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Physical And Mechanical Properties Of Mortars Produced From Disposable Polyetylene Glasses Without Using Cement

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ABSTRACT

In this study, production of mortars with disposable polyethylene glasses, but without cement, was investigated. The disposable polyethylene glasses were crushed and converted into fiber formation. Then fibers were molten with different types of sands at the temperature range of 180–200 ºC. Some physical (e.g. water absorption and abrasion resistance) and some mechanical (e.g. bending strength, compression strength, toughness) properties of mortars were tested. The results indicated that bending strength and toughness of mortars were improved. Besides, water absorption of mortar was negligible and abrasion was nearly equal to zero.

INTRODUCTION

Usage of disposable plastic material in concrete has become widespread since the last twenty years. In concrete, these plastics are used as aggregate or binding agent [1]. Polyethylene takes place with different formations in daily life and then it is evaluated by recycling [2]. Recently, many studies have been done on the usage of disposable materials in concrete [3–5]; especially on evaluating PEs as aggregate or fiber [6–13]. It is known that numbers of shrinkage cracks are decreased by adding polyethylene fibers into concrete. As considering that plastic shrinkage deforms quickly, importance of disposable plastic fiber is easily understood [14–16]. These shrinkages cause some durability problems such as; wetting-drying and freezing-thawing. It is commonly shown by many studies that flexibility is gained to these brittle materials by plastic fibers having different fiber lengths [17]. Fibers having low elastic modulus, increase performance rate of mortar and also prevent shrinkage occurrence by decreasing tensile stress. Durability problems are reduced by preventing shrinkage occurrence. Fibers, which have different fiber lengths and are homogeneously distributed in mortar, prevent shrinkage occurrence on the hardened mortar surface [18–20].

Toughness is the capacity of being deformed under dynamic forces. These plastic fibers gain toughness to hardened mortar.

5% carbon dioxide is released to atmosphere during cement production [21]. Durability is the other problem of mortars containing cement. It is known that Rome and Ottoman buildings have already been in good condition whereas durability problems cause considerably high expense for restoration of recently constructed buildings [22].

In this study, it is aimed to produce concrete block without cement. Disposable polyethylene glasses and sands were molten at the temperature of 200 ºC and then this mixture was molded. Bending strength, compression strength, water absorption and abrasion resistance tests were performed on these mortars.

MATERIALS

Disposable PE glasses, limestone, pumice, basalt and quartz sands were used in this study. PE glasses were taken 5% of sand in weight. All materials were heated up to 180–200 ºC in the same container. This process continued until PEs was completely molten. When homogeneous mixture had desired viscosity, mortars were poured into 4x4x16 cm and 10x10x10 cm molds.

Polyethylene (PE)

Chemical and mechanical properties of disposable PEs glasses are given in Table 1.

Table 1. Properties of disposable PE glasses

Properties	Values
Chemical structure	100 % polyethylene
Specific gravity	0.91 g/cm^3
Absorption	rarely
Melting point	160 °C
Ignition temperature	250 °C
Thermal conductivity	Low
Electrical conductivity	Low
Tensile strength	300 – 400 N/mm^2
Elastic modulus	~ 4000 N/mm^2

Pumice

Pumice is a porous, spongy and glassy volcanic Stone. It is resistant to chemical and physical factors and contains approximately 50% humidity. Its specific gravity can be decreased up to 0,5 g/cm^3 if its humidity is removed. Abrasion rate of these stone changes according to SiO_2 quantity. Heat resistance is directly related with Al_2O_3 rate. Na_2O and K_2O minerals are famous for their reactive properties in textile industry. Pumice used in this study is supplied from Osmaniye region and it has basaltic structure [23]. In concrete production, it is used pumice granules with dimensions of 0,5 mm.

Table 2. Physical and chemical properties of pumice

Components	% age
SiO_2	65.8
Al_2O_3	15.5
Fe_2O_3	2.5
CaO	2.4
MgO	2.7
$Na_2O + K_2O$	7.6
Color: Brown-Black	
Stiffness: 1.6	

Limestone, Basalt and Quartz

Physical properties and spectrographic examination results of these sands are illustrated as following tables.

Table 3. Physical properties of limestone, basalt and quartz sands

	Sand Type		
	Limestone	Basalt	Quartz
Specific gravity (kg/dm^3)	2.67	2.67	1.54
Absorption rate (%)	18.8	17.8	17.6
Fine material rate (%)	7.44	5.23	3.03
Light material rate (%)	0.20	0.98	2.10
Organic material	none	none	none

Table 4. Petrographic examination results

Stone Type	% Sand Type		
	Limestone	Basalt	Quartz
Limestone	63.4	19.5	-
Spilite, Basalt, Andesite	20.1	53	0.2
Chert, Opal	12.5	18	0.2
Serpentinized peridotite	-	-	1
Gabbro, Diorite	1.9	1	1.5
Quartz	1.1	8.5	97.1
Schist	-	-	-
Grit stone	-	-	-

2.2. Method

Concretes without cement were individually prepared with each sand type by using 33, 3% PE in weight. In material production, PEs was firstly molten at approximately 200 ºC. After desired viscosity was obtained, each sand was mixed with viscous PE molten in different containers. It was tried to provide optimum homogeneity during heating. These different mortars were poured into 4x4x16 cm and 10*10*10 cm molds (Figs.1–3).

Figure 1. Molding of mortars

Figure 2. 4x4x16 cm specimens

Figure 3. 10x10x10 cm specimens

Concrete mortars were produced by mixing sands with same quantities. Water-cement ratio was 0, 5 in weight. Compression strengths of these specimens were measured after curing them during 28 days. Abrasion and absorption values were also obtained.

RESULTS AND DISCUSSION

Compression Strength

Concrete specimens are used for obtaining amount of load per unit area and observing behaviors of concretes produced with these mortars. These technical data give ideas about practical applications. Compression strengths of these hardened plastic concrete specimens were tested with uniaxial compression testing device (Fig. 4). Results are given in Table 5.

Figure 4. Compression Strength Test

Test results are given in Table 5. Concretes containing plastic materials have satisfactory test results. Especially, compression strengths of concretes containing quartz and limestone are 60% higher than that of control specimens. The lowest compression strength is observed in concretes with pumice sands, even lower than control specimens.

Table 5. Compression strength test results

Specimens	Compression Strength (MPa)
Concrete with pumice sand	18.55
Concrete with limestone sand	27.57
Concrete with quartz sand	32.15
Concrete with basalt sand	29.17
Control (concrete with cement)	20.37

Bending Strength

Bending strengths of hardened plastic concrete specimens are measured with one-point bending test device (Fig. 6). Test results are shown in Table 6 and Figure 5.

Fig. 5. Bending Strength Test

Table 6. Elasticity, stress and strain results of specimens

Specimens	Elastic modulus (MPa)	Stress (MPa)	Strain (%)
Concrete with pumice sand	271.09	13.18	8.12
Concrete with limestone sand	322.36	13.77	5.13
Concrete with quartz sand	300.96	11.06	5.11
Concrete with basalt sand	288.45	14.12	5.02
Control (concrete with cement)	243.22	6.43	4.02

According to test results, relation between stress and strain is graphically shown in Figure 6 and toughness values of specimens are given in Table 7.

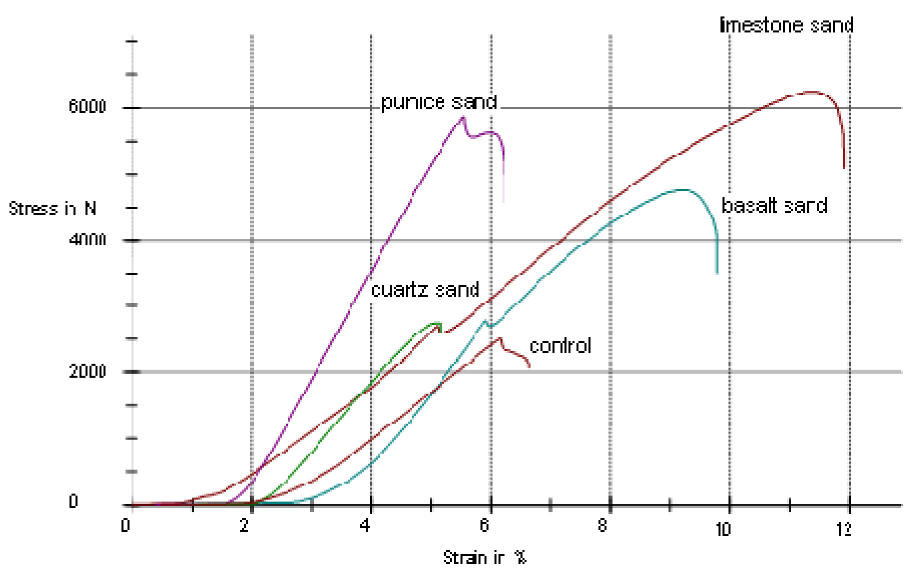

Figure 6. Stress-strain deformation curve

Table 7. Toughness values of specimens

Specimens	Toughness values
Control (concrete with cement)	74.8
Concrete with basalt sand	285.4
Concrete with pumice sand	124.7
Concrete with limestone sand	135.4
Concrete with quartz sand	36.2

Plastic increases toughness of concrete considerably and also develops flexibility of concrete. It is observed that specimens containing pumice sand have more flexible construction. Toughness values of concretes with quartz sands are the highest results. High flexibility values of concretes with pumice sands are caused by amorphous structure of pumice. Crystalline structure and stiffness of quartz leads to higher toughness values.

Abrasion and Absorption Values

New specimens with dimensions of 71x71x71 mm were prepared in order to obtain surface abrasion. Surfaces were numbered from 1 to 4 after controlling curves and dimensions of specimens. They were measured with micrometer. Specimens were placed on abrasion testing device, respectively. Each point on abraded surface was detected with high-sensitive micrometer. Abrasion rate was determined according to difference between first and second measurements [24]. Abrasion and absorption values are given in Table 8.

Table 8. Abrasion and absorption values of specimens

Specimens	Abrasion values according to weight loss (%)	Water absorption (%)
Concrete with pumice sand	0.68	0.18
Concrete with limestone sand	0.15	0.07
Concrete with quartz sand	0.04	0.05
Concrete with basalt sand	0.09	0.06
Control (without plastic)	12.45	10.32

CONCLUSION

Concretes containing plastic are more resistant to compression. Especially, concretes with quartz or limestone, have 60% higher compression strength than control concrete. The lowest compression strength is seen in concretes containing pumice. This is a result of pumice's porous structure.

Plastic improves flexibility of concretes and increases toughness. Concretes containing quartz have higher toughness. On the other hand, flexibility of concretes with pumice sand is higher than that of others. Pumice develops flexibility due to its high amorphous structure. Higher toughness is the result of high stiffness and more crystalline structure of quartz.

Absorption and abrasion rate of concretes are directly related with aggregate type and quantity. Concretes prepared with pumice sand, have higher abrasion and absorption rates. However, all specimens have lower abrasion and absorption rates than that of control concretes containing cement.

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