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Thermal and Mechanical Properties of Cement-Eps-Marble Powder Composites

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Ayse BICER[1*], Filiz KAR[1]

[1]Department of Chemical Engineering, Firat University, Elazig/Turkey

Abstract: This work was undertaken to produce a new construction materials which could have insulation and mechanical strength properties by using two different wasted materials. The waste expanded polystyrene (EPS) and marble powder were used as the aggregate in order to produce a new concrete material. After waste EPS is collected as packaging material, it is mixed with the cement of percentages; 20%, 40%, 60% and 80%. Marble powder is added to each of this cement at 0.0%, 0.5%, 1% and 1.5% of the weight of the mixture. 16 different samples were produced. At the end of 28 days of drying period, the samples were subjected to a number of tests so that their physical characteristics could be identified. As a result of these test, it was concluded that EPS ratio of the samples increased, their density, thermal conductivity, the compression and tensile strength decreased, while porosity increased. It was recommended that; using EPS aggregated and marble powder added concrete, *(i)* the waste EPS and marble powder can be evaluated as construction material, *(ii)* building heating and cooling energy will be saved.

Keywords: Waste expanded polystyrene, marble powder, light concretes, insulation material

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***Corresponding author. E-mail:** abicer@firat.edu.tr

INTRODUCTION

Today styropor can be used as insulation material in buildings; it is also widely used in packaging industry. As an important waste material in terms of environmental pollution, this material has to be recycled and re-economized. Revaluation of waste EPS as construction material is important both in terms of its contribution to economy and as a solution to environmental solution problem. Several studies have been made on the usage of EPS as construction material. A considerable portion of these studies are related to the use of aggregate in concrete. Some of these studies are summarized below.

Babu *et al*. examined the mechanical features of light concretes produced by using ly ash along with expanded polystyrene along with regular aggregate [1]. Miled et al. studied the impact of the change in the amount and dimensions of EPS found on aggregated concrete samples on the pressure resistance of the concrete [2]. Bourvard et al. worked on the physical features of high-performance concretes consisting of expanded polystyrene balls [3]. Chen studied on the characteristics of the light concrete which consists of polystyrene foam reinforced with steel fibre [4]. Babu et al. investigated the mechanical behaviours of the concretes which were mixed with silica fume at different rates in order to increase the resistance of low-intensity concrete consisting of EPS [5]. Demirboga and Kan displayed the changes in thermal conductivity, density and average drying contraction values of the concrete in the samples they produced by using 25, 30 and 100% EPS as aggregate in concrete [6],. Rossignolo and Agnesini studied the technical properties of concretes created with light aggregate mixtures of styrene-butadiene rubber (SBR) modified with two types of light aggregates [7],. Kaya and Kar investigated the physical characteristics of light concrete and gypsum coatings with waste EPS aggregates [8]. Kaya and Kar tested thermal and mechanical properties of the light weight concretes with EPS and tragacanth resin [9]. Sariisik and Sariisik determined the thermal conductivity value of concrete mixtures with cement, pumice and EPS [10]. Khedari et al. investigated a new lightweight construction material, composed of cement, sand and fiber of waste coconut [11].

In this paper, the mechanical features of samples produced by granulating the EPS particles which are liberated as waste material in packaging industry using certain amounts of cement and marble powder have been examined.

EXPERIMENTAL

Materials

Expanded Polystyrene Foam (EPS) is a foam-like- closed-pored thermoplastic material, typically in white colour, obtained from polymerization of styrene monomer (Figure 1). EPS products were acquired by bulking and amalgamation of polystyrene particles. “Pentane” gas was used for particle bulking and foam acquiring. Pentane is an organic component and after it ensures formation of many small particles within particles, it is exchanged by air in a very short time during and after the production. With the liberation of pentane, inert air is trapped in the abounding (3-6 billion in 1 m^3 EPS depending on density) number of small pored cells. 98 percent of the material is air and the rest is polystyrene (8). EPS is a close-pored material. Due to its very low level of water absorption, its features do not change even if it directly contacts with water. As it does not dissolve and disintegrate in water, the pore walls are water-proof.

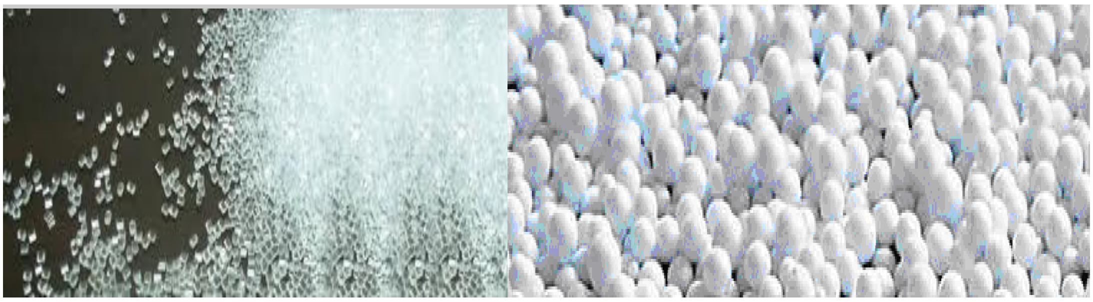

Figure 1: Polystyrene and expanded polystyrene (7).

Marble Powder (MP) are obtained from Marble manufacturing facility in Elazig.

CEM IV/B(P)32.5 R pozzolanic cement were used to EPS and marble powder as a binder. Chemical components of cement are given in Table 1.

Table 1: Chemical composition of cement used.

Component	**SiO_2**	**CaO**	**Al_2O_3**	**Fe_2O_3**	**MgO**	**SO_3**	**Cl**	**Fire loss**	**Not available**
(%)	23.51	58.51	6.15	4.00	2.27	2.37	0.10	2.04	0.72

The prepared blends were mixed with sufficient amount of water and poured into the pre-assembled molds. The weights after mixing the cement, EPS and marble powder with the mentioned percentages are listed in Table 2. The molds that were formed had the dimensions of 100x100x100 mm for mechanical tests and the dimensions of 20x60x150 mm for thermal tests (Figure 2).

Table 2: Details of the cement-EPS-marble powder mixes.

Samples	Volumetric ratio		Weight (g)		Total weight	Marble powder	Marble powder	(W)/(C+E+M)
	EPS	cement	EPS					
Sample 1	80	20	20.4	450	470.4	0.0	-	0.5
Sample 2	60	40	15.6	900	915.6		-	
Sample 3	40	60	10.4	1350	1360.4		-	
Sample 4	20	8080	5.2	1800	1805.2		-	
Sample 5	80	20	20.4	450	470.4	0.5	23.53	0.5
Sample 6	60	40	15.6	900	915.6		45.78	
Sample 7	40	60	10.4	1350	1360.4		68.02	
Sample 8	20	80	5.2	1800	1805.2		90.26	
Sample 9	80	20	20.4	450	470.4	1	47.0	0.5
Sample	60	40	15.6	900	915.6		91.5	
Sample	40	60	10.4	1350	1360.4		136	
Sample	20	80	5.2	1800	1805.2		180.52	
Sample	80	20	20.4	450	470.4	1.5	70.5	0.5
Sample	60	40	15.6	900	915.6		137	
Sample	40	60	10.4	1350	1360.4		204	
Sample	20	80	5.2	1800	1805.2		270	

W:Water, **C:**cement, **E:**EPS, **M:**marble powder

Figure 2: Rectangular and cubic block samples.

Thermal and Mechanical Test

The thermal conductivities of specimens were detected by *Isomet 2104* unit, which makes measurements by using the hot wire method according to *DIN 51046.* Its range and sensitivity were 0.02-6.00 W/mK respectively and its precision was ±5% [9]. Each sample block was measured three times at three locations to show the average of nine values. The temperature was between 22°C and 25°C during measurement.

Compressive strength tests on the samples were undertaken according to the *ASTM C 109-80* standard. The tensile strength values calculated according to the *TS 500* standard by Eq. 1 [13].

$$f_{ctk} = 0.35\sqrt{f_{ck}} \qquad \text{(Eq. 1)}$$

Here;

f_{ck}: Compressive strength (MPa) f_{ctk}: Tensile strength (MPa)

Elasticity module is mostly calculated by theoretical methods [12]. Elasticity module values are calculated according to the *TS 500* standard by Eq. (2) [13]:

$$E=3.25*(fck)^{1/2}+14 \quad \text{(Eq. 2)}$$

In this equation, *E* is the elasticity module (GPa), and f_{ck} is the characteristic compressive strength (MPa).

The water absorption test aimed to analyze the maximum water uptake amount. This characteristic is significant to designate whether the material is appropriate for use against freezing risks. The critical moisture amount is 30% of the total dry volume and the material does not deform when frozen below this amount. The tests were performed by complying with BS 812, Part 2 standard and keeping the samples in water.

$$\text{Water absorption}=\{[W_d-W_k]/W_k\}.100 \quad \text{(Eq. 3)}$$

In the equation, W_k is the dry weight of sample and W_d is the wet weight of sample.

The purpose of drying ratio test is to search the respiration abilities of the samples. After being left in water contained for 48 hours the samples were taken from the water, wiped with a wet piece of cloth and left to natural drying at 22^{o}C room temperature. The drying ratio values are calculated by Eq. (4). Drying occurs through evaporation from the surface of the material; here it is about the movement of water from the depth of the material through capillary canals, meaning that moisture is expelled from the body through steam permeability resistance and drying occurs.

$$\text{Drying ratio}=\{[W_d-W_k]/W_d\}.100 \quad \text{(Eq. 4)}$$

The results are shown in Table 3.

Table 3: Thermal and mechanical properties of samples

Sample no	Density (g/cm^3)	Thermal conductivity(W/mK)	Compressive strength (MPa)	Tensile strength (MPa)	Elasticity module (GPa)	Water absorption (%)	Drying ratio (%)
1	1.36	0.071	18.50	1.50	27.98	23.41	16.83
2	1.15	0.135	14.58	1.34	26.41	22.06	14.10
3	0.89	0.250	9.15	1.06	23.83	19.55	11.66
4	0.65	0.390	5.12	0.79	21.35	16.6	8.32
5	1.42	0.083	18.94	1.52	28.14	22.05	16.00
6	1.22	0.184	14.89	1.35	26.54	20.10	13.25
7	1.08	0.290	10.18	1.12	24.37	17.11	10.42
8	0.75	0.424	5.38	0.81	21.54	15.85	7.00
9	1.52	0.094	19.04	1.53	28.18	20.90	15.10
10	1.35	0.213	15.15	1.36	26.64	8.80	12.96
11	1.25	0.333	10.36	1.13	24.46	16.74	8.90
12	0.88	0.441	5.70	0.84	21.75	14.17	6.50
13	1.61	0.101	13.48	1.29	25.93	18.75	13.28
14	1.45	0.232	10.60	1.13	24.58	16.45	11.05
15	1.36	0.360	6.27	0.88	22.14	14.56	7.10
16	0.96	0.462	2.58	0.56	19.22	12.28	6.02

RESULTS AND DISCUSSIONS

When Figure 3 is examined, it can be seen that density values of the samples decrease as EPS ratio increases. This reduction is directly related to the density of EPS. But density of the samples increase marble powder ratio decreases.

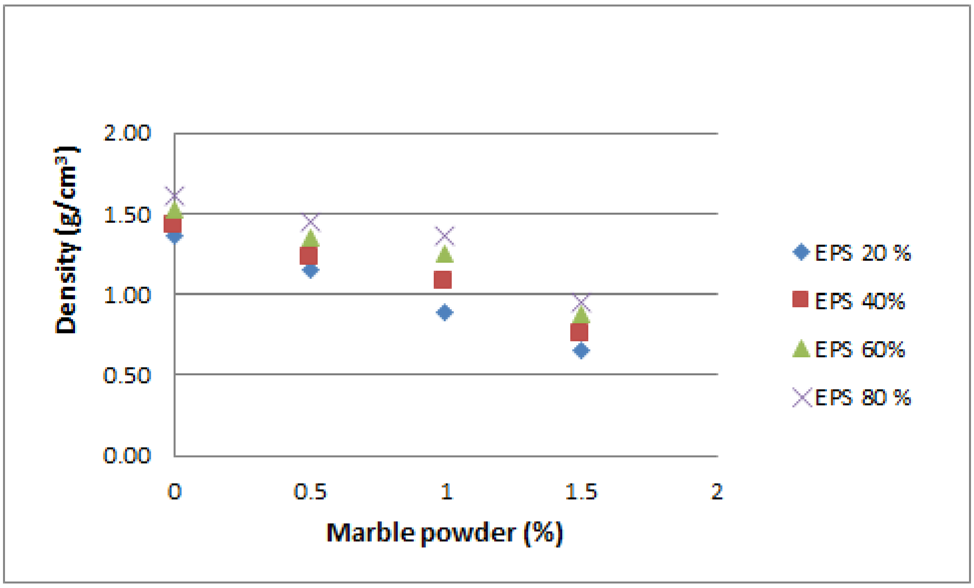

Figure 3: Density ratio of samples versus EPS percentages

Considering Figure 4, it is clear that thermal conductivity drops as EPS ratio climbs. Thermal conductivity depending on EPS ratios, 20% and 80%, decreased by 81.79 %. In the case of 0% and 1.5% ratios of marble powder in the mixture the thermal conductivity increased as 28.16-17.94%.

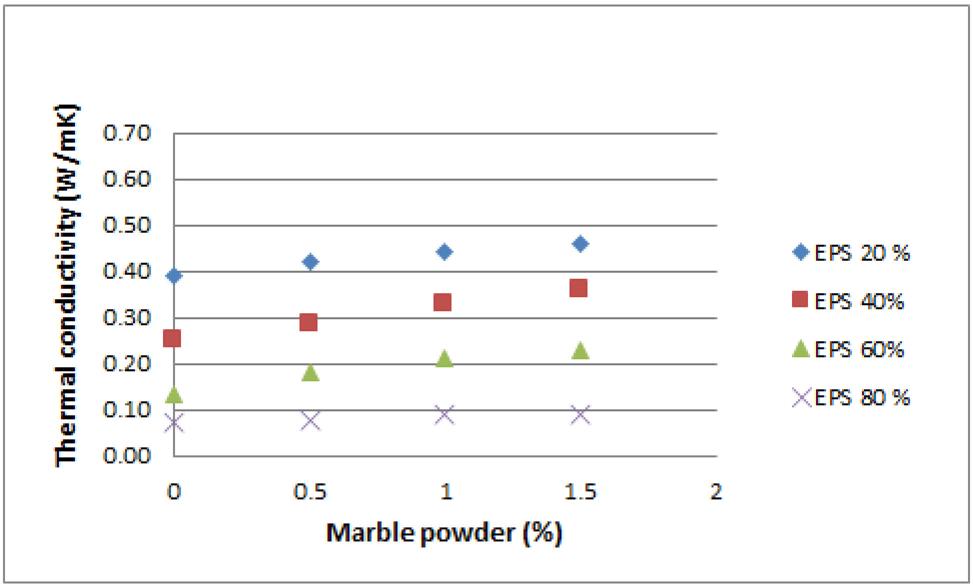

Figure 4: Thermal conductivity variation according to EPS and MP.

The Figures 5, 6, 7 shows that compressive strength, tensile strength and elasticity module values increases from 0 to 60% EPS and marble powder 1% ratios. But their values decreases after from the rate of the 1% marble powder. Because, cement and marble powder aggregate (1%) are creating a good mix.

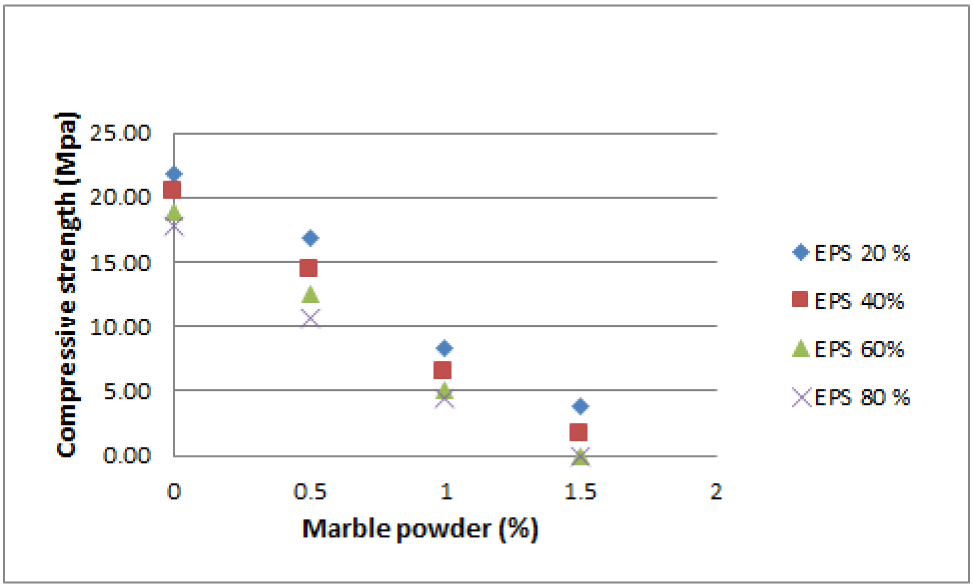

Figure 5: Compressive strength-EPS and marble powder percentage relation in the specimens.

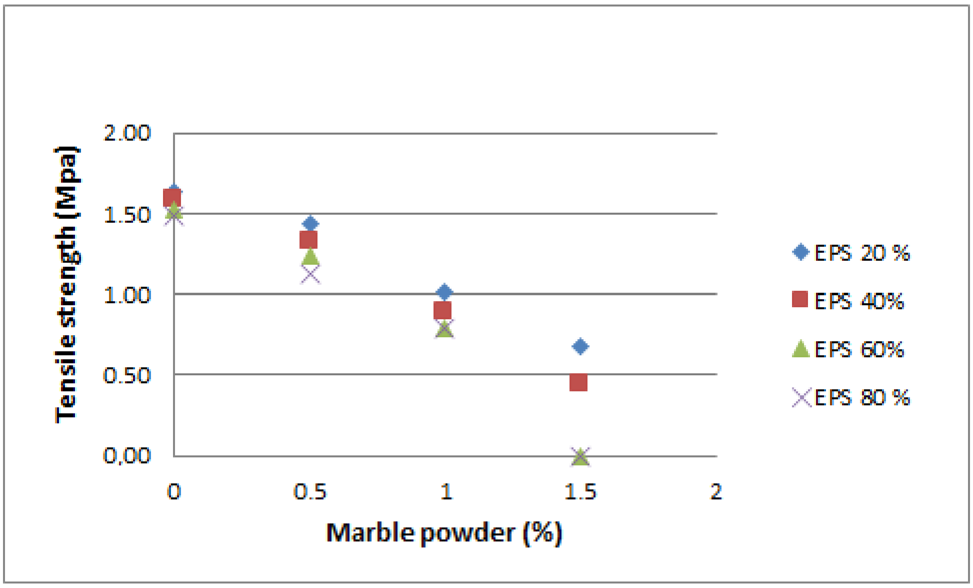

Figure 6: Tensile strength-EPS and marble powder percentage relation in the specimens.

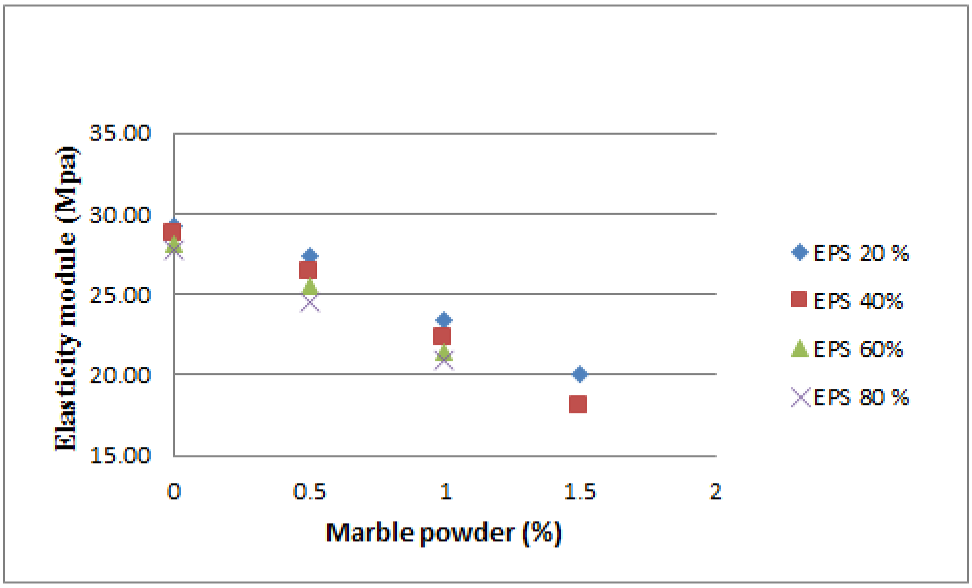

Figure 7: Variation of drying ratio of samples versus EPS percentages.

Almost all of the samples with resin added cement binders remained below 30%, which is the critical level for water absorption (Fig. 8). Therefore these materials can be used without the risk of freezing under 0^{o}C temperature in places which is in contact with water.

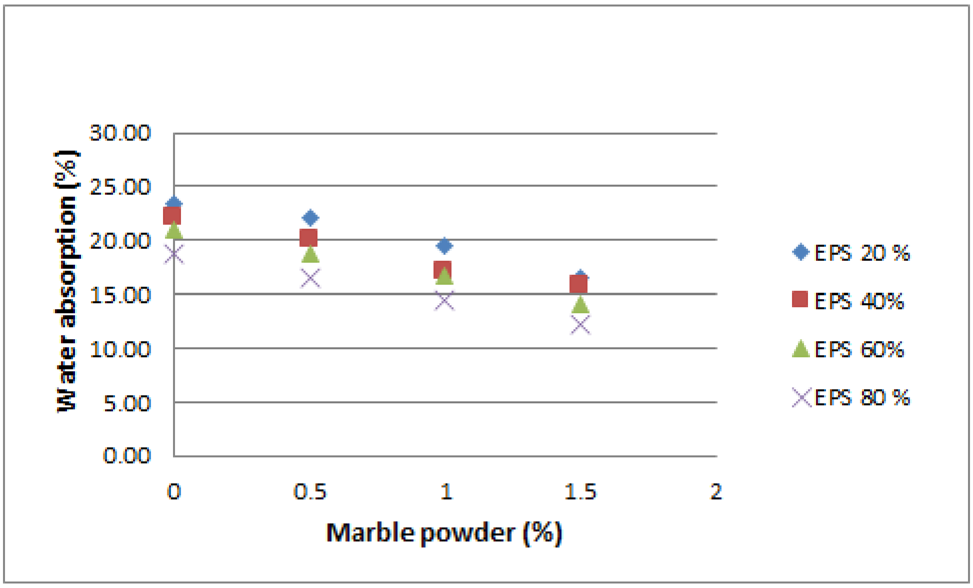

Figure 8: Variation of water absorption ratio of samples versus EPS percentages.

Considering Figure 9, it is clear that the sample drying ratios diminish as the EPS particle addition ratio grows. The moisture contained in the material moves towards the surface by means of capillary channels. This indicates the material’s respiration ability.

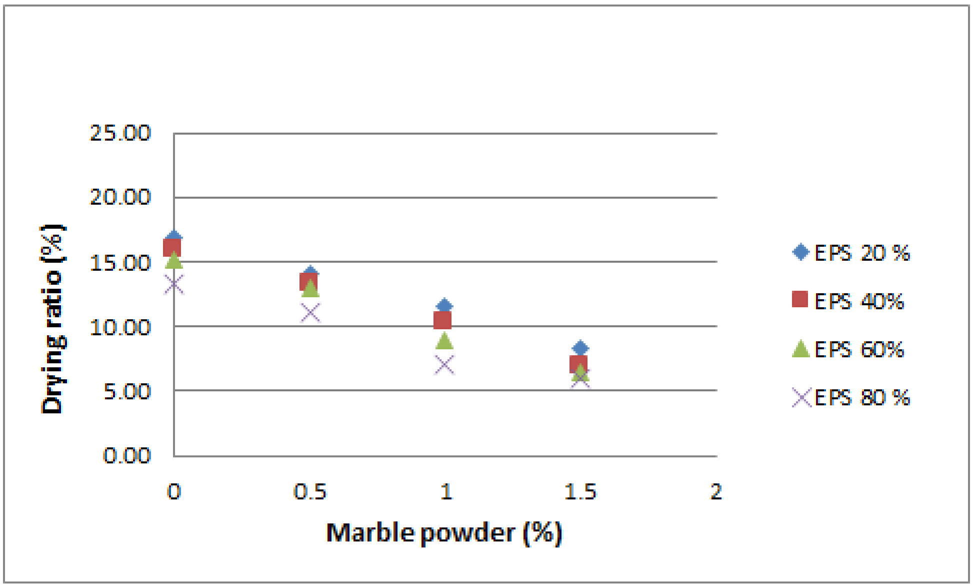

Figure 9: Variation of drying ratio of samples versus EPS percentages

CONCLUSION

This study was conducted to illustrate whether the use of waste EPS and marble powder in concrete was possible in place of natural aggregate materials.

Low-density concrete with EPS and marble powder aggregate can be used in panel walls, floorings and floor deck concretes as well as construction applications such as concrete briquettes, whereas blocks of plaster with the same additives can be used as insulation coating.

These materials should not be used as columns and beams components in buildings due to low compressive, tensile strength and elasticity module values of the samples. Nevertheless, these concretes with low density are designated as flooring, ceiling and wall concrete.
The rate of water absorption of samples is less than 30%. From this result, it is concluded that these materials can be used as concrete and external plaster or inner plaster material that subjected to water.

In conclusion, the concrete material containing EPS and marble powder can be used as building material and simultaneously solve the environmental pollution problem by recycling waste EPS and marble powder.

REFERENCES

1. Babu DS, Babu KG, Wee TH, Properties of lightweight expanded polystyrene aggregate concretes containing fly ash, Cement and Concrete Research, 2005, 35, 1218 – 1223.

2. Miled K, Sab K, Roy RL, Particle size effect on EPS lightweight concrete compressive strength: Experimental investigation and modeling, Mechanics of Materials, 2007, 39, 222-240.

3. Bouvard D, Chaix JM, Dendievel R, Fazekas A, Létang JM, Peix G, Quenard D, Characterization and simulation of microstructure and properties of EPS lightweight concrete, Cement and Concrete Research, 2007, 37, 1666-1673.

4. Chen B, Liu J, Properties of lightweight expanded polystyrene concrete reinforced with steel fiber, Cement and Concrete Research, 2004, 34, 1259 – 1263.

5. Babu, K.G. and Babu D.S., Behavior of lightweight expanded polystyrene concrete containing silica fume, Cement and Concrete Res. 2003, 33, 755-762.

6. Demirboga R, Kan AK, Thermal conductivity and shrinkage properties of modified waste polystyrene aggregate concretes, Construction and Building Materials, 2012, 35, 730–734.

7. Rossignolo YA, Agnesini MVC, Mechanical properties of polymer modified lightweight aggregate concrete, Cement and Concrete Research, 2002, 32, 329-334.

8. Kaya A, Kar F, Thermal and mechanical properties of concretes with Styropor, Journal of Applied Mathematics and Physics, 2014, 2-6, 310-315.

9. Kaya A, Kar F, Properties of concrete containing waste expanded polystyrene and natural resin. Construction and Building Materials, 2016, 105: 572-578.

10. Saiisik A, Sariisik G, New production process for insulation blocks composed of EPS and lightweight concrete containing pumice aggregate. Mater. Struct., 2002, 45(9), 1345-1357.

11. Khedari J, Suttisonk B, Pratinthong N, Hirunlabh J, New lightweight composite construction materials with low thermal conductivity. Cement and Concrete Composites, 2001, 23: 65-70.

12. Cui HZ, Lo TY, Memon SA, Xing F, Shi X. Analytical model for compressive strength, elastic modulus and peak strain of structural lightweight aggregate concrete. Construction and Building Materials, 2012, 36: 1036-1043.

13. TS 500, Turkish Standard, 2000, Ankara.