THE EFFECT OF GRANULE EPS ON DRYING SHRINKAGE OF FOAM CONCRETE

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ABSTRACT
Drying shrinkage is major problem in foam concrete. The absence of coarse aggregate and high cement dosage in the mixture of foam concrete increase the drying shrinkage. Subsequently, micro-cracks develop within 1 to 6 months in foamed concrete and rapidly spread throughout the structure. Cracks due to the drying shrinkage are an important problem in the production of foam concrete-precast construction elements and lightweight-floor screed applications.
In this study, the effect of using EPS granule obtained from waste EPS as light aggregate was investigated on the shrinkage of low density foam concrete (400-500 kg/m^3). The EPS granule amounts in four different foam concrete specimens were 0, 2.5, 5 and 7.5 kg/m^3 respectively. The cement dosage (350 kg/m^3) and the w/c ratio (0.42) were fixed in the foam concrete specimens. Length changes of 1 "x1" x11 "mortar bars were measured for 5 months in accordance with ASTM C 596 standard. Dry shrinkage ratios of specimens with 0, 2.5, 5 and 7.5 kg/m^3 EPS granules were determined as 0.28%, 0.59%, 0.38% and 0.29% respectively. The addition of low amount of EPS granules (2.5 and 5 kg/m^3) to foam concrete increased the drying shrinkage. On the other hand, the shrinkage of the specimen with high EPS (7.5 kg/m^3) content was the same as the specimen without EPS.

Keywords: *Foam concrete, Drying shrinkage, Micro-crack, Waste-granule EPS*

INTRODUCTION
Shrinkage of foam concrete (FC) is an important problem. The drying shrinkage in the FC can occur in a severe form between 1 to 6 months depending on the ambient humidity conditions and the temperature. This effect is the most important factor restricting the use of FC.
The volume change (drying shrinkage) of a cementitious material caused by moisture loss is primarily due to the volume change of the hydrated cement paste due to the removal of adsorbed water from the surface of the gel pores (Neville 1995). When the normal concrete is considered, the main parameters affecting the shrinkage are the shrinkage of the cement paste and the aggregate content (Hansen and Almudaiheem 1987).
Due to the lack of coarse aggregates in their composition, drying shrinkages of cellular concretes such as autoclaved aerated concrete and FC is more than 10 times compared to a concrete with normal weight (Valore 1954 and Jones et al. 2003).
Ramamurthy and Narayanan (2000) stated that autoclaving process caused a significant reduction in shrinkage of aerated concrete and showed that the shrinkage of the structure was mainly a function of the physical structure of the hydration product (Ramamurthy and Narayanan 2000). Tada and Nakano (1983) suggested that the increase in shrinkage of foamed concrete was due to the increase in pore volume (Tada and Nakano 1983). Georgiades and Ftikos (1991) have noted that the bulge was related to the volume and specific surface areas of the micropores in the structure (Georgiades and Ftikos 1991). Schubert (1983) attributed shrinkage to pore volume, pore distribution, and moisture content (Schubert, 1983). Jones et al. (2003) used sand and fly ash (FA) as fillers and found that sand particles were restricted in shrinkage more than FA particles (Jones et al. 2003). Nmai et al. (1997) found that there was a significant reduction in shrinkage rate as density decreased, in a research they conducted on a new foam agent (Nmai et al. 1998). Regan and Arasteh (1990) stated that light aggregate could be used to reduce the shrinkage of foamed concrete (Regan and Arasteh 1990). Nambiar and Ramamurthy (2009) found that the shrinkage of

foamed concrete containing 50% foam was 36% lower than the base mixture (Nambiar and Ramamurthy 2009).
In this study, the effect of wasted EPS granules on FC with dry density of 500 kg/m^3 was investigated.

MATERIAL AND METHOD

In the production of FC, CEM I 42.5 R Portland cement as binder, limestone powder (<40 □m) to increase adherence, micronized-sieved limestone as aggregate (between 600-100 □m), synthetic foam agent as foam and waste polystyrene (EPS) particles with density of 18 kg/m^3 as lightweight aggregate were used. 1 kg of synthetic foam agent was mixed with 50 kg of water and foam was obtained at a density of 85 g/L from the mixture obtained using the foam generator. All components were mixed in a laboratory-type ribbon mixer for 5 minutes.
The cement properties used in the mixture were given in Table 1 and the components of foamed concrete samples were given in Table 2.
Table 1. Physical and chemical properties of cement

Chemical Properties of Clinker (%)		Physical Properties of Cement	
SiO_2	20.52	Vol. expansion (mm)	≤ 1
Al_2O_3	4.00	Fineness (90μ, %)	0.10
Fe_2O_3	3.45	Fineness (200μ, %)	1.10
CaO	64.28	Specific Surface Area (cm^2/g)	3340
MgO	1.63	Initial setting time (min)	185
SO_3	2.53	Final setting time (min)	240
Na_20+K_2O	1.35	Specific Gravity (g/cm^3)	3.12
Mechanical Properties of Cement (MPa)			
7 days	Flexure Strength (MPa)	5.8 Compressive Strength (MPa)	39.3
28 days	Flexure Strength (MPa)	7.2 Compressive Strength (MPa))	51.0

Table 2. Components of FC samples

	Component (kg/m^3)							
Specimen No	Cement	Limestone Powder	Micronized Aggregate	EPS	Water	Foam	w/c	w/s
E0	350	50	50	0	168	58	0.48	0.37
E2.5	350	50	50	2.5	168	44	0.48	0.37
E5	350	50	50	5.0	168	30	0.48	0.37
E7.5	350	50	50	7.5	168	16	0.48	0.37
w/c : water-cement ratio				w/s : water-solid ratio				

The prepared FC mixtures were poured into 25x25x285 mm prism molds. After completing the shrinkage measurements, the mortar bar specimens were dried to constant weight at 60°C and dry densities were calculated according to TS EN 678 (1995). The weights of the mortar bars were weighed by electronic scale with a sensitivity of 1/100 g. The dimensions of the samples were measured using an electronic caliper with a sensitivity of 1/100 mm and the volumes of the samples were determined from the measured dimensions. Dry densities were calculated from the W / V (mass / volume) equilibrium.
The mortar bar specimens removed from the mold were stored in the climate chamber at 23 °C and 40% relative humidity. The length changes of the specimens were measured with a sensitivity of 1/1000 mm at every 3 days until 28 days of curing and then every week. The drying shrinkage test was carried out in accordance with ASTM C 596-01 (2001).
The length changes of the mortar bars are calculated according to Equation 1:

$$r = \square Ln / L_1 \qquad (DLn = (L_n - L_1) \qquad (1)$$

Where;
r : Drying shrinkage (or expansion) of mortar bars (%)
$\square L_n$: Length changes of mortar bar at nth day (mm)
L_1 : Initial length of mortar bar (mm)

The size changes of the mortar bars were calibrated with the setting rod according to the Equation 2:

$\Delta L_n = (L_1-a_1) \cdot (L_2-a_n)$ (2)

Where;

a_1 : Initial length of setting bar (mm)

a_n : Length of setting rod at nth day (mm)

The weights of the mortar bars were weighed using an electronic scale on each cure. The weight loss rates according to the curing time were also determined according to Equation 3:

$\Delta W = (W_n - W_0) \times 100 / W_0$ (3)

Where;

ΔW_n = The weight loss rate of mortar bar at nth day, %

W_n : The weight of mortar bar including pins at nth day, g

W_0 : The initial weight of mortar bar including pins, g

CONCLUSION

The dry densities of FC specimens with E0, E2.5, E5 and E7.5 symbols were determined as 521, 567, 492, 487 kg/m^3, respectively. The dry densities of the specimens deviated a little from the theoretical density value (450 kg/m^3) due to the collapse.

Moisture loss and drying shrinkage ratios of mortar bars were calculated from the results of the shrinkage test. The findings were given in Table 2 and in Figure 1.

Table 2. Weight changes and shrinkage rates of mortar bars due to curing time

E0			E2.5			E5			E7.5		
Days	ΔW	r	Days	ΔW	r	Days	ΔW	r	Days	ΔW	r
2	7.22	0.189	2	5.64	0.258	2	3.39	0.034	3	2.83	0.123
5	7.45	0.203	4	6.49	0.372	5	5.02	0.211	5	2.93	0.158
7	7.46	0.207	6	6.66	0.390	7	5.37	0.236	7	3.31	0.184
10	7.48	0.203	9	6.90	0.411	9	6.04	0.269	9	3.41	0.200
13	7.48	0.200	11	6.88	0.414	12	6.24	0.280	12	3.60	0.207
18	7.49	0.205	14	6.90	0.410	14	6.40	0.287	14	3.64	0.211
25	7.81	0.217	17	6.87	0.408	16	6.39	0.289	17	3.61	0.207
33	7.68	0.222	22	6.91	0.416	19	6.35	0.282	20	3.61	0.205
40	7.41	0.217	29	7.18	0.423	22	6.35	0.280	25	3.63	0.209
47	7.72	0.245	37	6.96	0.434	27	6.37	0.284	32	3.89	0.223
67	7.75	0.228	44	6.50	0.430	34	6.57	0.301	40	3.51	0.226
91	7.12	0.252	51	7.00	0.465	42	6.26	0.297	47	3.23	0.224
124	6.89	0.270	71	6.70	0.463	49	5.96	0.300	54	3.55	0.250
152	6.32	0.285	95	6.28	0.477	56	6.38	0.327	74	3.30	0.249
			128	5.94	0.491	76	6.04	0.323	98	3.04	0.263
			156	5.27	0.589	100	5.78	0.346	131	2.86	0.279
						133	5.61	0.375	159	2.22	0.285
						161	4.94	0.382			

ΔW : Weight losses of mortar bars due to curing day, %

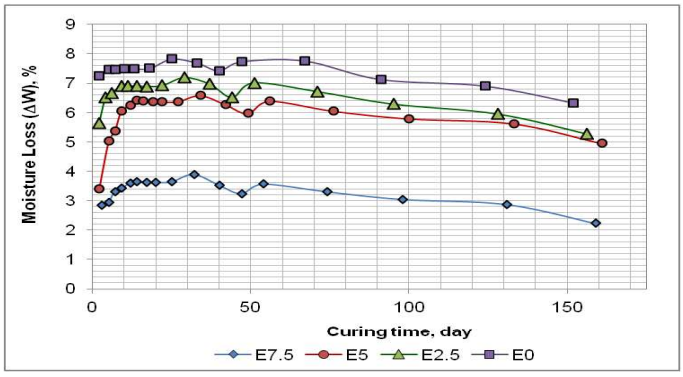


Figure 1. The weight losses of mortar bars due to curing time

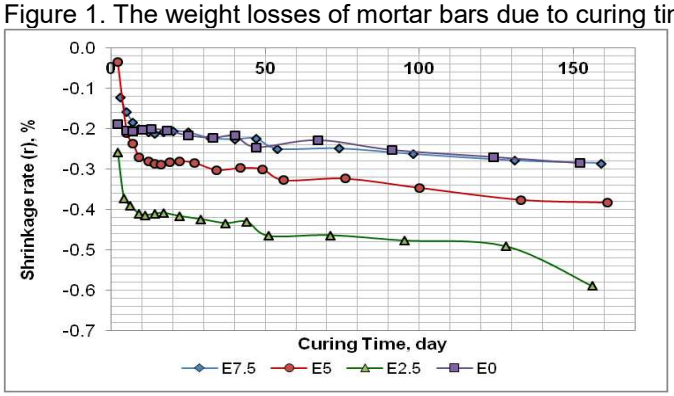


Figure 2. The drying shrinkage rates of mortar bars due to curing time

When Table 1 and Figure 1 were evaluated, it was seen that there was a minimum loss of moisture at E7.5 and a maximum loss of moisture at E0 between the FC-mortar bars kept at 40% relative humidity for 5 months. The moisture loss rates of the E2.5 and E5 specimens were less than the E0 specimen. According to these findings, it could be said that the moisture loss in FC samples was reduced slightly by EPS granules. At the end of 5 months, the moisture loss was 6.3% in E0 and 2.2% in E7.5.

When the findings given in Table 1 and Figure 2 were evaluated, the lowest drying shrinkage ratios at the end of the ~5 month curing period were exhibited by E0 and E7.5 specimens (%-0.285). In contrast, the maximum drying shrinkage was observed at E2.5 specimen (-0.589%). Also, the relationships between density- shrinkage and moisture loss-shrinkage in FC specimens with EPS were also investigated in Figure 3.

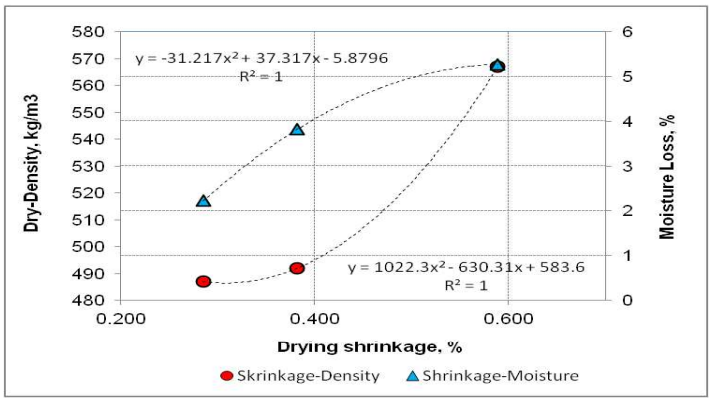


Figure 3. The relationships between density- shrinkage and moisture loss- shrinkage in FC specimens with EPS

There was a strong correlation between the ratio of drying shrinkage - dry density and drying shrinkage - moisture loss in FC specimens containing waste EPS granules (R^2 = 1). As the dry density increased, the ratio of drying shrinkage increased in the specimens with EPS. Similarly, as the ratio of moisture loss increased, the drying shrinkage increased too.

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