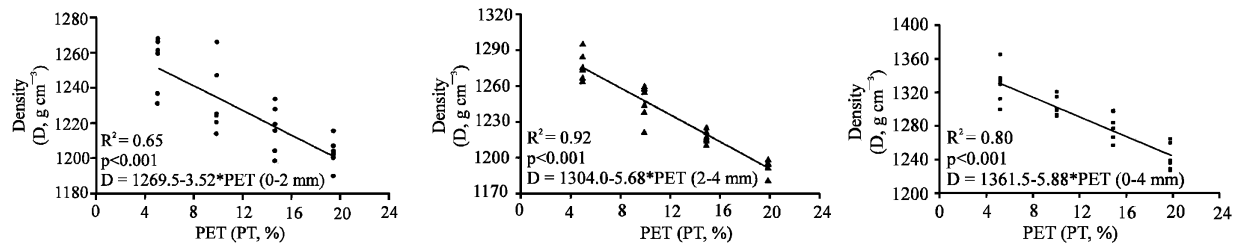


Fig. 1: Relationship between density and waste PET rates in composite materials

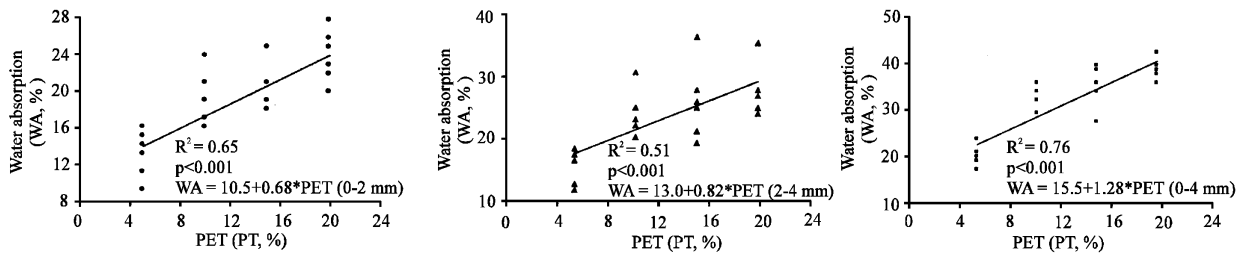


Fig. 2: Relationship between water absorption and waste PET rates in composite materials

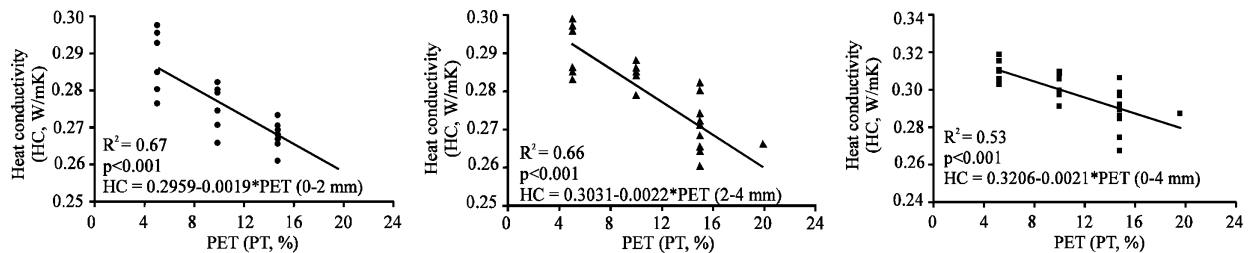


Fig. 3: Relationship between heat conductivity and waste PET rates in composite materials

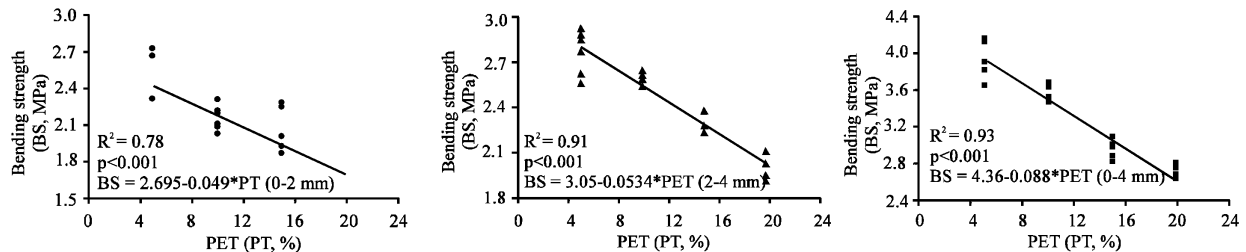


Fig. 4: Relationship between bending strength and waste PET rates in composite materials

insulation in buildings. As the heat conduction of its elements is good, it positively affects heat comfort of buildings it covers. Figure 3 shows that as the proportion of waste PET bottles added to gypsum increased, the heat conduction coefficient decreased ($R^2 = 0.67$ and $p < 0.001$).

The composite material obtained provided a very low heat conduction value due to the pores in its body. Therefore it is possible to use it in buildings as heat insulation material. It can also be used for walls, roofs and roof floors as insulation material.

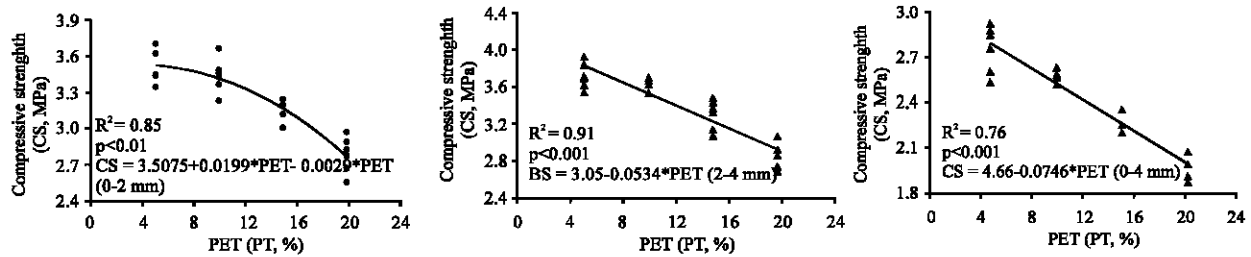


Fig. 5: Relationship between compressive strength and waste PET rates in composite materials

Bending strength: The interfaces are found in a composite material produced by the mixture of different materials (Gouozhong *et al.*, 2003). This results in occurrence of materials with low bending strength. As the proportion of waste PET bottles in the mixture increased, the bending strength of the material decreased sharply (Fig. 4). A linear regression equation described the relationship obtained between bending strength of composite materials and the ratio of waste PET bottles ($R^2 = 0.78$ and $p < 0.001$). Since the material has a lower bending resistance, it is better to use it in places where it is not exposed to pulling tension.

Compressive strength: Use of waste PET bottles as a component of gypsum composite materials decreased the density (Fig. 1) and compressive strength (Fig. 5) of the composite materials produced. Figure 5 shows negative relationships between compressive strength and different sized waste PET materials ($R^2 = 0.85$ and $p < 0.01$). Anonymous (1982) stated that compressive resistance of gypsum used in the buildings (especially in roofs and roof floors) should possess minimum compressing strength of 6.87 MPa. Present results revealed that the composite material produced in this study failed to possess enough compressive strength; thus, it can not be used in roofs and roof floors. Pressure resistance can be increased by placing protection material over gypsum in conditions where resistance is inadequate.

CONCLUSIONS

The proportion of waste PET bottles added to gypsum influences the physical and mechanical features of the material to a great extent. The composite material obtained by increasing the proportion of waste PET bottles can be used for heat insulation and the composite material obtained by increasing the proportion of gypsum can be used as filling material for walls, roofs and roof floors. Using the composite material in question, especially in agricultural buildings as heat insulation

material is important in that it decreases air and environment pollution, saves energy and helps build lighter structures.

We concluded that waste PET bottles produced was qualified enough to use in agricultural buildings. Our implication for future research is that studies must be conducted to obtain higher resistance with respect to physical and mechanical features on samples produced by using waste PET bottles. Waste PET bottles as light aggregates will let us put the waste material to good use and therefore it will lower costs. Use of waste PET bottles in light weight aggregates is an alternative to chemical recycling to minimize the disposal problems.

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