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Experimental study of the effect of slag of Ahvaz Steel Plant on the properties of cement-slag mortars

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ABSTRACT: One way to improve cement production is to replace some of it with inexpensive and available additives. Considering the importance of using cement mortars in the construction of masonry structures, the effect of slag produced by Ahwaz Steel Plant, which is a special slag due to significant differences in its chemical composition compared to common slags in the world. The rheological, mechanical and durability properties of mortars were studied. The effect of using slag powder from Ahwaz Steel Plant on the production of cement-slag mortars was investigated. The powder of this slag was replaced with a part of cement at 20% to 70% with 10% increases and the specimens were tested at the ages of 28, 56, 91 and 120 days. Flow table, compressive, flexural, and electrical strength as well as two penetration depth and water absorption tests were performed. The results showed that slag powder at 28 and 56 days of age did not have much effect on the mechanical properties of the specimens, but at 120 days of age the compressive and flexural strengths of specimens containing 20% and 30% of slag powder increased compared to the reference sample; From a technical and economic point of view, 30% is suggested as the optimal replacement percentage. Water absorption at 120 days of age in specimens containing 20% and 30% slag increased by 30% and 61% and water penetration depth of 25% and 33%, respectively, compared to the reference specimen; but the electrical resistance decreased by 11% and 23%, respectively.

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1- Introduction

Mortar is a paste material that is used to connect building materials to each other and to create a bed for load distribution in the interior and exterior coatings of buildings. Mortar should be considered as one of the oldest building materials that is used to bond stone pieces with other building and plating parts. Remains of building mortars or plastering mortars date back to about 5000 years ago, but after the 1950s, cement-based mortars gradually found their place among other types of mortars and were considered as one of the most widely used mortars [1]. In the present study, 20%, 30%, 40%, 50%, 60% and 70% of the slag of Ahvaz Steel Plant in powder form replaced part of the cement used in making mortars and the speceimens were tested at the ages of 28, 56, 91 and 120 days. Flow table, compressive and flexural strengths, electrical resistance, water penetration depth and volumetric water absorption tests were performed on cement-slag mortar specimens.

2- Methodology

Consumable cement in the research was prepared from Karun Cement Factory located in Khuzestan, and has met the requirements of Iran Standard 389 [2] and ASTM C150 [3]. Consumer slag is a product of Ahvaz Steel Factory. The chemical composition of cement and slag used is presented in Table 1. Table 2 provides a complete comparison of the common steel slag types in the world with the slag used in the research. The biggest differences between the chemical components of slag in this study and other slags in other countries of the world are related to silica (silicon oxide) and ferrite (iron oxide 3). The minimum and maximum silica content in the slag of other countries are 34.2% and 36.0%, respectively, and in Ahvaz steel slag are 20.1%. The percentage of silica in the slag of this study is 41% and 44% lower than the minimum and maximum amount of silica in the slag of other countries, respectively. Also, the percentage of slag ferrite in this study is 14727% and 112% higher than the lowest and highest slag ferrite in other countries, respectively. These percentages indicate the existence of extraordinary differences in two important chemical compounds (silica and ferrite) affecting the properties of mortars produced using this research slag compared to other common slags in the world that have caused adverse changes in the properties of research mortars.

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Table 1. Results of XRF test performed on cement and slag used in research (%)

LOI	MnO	SO_3	K_2O	Na_2O	MgO	TiO_2	CaO	Fe_2O_3	P_2O_5	Al_2O_3	SiO_2	Properties
1.06	0.09	2.0	0.88	0.02	4.0	0.41	61.7	4.6	0.08	4.16	21.0	Karun cement type 2
0.00	0.29	0.06	0.17	0.00	8.3	1.3	19.5	43.0	0.48	5.7	20.1	Ahvaz Steel Plant slag

Table 2. XRF test results performed on steel slag in different countries of the world (%) [4]

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	SO_3	TiO_2	MnO	Country	Reference
35.04	13.91	0.29	39.43	6.13	0.34	0.39	0.44	0.42	0.43	Australia	Collins & sanjayan (2001)
35.30	9.90	0.60	34.70	14.60	0.30	0.40	1.00	0.50	---	Canada	Shi (1992)
36.00	9.00	1.30	41.00	8.00	---	---	1.10	0.90	0.85	Finland	Gjorv (1989)
35.40	12.90	0.30	41.80	6.80	0.26	0.38	1.00	1.65	0.42	Japan	Sato et al (1986)
35.00	13.50	20.30	36.50	7.50	---	---	0.60	2.00	1.25	Norway	Gjorv (1989)
35.30	9.40	1.10	39.70	10.03	0.98	---	1.16	0.72	0.98	Sweden	Byfors et al (1989)
34.90	7.12	1.02	42.87	10.30	0.24	0.50	1.16	0.39	---	America	Hogan & Rose (1986)
34.20	11.30	1.11	41.60	8.21	0.26	0.40	0.48	0.77	0.25	Ukraine	Osborne & Singh (1995)
20.1	5.7	43.00	19.5	8.3	---	0.17	0.06	1.30	0.29	Iran	Razi Metallurgical Laboratory- Iran (2022)

Table 3. Details of the research mix design (g/cm3)

SP	Water	Slag	Cement	Sand	Design code	Description of mortar	Row
9	600	0	1500	4125	MC	Reference	1
9	600	300	1200	4125	MC80S20	with 20% slag	2
9	600	450	1050	4125	MC70S30	with 30% slag	3
9	600	600	900	4125	MC60S40	with 40% slag	4
9	600	750	750	4125	MC50S50	with 50% slag	5
9	600	900	600	4125	MC40S60	with 60% slag	6
9	600	1050	450	4125	MC30S70	with 70% slag	7

The fine aggregates used in this study are crushed and washed sand with a specific gravity of 2.64 g/cm^3, in accordance with ASTM C127 [5]. These aggregates were prepared from the supply of consumed sand from the mines of Shushtar city in Khuzestan province. The water needed to make mortars and curing specimens in all mixing designs was Ahvaz drinking water. To make the specimens, first designs were made based on previous research records [6-8], fresh mortar tests were performed on the specimens, and finally the reference mortar mixing design was selected, and then the rest of the designs were made and the specimens were tested. Seven mixing designs were made. The MC70S30, for example, means that the mortar contains 30% slag as a substitute for cement and 70% as cement. In all designs, the ratio of water to cement was 0.41. Details of the research mix designs are provided in Table 3.

3- Results and discussion

Compressive strength (CS) test was performed on specimens at 28, 56, 91 and 120 age days based on ASTM C109 [9]. CS changes are shown in Figure 1. Changes in water penetration depth in terms of CS of specimens at 28 and 120 days of age are shown in Figure 2.

4- Conclusions

In this research, slag produced in Ahvaz Steel Plant was

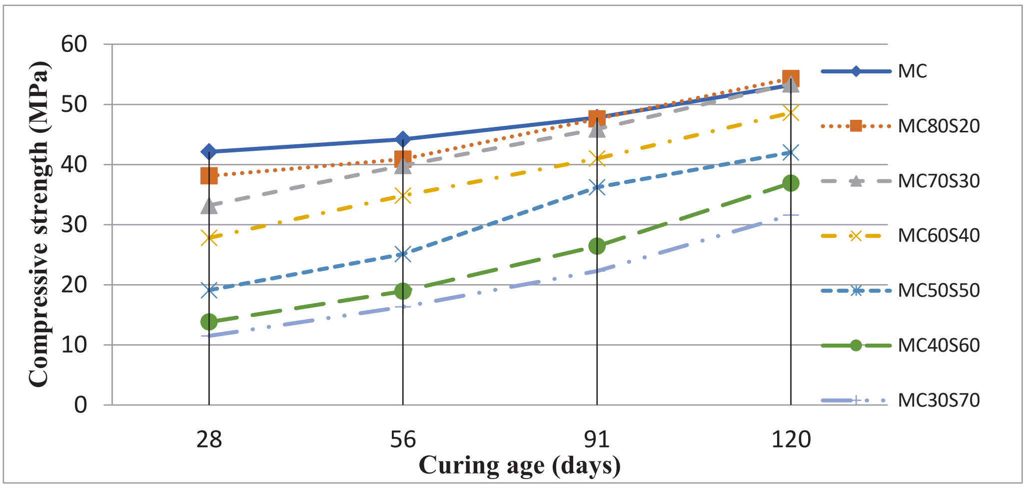

Fig. 1. CS changes of specimens containing slag powder of Ahvaz Steel Plant at different curing ages

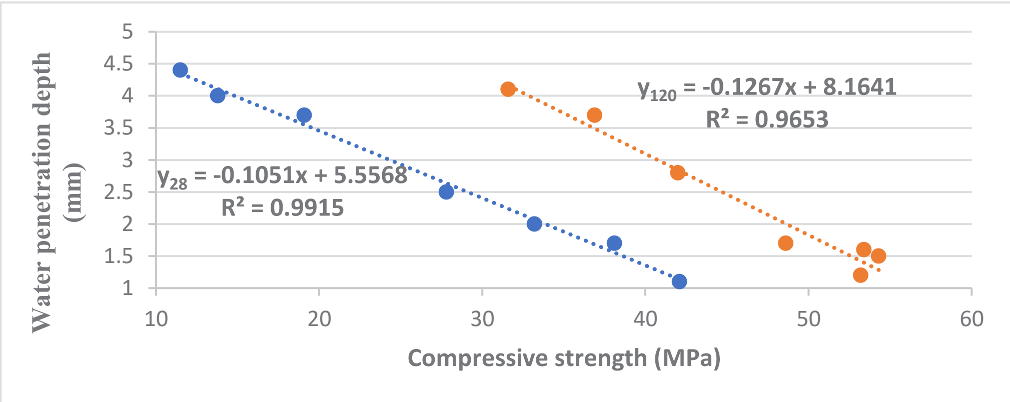

Fig. 2. Relation between water penetration depth and CS of cement-slag specimens at 28 and 120 age days

used to develop the production of environmentally friendly cement-slag mortars. The key results are as follows:

• The flow table test showed that the presence of slag in the mortars increased their flow.

• Slag at 28 and 56 days of age did not have a significant effect on the mechanical properties of mortars, but at 91 days of age, the CS of specimens containing 20% slag was close to the strength of the reference specimen.

• At 120 days of age, specimens containing 20% and 30% slag showed an increase in CS compared to the reference specimen.

• In the specimens containing slag compared to the reference one, a decrease in electrical resistance occurred.

• In the results of the water penetration test, specimens containing 20%, 30% and 40% slag at the ages of 56, 91 and 120 days, no significant change is observed; however, specimens containing 50%, 60% and 70% slag showed a greater difference in water penetration depth than specimens containing lower replacement percentages.

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