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Effect of GGBS on the frost resistance of self-consolidating concrete

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HIGHLIGHTS

- Effects of GGBS on freezing-thawing resistance of SCC evaluated.
- GGBS decreases freezing-thawing resistance of SCC.
- GGBS decreases compressive strength of SCC.
- GGBS makes the rheological behavior of SCC worse.
- Adding Silica fume, increases frost resistance of SCC with GGBS.

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ABSTRACT

Frost resistance of self-consolidating concrete (SCC) is very important in structures exposed to cold weather. On the other hand, Ground granulated blast-furnace slag (GGBS) as a waste material of industries can be replaced by cement in order to reduce cost of concrete production and also decreases the environmental Pollution. In this study, freeze-thaw resistance of SCC mixture prepared with w/c ratio of 0.44 and having cement as 418 kg/m3 was investigated in accordance with ASTM C 666 standard. In These Experiments Cement is replaced with 0%, 30%, 50%, 65% and 80% GGBS. Another SCC mixtures combining 50% GGBS with 5%, 10% and 15% silica fume were tested for Freezing-thawing resistance evaluation. Results of Experiments have shown that the more GGBS replaced with Cement, the lower frost resistance concrete has. It is also seen that increasing GGBS percentage in SCC reduces Compressive strength.

1. Introduction

Self-consolidating concrete (SCC) is highly flowable, non-segregating concrete that can spread into place, fill the formwork, and encapsulate the reinforcement without any mechanical consolidation. In general, SCC is concrete made with conventional concrete materials and in some cases with a viscosity-modifying admixture (VMA). SCC also has been described as self-compacting concrete, self-placing concrete, and self-leveling concrete, which all are subsets of SCC [1].

Slag is a by-product of iron and steel manufacturing process and consists mainly of Calcia, Silica, Magnesia and Alumina derived from the metallic ore, gangue material and lime added as a fluxing agent. When it is used in manufacturing concrete, ground granulated slag is a latent hydraulic binder which develops cementing properties when activated by the alkaline hydration products of Portland cement (PC). The performance of slag as a cementitious material depends mainly on the chemistry of material, the glass content and fineness of ground granulated blast furnace slag [2].

Technical advantages of slag concrete is related to lower heat of hydration, which is of particular importance for massive concrete elements, increase durability of reinforced concrete in the marine environments and increase long – term strength, in comparison with plain PC concrete [3,4]. An improvement of workability was observed up to 20% of slag content with an optimum content of 15%. Workability retention of about 45 min with 15% and 20% of slag content was obtained using a polycarboxylate based superplasticizer; compressive strength decreased with the increase in slag content, as occurs for vibrated concrete, although at later ages the differences were small [11].

GGBS activation is usually negotiated with ASTM C989 and reported as SAI. ASTM C989 defines the Slag Activity Index (SAI) as the percentage ratio of slag cement mortar cubes

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(at a replacement ratio of 50%) to the compressive strength of the plain cement, reference mortar cubes at a designated age shows the SAI index.

This index is reported as 80, 100 and 120 based on ASTM C989, which shows the low, medium and high activation of slag [5,6]. The slag used in this study is derived from Isfahan steel industry which has SAI grade 80, which means the slag with low activity.

Frost resistance of concrete is one of the major durability issues of Girder bridges and Piers in cold regions. Freez-thaw durability of concrete has close relationship with its pore structure. Hydraulic pressure of ice-formation in pores of concrete makes deterioration and can be evaluated. Air entraining affects mainly mechanical properties of concrete against freezing-thawing cycles [7]. Freezing-thawing resistance of concrete in this study performed based on ASTM C-666 procedure A. In this code specimens are exposed to freezing-thawing cycles and three tests were done in each cycle's period. Tests were Relative Dynamic Elasticity Modulus, Weight loss and length change of specimens [8].

2. Materials and methods

2.1. Cement

Ordinary Portland cement type I-425 from Hegmataneh industry was used. Its chemical properties are given in Table 3 and physical properties are given in Table 1.

2.2. GGBS

Ground Granulated blast furnace slag was provided from Isfahan Iron Melting industry and grinded in Ball mill Abeyek Qazvin. Its chemical properties are given in Table 3 and its physical properties are given in Table 2. Its Activity Index complying with ASTM C 989 was grade 80 [6].

2.3. Silica fume

Silica fume (SF) used in this experiment was brought from Azna Ferus-silica industry. Chemical properties of silica fume are shown in Table 3 and its Physical specification was brought to Table 4. SF is the abbreviation used for silica fume in this research.

2.4. Admixture

Super plasticizer (SP) used in the mixtures was bought from LG-South Korea Company. It was super plasticizer type III based on Poly carboxylic acid complying with ASTM C 494 type F, with density approximately 1100 kg/m^3 [9]. This superplasticizer didn't have any retarding or accelerating behavior.

2.5. Aggregates

Sand with maximum size of 5 mm used as fine aggregates was brought from Shensa- Saveh mine and its grading is shown in Fig. 1.

Gravel with maximum size of 19 mm used as coarse aggregates was brought from Almas mine and its grading is shown in Fig. 2.

Table 1
Physical properties of cement.

Result	Specification
25	3 days compressive strength (Mpa)
47.6	28 days compressive strength (Mpa)
0.1	Expansion
3570	Blaine specific surface area (cm^2/gr)
3.12	Specific gravity

Table 2
Physical properties of Ground granulated blast furnace slag.

Result	Specification
3000	Blaine specific surface area (cm^2/gr)
0.08%	Expansion
≤10 to ≤12	Mpa (3 days compressive strength)
≤18 to ≤22	Mpa (7 days compressive strength)
≤30 to ≤36	Mpa (28 days compressive strength)
100–180	Early setting time (min)
180–220	Final setting time (min)
2.43	Specific gravity

Table 3
Silica fume chemical properties.

Cement	GGBS	Silica fume	Composition (%)
21.42	25.5–26.5	85–95	SiO_2
4.52	6.6–7.1	0.5–1.7	Al_2O_3
3.48	2.9–3	0.4–2	Fe_2O_3
–	–	0.1–0.9	MnO_2
–	–	0.15–0.2	Na_2O
–	–	0.15–1.02	K_2O
63.21	57–58	–	CaO
–	4.02–5	–	MnO
2.36	1.2–1.3	–	SO_3
1.48	–	–	MgO
0.52	–	–	Na_2O
0.72	–	–	K_2O
0.026	–	–	Cl
1.65	–	–	LOI
–	–	1.5–2.5	Heat loss

Table 4
Silica fume physical specification.

Result	Specification
0.03	Minimum Aggregate size (μm)
0.77	Maximum Aggregate size (μm)
0.2	Average Aggregate size (μm)
14,000	Blaine specific surface area (m^2/kg)
2.21	Specific gravity

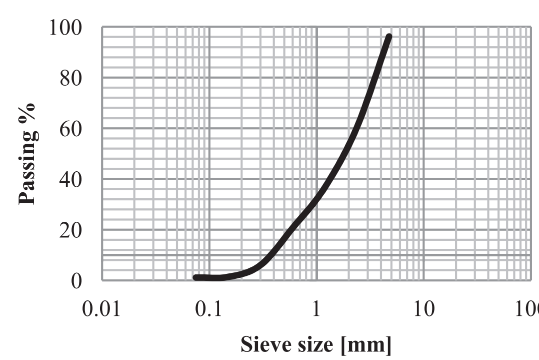

Fig. 1. Sand grading.

2.6. Lime powder

In order to increase viscosity of mixtures, Lime powder (LP) instead of VMA is used. This lime powder is brought from Maryanaj lime powder industry.

2.7. Mix proportion and preparation

In mixing composition of SCC, EFNARC code was used to verify concrete produced in tests [10]. Superplasticizer used in SCC mixes was also diluted in water before adding to concrete mixture for