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Studying the Effect of the Amount of Source Materials and Water to Binder Ratio on Chloride Ions Ingress in Alkali-Activated Slag Concretes

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ABSTRACT: Due to the high amount of CO_2 emission through the production of cement and great energy consumption in the cement industry, one of the most important issues in concrete technology is to find out an appropriate replacement for Portland cement. Alkali activated materials are the new approach for solving this problem. In fact, alkali activated concrete consists of an inorganic structure containing two parts: source material and alkaline activator liquid. In this study, the effect of the amount of source material and water to binder ratio on chloride ions ingress was evaluated. For this purpose, 5 mix designs were used to make alkali activated slag (AAS) concretes and for activating slag, 6 molar potassium hydroxide and sodium silicate solutions (wt. ratio: Na_2O/SiO_2 = 2.33) were employed as alkaline activator liquid. Additionally, one mix design was dedicated to ordinary Portland cement (OPC) concrete for the sake of comparison.

The properties of AAS concretes were examined by means of slump loss test, measurement of compressive strength at the ages of 1, 7, 28, 90 and 180 days and also capillary water absorption test at 7, 28 and 90 days. Furthermore, chloride ions penetration was measured through electrical resistivity test, rapid chloride migration test (RCMT) and resistance against chloride ions diffusion test according to NT Build 443. The results indicated that the performance of water to binder ratio and also the amounts of source material were comparable to that of ordinary Portland cement (OPC) concretes. Additionally, alkali activated slag (AAS) concretes had higher compressive strength and also superior durability against chloride ions penetration compared to OPC concretes.

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1- Introduction

Today, reducing air pollution is a critical objective for every industry. Production of cement is considered as one of the most pollutant industries due to its high volume of CO_2 emissions. Additionally, CO_2 is the most important greenhouse gas which leads to global warming. Since, cement is the main constituents of concrete, researchers try to find appropriate alternatives for Portland cement in order to decrease the environmental impacts. Replacing cement with supplementary cementitious materials such as blast furnace slag could be introduced as one of such alternatives [1]. Additionally, alkali activation of blast furnace slag with suitable amounts of activators could result in higher compressive strength in comparison with OPC concretes at early ages. In fact, alkali activated concretes are the novel construction materials with suitable mechanical and durability properties which consist of two main parts: Source material and alkaline activator liquids. In this study, blast furnace slag was utilized as source material and potassium hydroxide and sodium silicate solutions are employed to activate slag.

Compared to OPC concretes, AAS concretes have many advantages. According to the investigations, high and rapid strengths can be achieved without using chemical additives or any special treatment. In addition, lower hydration heat, superior durability and high resistance to chemical attacks are some other advantages of AAS concretes [2]. Chloride ion penetration is considered as one of the causes of concrete deterioration, and as such many researches has been carried out to characterize the degradation process caused by these ions. This study focuses on studying the chloride ion ingress in AAS concretes.

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2- Experimental program

The source material used in making alkali activated concretes was blast furnace slag which fulfilled the requirements of ASTM 989. Also Type I Portland cement was employed in OPC mix designs.

The aggregates used were categorized in three classes of different sizes: fine aggregates (natural sands) which were incorporated with a mass ratio of 0.6, fine gravel with a ratio of 0.24, and coarse gravel with a ratio of 0.16.

Table 1 presents the details of the mix designs. 5 first mixes refer to alkali activated mix designs.

Table 1: Mixing proportions

Mix design ID	PC (kg/m^3)	Slag (kg/m^3)	w/b	alkaline activator / slag	$Na2SiO_3$ / KOH
S=300	-	300	0.4	0.15	0.6
S=350	-	350	0.4	0.15	0.6
S=400	-	400	0.4	0.15	0.6
w/b=0.35	-	400	0.35	0.15	0.6
w/b=0.45	-	400	0.45	0.15	0.6
OPC	426	-	0.4	-	-

3- Tests

The slump loss test [3] was used to assess the fresh concrete properties. Also, the compressive strengths of specimens were measured at the ages of 1, 7, 28, 90 and 180 days. Permeability of concrete was determined by capillary water absorption test [4]. Moreover, the amount of chloride ion penetration into concrete was measured by rapid chloride migration test (RCMT) at the ages of 7, 28, 90 and 180 days ages [5] and resistance against chloride ions diffusion test according to NT Build 443 [6]. Besides, electrical resistivity test was used to evaluate the durability of AAS concretes [7].

4- Summary of results

Figure 1 presents the results of slump loss test.

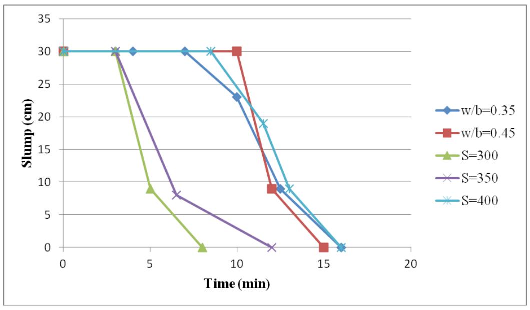

Figure 1: Slump loss test results

In Figure 2, the results of compressive strength test can be observed.

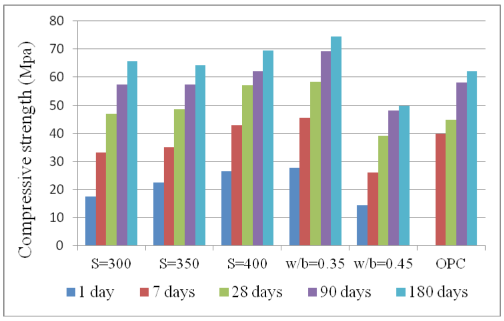

Figure 2: Compressive strength results

The results showed that the differences between the absorbed water were little, and the capillary water absorption test was not suitable for evaluating the effect of source material amounts. This is attributed to the micro-cracks created in AAS concrete. Additionally, reduction in w/b ratio decreased the water absorption and permeability. At 28 days, the amount of absorbed water for OPC concrete was slightly lower than the control AAS mix. However, at 90 days, the permeability of the AAS mix was lower than the OPC mix. Diffusion coefficients obtained according to NT build 492 and NT build 443 are listed in Table 2.

Table 2: Diffusion coefficients in m^2/s

Test name	age	S=300	S=350	S=400	w/b=0.35	w/b=0.45
NT build 492 ($E*10^{-10}$)	7	13.23	12.97	11.79	11.17	12.26
	28	11.12	10.09	9.04	8.02	10.20
	90	9.39	7.26	7.02	6.12	9.14
	180	6.24	5.73	4.78	4.19	6.13
NT build 443 ($E*10^{-12}$)	7	6.38	4.78	3.62	3.59	4.41
	28	4.42	4.01	3.28	3.05	3.91
	90	3.27	2.30	1.34	1.25	1.54

5- Conclusions

The following conclusion can be drawn from the results obtained in this investigation:

- Alkali activated slag (AAS) fresh concretes are viscous compounds with low workability. Thus, it is suggested that suitable admixture be found for AAS concretes.
- Increase in slag content as source material causes better fresh and hardened concretes properties.
- The effect of water to binder ratio in AAS concretes was similar to OPC concrete in hardened concrete while having no impact on fresh concrete properties
- Due to the errors in capillary water absorption test, it is suggested that other test methods be used for evaluating the permeability of AAS concretes.
- Electrical resistivity is not a suitable test for AAS concretes because of their electrical conductivities.
- Based on the results of this investigation, AAS concrete shows higher compressive strength and superior durability against chloride ions penetration compared to OPC concrete.
- Using blast furnace slag with the amount of 400 kg/m^3 is reasonable in order to achieve better fresh concrete properties, mechanical characteristic and durability against chloride ingress in AAS concretes.

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