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Water Absorption and Sorptivity Properties of Concrete Containing Granulated Blast Furnace Slag

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Abstract : *This paper describes on analyzing the effects of use of granulated blast furnace slag in the water absorption and sorptivity properties of concrete. The purpose of this study was to use of concrete reinforced by the various percentages of granulated blast furnace slag (GBFS) (0, 10 & 20%) as a partial replacement for cement. The tests have been done to determine some aspects namely water absorption and sorptivity at age of curing 28 days was conducted on reference and concrete specimens. The results show that the use of polyolefin fiber gives an improvement in these properties.*

Keywords : *Blast Furnace Slag, Cement, Concrete, Sorptivity, Water absorption.*

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I. Introduction

Concrete is the most widely used construction material due to its high and early compressive strength and low cost. On average approximately 1 ton of concrete is produced each year for every human being in the world [1]. Cement and other additives are mixed to concrete. Cement is one of the most important components of concrete [2]. Because of its abundance in the world market, understanding the environmental implications of concrete and cement manufacturing are becoming increasingly important [1]. The usage of cement, as the basic material with respect to strength and cost of concrete increases rapidly in developing countries for construction of reinforced concrete structures.

Today, pozzolan and cementitious materials plays an important role in concrete. Wastes of industries and constructions which have pozzolanic or cementitious property, not only can reduce environmental pollution and energy consumption of construction industry [3]. Therefore, construction industry is seeking alternative ways to produce this familiar material. It can be classified into two ways. One alternative is to use supplementary materials as a partial replacement of cement in concrete. Another is to prolong the service life of existing building [4, 5].

Currently, the use of supplementary cementitious materials, whether natural, waste, or by product, has been an increasing trend in the manufacturing of cements, for ecological, economical, and quality reasons. In the design, fly ash, waste glass, silica fume, recycled concrete, blast furnace slag, red mud, etc. are waste materials used in concrete [6-10], the contents of cement appear to be similar to those of the major oxides, SiO_2, CaO, Al_2O_3, and MgO, which are found in granulated blast furnace slag [11].

In this paper investigates the effect of replacement of granulated blast furnace slag instead of cement with different percentage and properties of water absorption and Capillary water absorption test was studied.

II. Materials and Methods

2.1. Materials

Cement (CEM I 42.5 R) was supplied from Akçansa in Turkey. The chemical analysis of cement is given in Table 1, physical and mechanical properties of the cement are given in Table 2. Specific surface area of granulated blast furnace slag is 4430 cm^2/g. Specific gravity of granulated blast furnace slag is found to be 2.92 g/cm^3. Chemical properties of granulated blast furnace slag are given in Table 1.

Table 1. Chemical analysis of cement and Granulated blast furnace slag

Chemical composition, %	SiO_2	CaO	Al_2O_3	Fe_2O_3	MgO	K_2O	SO_3	Na_2O	LOI
Cement	21.80	63.56	5.12	3.20	0.80	0.75	3.22	0.55	1.00
Granulated blast furnace slag	44.3	36	9.3	1.7	5.9	0.3	0.29	0.23	0.52

Table 2. The physical, chemical and mechanical properties of cement

	PROPERTIES	UNIT	Cement
PHYSICAL PROPERTIES	Specific Gravity	g/cm^3	3.15
	Specific Surface Area	cm^2/g	3710
	Initial setting time	min	146
	Final setting time	min	193
	Volume expansion	mm	1
	Fineness 45 μm	%	5.8
	Fineness 90 μm	%	0.3
MECHANICAL PROPERTIES	Compressive Strength, 2 days	MPa	28.9
	7 days	MPa	43.8
	28 days	MPa	58.3

The maximum 16 mm nominal size of crushed aggregate was used. The coarse aggregates were calcareous stone as crushed stone I 16-8 mm and natural sand in 0-6 mm. The specific gravity of raw materials is listed in Table 3.

Table 3. Specific gravity of raw materials

Material	Portland cement	Crushed stone I	Natural sand
kg/m^3	3.15	2.60	2.61

2.2. Mixture Preparation

The blast furnace slag replacements were 0, 10 and 20% by weight replacement of cement. The proportion of the aggregate used was 40% sand and 60% coarse aggregate by the total volume of the aggregate. Concrete samples measuring 150x150x150 mm were cast. Samples were kept in molds for 24 h after they were placed. After curing/staying in water 28 days, sorptivity and water absorption test were determined.

2.3. Testing Methods

2.3.1. Capillary water absorption test

The test measured the capacity of water to penetrate into the mortar. The amount of water absorbed was calculated and normalized with respect to the cross-section area of the specimens exposed to the water at various times such as 0, 5, 10, 20, 30, 50 and 60 min. A test was also carried out to determine the sorptivity coefficient of specimens (Eq. (1)) at the 28 day according to TS EN 12390-3 [12].

$$Q/A=k\sqrt{t} \quad (1)$$

Q = the amount of water absorbed, m^3
k = the sorptivity coefficient of the specimen, $m/s^{1/2}$
A = the cross-section of specimen that was in contact with water, m^2
t = time, s

2.3.2. Water Absorption

Water absorption test measurements on the hardened samples were carried out at 28 days according to TS EN 12390-7 [13]. First, the specimens were placed in an oven at a 105°C for 24 hours. Afterwards, they were removed from the oven, cooled, and were weighted (Md). The specimens were immersed in water for 48 hours and weighted (Ms). The total water absorption was the difference of mass Saturated and dry (Eq. (2)).

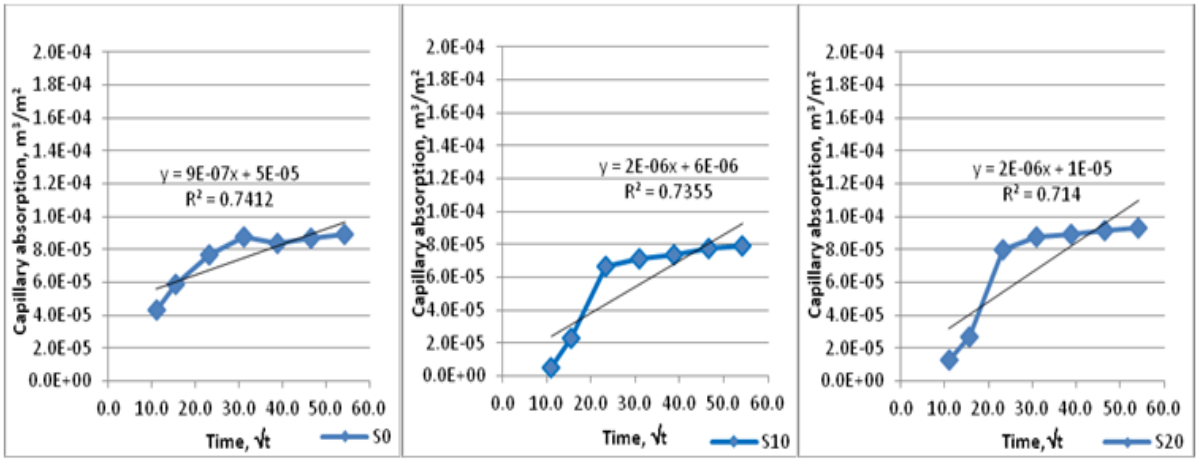
$$W.A.= ((Msat- Md) / Md) \times 100 \quad (2)$$

W.A. = water absorption of hardened concrete specimen, %
Ms = saturated surface dry weight of specimen, g
Md = oven-dried weight of specimen, g.

III. Results and Discussion

3.1. Capillary water absorption test

The test results are shown in Fig. 1. The capillary absorption coefficients were also significantly influenced by the binder combination used and was improved through the use of GBFS as cement replacement. This improvement of the capillary water absorption due to the more pore structure refine, the distribution and dimension of the capillary porosity which is mainly due to the formation of the secondary C-S-H gel issued from the pozzolanic reaction of GBFS [14].



a. 0% GBFS b. 10% GBFS c. 20% GBFS

Fig. 1. Capillary water absorption with time

In this graphs the slope of the line is increases as we are increasing the percentage of blast furnace slag in concrete. The line with lower slope shows the sorptivity at 20% GBFS and highest slope line with 0% GBFS. Basically sorptivity is the absorption of water due to capillary voids present in concrete. The value of sorptivity coefficient is decreasing as we are increasing the % replacement of GBFS.

3.2. Water absorption test

Figure 2 shows the water absorption with various percentage replacement of blast furnace slag instead of cement after curing. In Figure 2, concrete specimens containing 20% replacement of blast furnace slag attained lowest percentage of water absorption when compared to the control sample (S0). Water absorption has a direct relationship with the voids, so the absorption decrease as the voids decrease. The incorporation of 20 % GBFS as partial cement replacement material has notable effect on its water absorption.

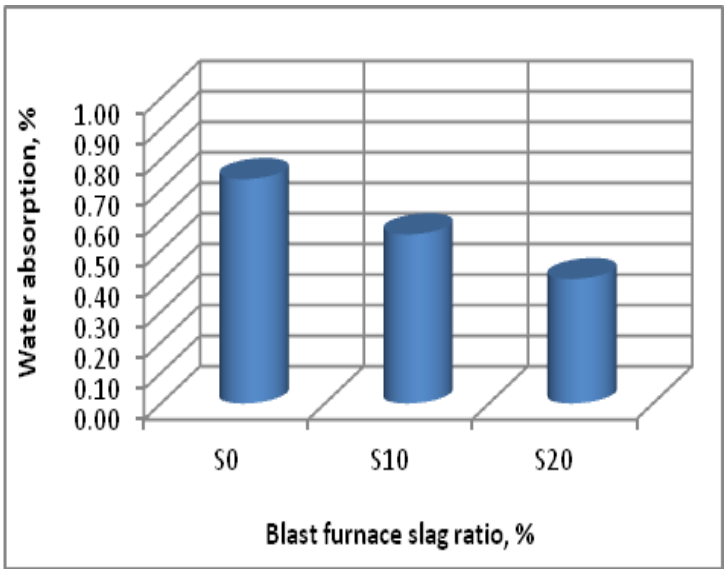


Fig. 2. Water absorption

IV. Conclusion

This paper investigates the effect of replacement of granulated blast furnace slag instead of cement with different percentage in concrete. The following concluding remarks are presented on the study; The value of sorptivity coefficient is decreasing as we are increasing the replacement of GBFS. This improvement of the capillary water absorption due to the more pore structure refine. Water absorption has a direct relationship with the voids, so the absorption decrease as the voids decrease. The incorporation of 20 % GBFS as partial cement replacement material has notable effect on its water absorption.

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