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Use of Sunflower Stalk and Pumice in Gypsum Composites to Improve Thermal Properties

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Abstract: The objectives of this study were to utilize sunflower stalks and grinded pumice as components of composite materials and to evaluate mechanical and physical properties of composite materials composed of sunflower stalk and sunflower stalk plus grinded pumice. The experiment was conducted in two stages. In the first stage, varying rates of sunflower stalks were mixed with gypsum and in the second stage, varying rates of sunflower stalk and pumice were mixed with gypsum. Increasing the ratio of sunflower stalk added in gypsum gradually decreased the unit weight and increased thermal insulation capacity that could be described by a linear regression equation (R^2 = 0.89 and R^2 = 0.81). However, mechanical and bending resistances decreased and water absorption capacity increased that could be described by a second degree polynomial regression equation in the former case and linear regression equation in the later case (R^2 = 0.94, R^2 = 0.85 and R^2 = 0.84). When used together with pumice, increasing rates of sunflower stalk affected thermal and physical properties of the final product differently compared to when used alone. Low unit weight and good heat insulation feature favored the use of final products.

Key words: Sunflower stalk, gypsum, pumice, heat insulation, composite material

INTRODUCTION

The term composite material refers to the material with high performance that developed as durable against outside factors or used for material obtained by physical mixture or composition with other ingredients to produce a final material in desired performances. The widespread use of composite material in construction has started since the beginning of the production with industrial methods (Ragsdale and Raynham, 1972; Arikan and Sobolev, 2002; Li *et al*., 2003).

Heat, moisture and acoustical isolation characteristics are major concerns in deciding for the correct construction material. The use of composite materials in structures resulted in increasing the useful spaces in buildings and heat and acoustic insulation problems were solved. Consequently, the cost of maintenance, repair and management was decreased. Composite material is cost effective; saves energy and time; does not pollute the environment; and is not harmful to human health (Lindley and Whitaker, 1996; Herhández *et al*., 1999; Uzun, 2001; Li *et al*., 2003). However, the use of natural fibers in building materials some disadvantages, such as low modules of elasticity, high water absorption, a propensity to decompose in alkaline environments and variability in mechanical and physical properties (Savastano and Warden, 2001).

Composite materials can be produced as open or closed components of a prefabricated system. The composite materials could also be produced in work sites. It is possible to produce cheaper composite materials and build better qualified agricultural constructions by adding plant waste that is abundant in rural areas into the gypsum. In addition to the use of plant wastes in composite materials, addition of pumice with considerably low unit weight into the composite materials results in low density materials.

Mechanical and physical properties of composite materials produced with sunflower stalk and sunflower stalk plus pumice added into gypsum were investigated in this study. Vast quantities of sunflower stalk are available in rural areas and obtaining the grinded pumice which is a light material and has a binding feature, is 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 were to utilize the sunflower stalks and grinded pumice as components of composite materials and to assess the mechanical and physical properties of composite materials produced by adding sunflower stalk and sunflower stalk plus grinded pumice in varying rates.

MATERIALS AND METHODS

Gypsum produced by ABS Company in 2004 was used as binder; the additives used were sunflower stalk and grinded pumice. The experiment was conducted in

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Table 1: Selected properties of gypsum and pumice used in the study

Gypsum		Pumice (%)	
Water/gypsum	75%	MgO	0.01
Freezing start	8-12 min	Al_2O_3	13.20
Freezing ending	25-30 min	SiO_2	71.35
Pressure resistance	min 9.80 MPA	CaO	1.84
Water absorption (by weight)	42%	Fe_2O_3	1.54
Thinness	0.2 mm, upper sieve 0.0 %	SO_3	0.04
Hardness of dry surface	50 shore D	K_2O	5.00
Water content	2.5	Na_2O	3.40
Compressive strength (MPa)	11.3	TiO_2	0.25
Density (g cm^{-3})	2.597	SO_3	3.37
Heating losses	72.4		

collaboration with Ataturk University and Gaziosmanpasa University at two stages. In the first stage, varying rates of sunflower stalks were mixed with gypsum and in the second stage, varying rates of sunflower stalk and pumice were mixed with gypsum. Pumice used in the second experiment was provided by (Product code is Perlisol 12) (ABS Alci, 2005). The properties of the gypsum, pumice and sunflower stalk used are presented in Table 1.

Two different composite materials were prepared by mixing gypsum with sunflower stalk grinded to 5-10 mm length and 0.5-3 mm diameter and pumice grinded to 212 μm thicknesses. The first serial was prepared in five different sunflower stalks to gypsum ratios (90-10, 85-15, 80-20, 75-25 and 70-30% gypsum-sunflower stalk, respectively). The second serial was also in five different ratios of sunflower stalk and grinded pumice added into gypsum, (45-45-10, 42.5-42.5-15, 40-40-20, 37.5-37.5-25 and 35-35-30% gypsum-grinded pumice-sunflower stalk, respectively). The samples included 6 pieces of 25*5*2 cm patterned (for bending strength and heat conductivity testing) and 3 pieces of 5*5*5 cm patterned samples (for mechanical strength testing) for each proportion. Totally 90 samples were produced to determine the physical and mechanical properties of composite materials in the experiments. The samples were left in steam cure under 45°C and 95% relative humidity for 24 h (Arikan and Sobolev, 2002).

The samples were held in water for 2-24 h to determine water absorption and unit weight experiments and heat conduction coefficient measurements were conducted. The mechanical resistance was determined considering bending and pressure resistance values of the samples. Bending and pressure resistance experiments were conducted with a universal experimenting tool with 14 N/mm^2/min loading speed. Heat conduction coefficient was found using a KYOTO 500 model device with hot wire method. The procedures given by Anonymous (1982), Uzer (1996), Arikan and Sobolev (2002) and Li *et al.* (2003) were applied in preparing samples and conducting experiments.

Statistical analyses were conducted using STATMOST software (STATMOST, 2.01). Normality test was conducted to test the hypothesis that assumes each property has a normal distribution. Regression analyses were performed between sunflower stalk content and each of properties investigated.

RESULTS AND DISCUSSION

Mean values for physical and mechanical properties of composite materials obtained from sunflower stalk and grinded pumice added into gypsum are presented in Table 2.

Unit weight: Since weight of a construction material is an important factor in transportation, application and processing, composite materials with low unit weight are desired (Li *et al.*, 2003). Present findings are similar to those reported and recommended by Anonymous (1982) for gypsum composite materials. Increasing proportion of sunflower stalk resulted in a linear decrease of the unit weight of composite material (Fig. 1). Increasing sunflower stalk in gypsum-pumice resulted in lighter composite materials. Effect of sunflower stalk on unit weight of composite material was successfully described by a second degree polynomial regression equation (Fig. 1). The figure shows that unit weight of the composite materials decrease linearly up to 25% sunflower stalk and increase by further additions.

Water absorption: Due to the effect of capillary forces arising from combined effect of adhesion and cohesion forces inside the capillary pores, porous material absorbs water. As gypsum structure elements are porous; they have little resistance to rain leakages. Absorption of excess amount of water by a material causes most of the features to be affected negatively. The solubility of gypsum in water is higher than any other construction material used. Therefore it should not be used at outside without any protection. Constructive measures are taken to prevent gypsum from contacting water so that water absorption can be decreased.

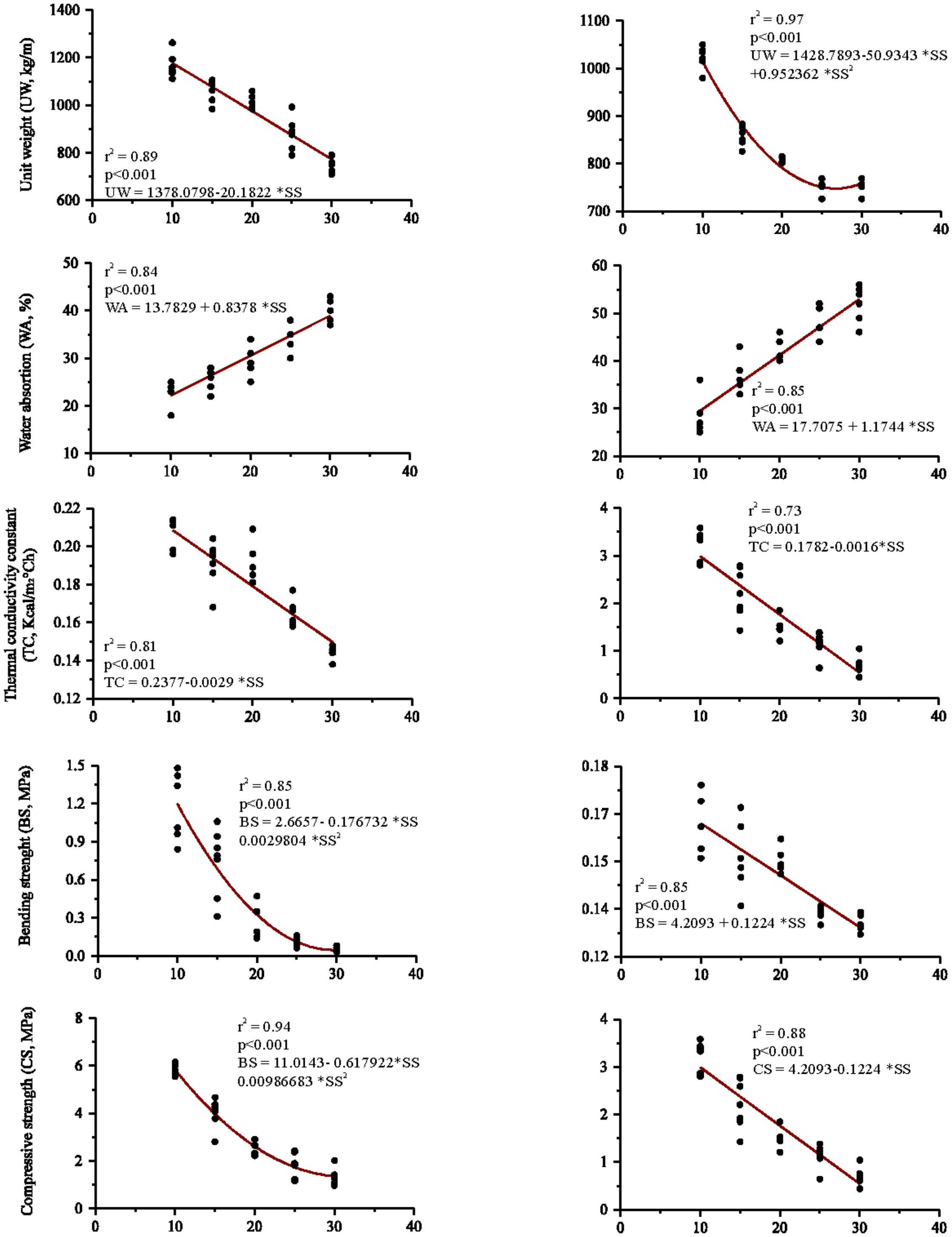

Fig. 1: Relationship between sunflower stalk addition and some physical and mechanical properties of final products

Table 2: Physical and mechanical properties of composite materials produced (for each treatment n = 10)

Serial		Unit weight (kg m^{-3})	Water absorption (%)	Heat con. coef (Kcal/m°Ch)	Bending strength (MPa)	Compressive strength (Mpa)
I	1	1168	23	0.205	5.47	6.01
	2	1080	26	0.195	1.86	4.37
	3	1017	29	0.188	0.62	2.32
	4	880	34	0.165	0.25	2.38
	5	754	40	0.147	0.17	1.27
II	1	1093	28	0.163	1.48	3.33
	2	1023	35	0.155	0.79	1.85
	3	867	43	0.148	0.15	1.85
	4	810	47	0.133	0.16	1.29
	5	754	52	0.139	0.04	0.44

The results showed in both series that as the proportion of sunflower stalk in mixture was increased, the degree of water absorption also increased. The amount of water absorbed by the products in serial II was more than that of products in serial I (Fig. 1). In both experiments, the increase in water absorption depends on the ratio of sunflower stalk added into gypsum mixture. Therefore, high water absorption feature of the final product needs to be considered when applied outside.

Heat conduction: Heat conduction of a material varies depending on the amount of pores in the material and its unit weight. Pores in different diameters form during the hardening gypsum. Air inside these pores increase heat insulation in buildings. As the heat conduction of its elements is low, it positively affects heat comfort of the buildings it covers. Gypsum is a material similar to wood with 0.47 Kcal/m°Ch heat conduction coefficients. The heat conduction coefficient of gypsum panels varies from 0.25 to 0.50 Kcal/m°Ch depending on unit size weight. The data on heat conduction coefficient measurements indicated that as the proportion of sunflower stalk added both to gypsum and gypsum plus pumice mixture was increased, the heat conduction coefficient linearly decreased (Fig. 1).

The composite material obtained in the second experiment was quite porous (Fig. 2a) which resulted in lower coefficient for heat conduction of composite materials. Therefore, composite materials prepared by using grinded pumice into the mixture along with sunflower stalk would increase the heat insulation feature of final product and can be used for walls, roofs and roof floors as insulation material.

Bending strength: The interfaces between different phases are found in a composite material produced by the mixture of different materials (Li *et al.*, 2003). It is clearly seen in Fig. 2a that sunflower stalks' surface is smooth and matrix material does not completely glue it. This results in occurrence of materials with low bending strength. The results indicated that increasing the ratio of sunflower stalk in mixture resulted in decreasing the bending resistance of composite materials produced in both experiments (Fig. 1). However, the bending resistance of material was reduced in greater degree y addition of sunflower stalks as compared to that of the materials produced by gypsum plus grinded pumice. Since the material has a lower bending resistance, it is better to use in places where it does not expose to pulling tension.

Fig. 2a: Electromicroscope analysis of composite material obtained in serial 2

Compressive strength: Use of sunflower stalk and pumice as components of gypsum composite materials increased the porosity and decreased the density of composite material. Therefore, compressive strength of the final products was decreased as the rate of sunflower stalk increased (Fig. 1). The pressure resistance of gypsum used in the buildings (especially in roofs and roof floors) should possess minimum compressing strength of 6.87 Mpa (ABC Alci, 2005). 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.

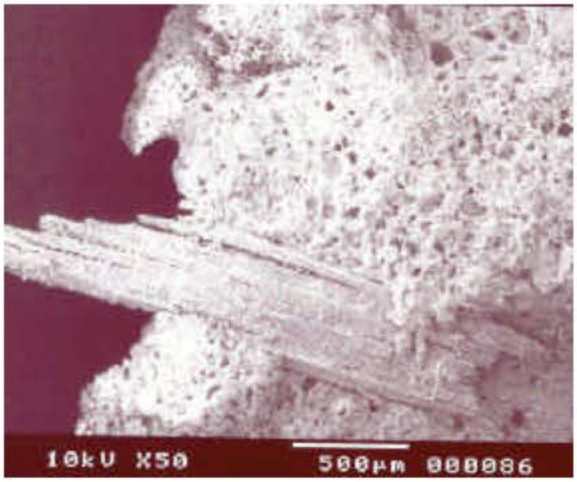

Fig. 2b: Electromicroscope analysis of composite material obtained in serial 2

Materials produced in the second experiment possessed even lower mechanical strength due to having high porosity of pumice used in the mixture (Fig. 2b). In the first experiment, a linear regression equation adequately described the relationship between mechanical strength of the material and sunflower stalk content of the material; however, a second degree polynomial regression equation described the same relationship in the second experiment. Increasing sunflower stalk content resulted in sharp decrease in the compressive strength of the material at the beginning, as clearly seen from Fig. 1. However, the decrease in mechanical strength after a certain rate was very slow.

CONCLUSIONS

Addition of sunflower stalk alone or along with grinded pumice into gypsum improved the heat insulation feature of the composite material. The final product had low unit weight which made it easy to apply. However, lowering unit weight of the material decreased the bending resistance and mechanical resistance and increased the water absorption capacity of material. In this case, the material should be protected against all types of loads and water with rigid layers in definite thicknesses. Choosing sunflower stalk and pumice as light aggregate will let one evaluate waste material in construction lowering the costs.

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. Further studies with the purpose of improving resistance and physical and mechanical features of sunflower stalks waste and pumice in mixtures should be conducted.

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