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Compressive Strength Development of Normal Concrete and Self-Consolidating Concrete Incorporated with GGBS

M. Nili, S. Tavasoli, A. R. Yazdandoost

Abstract**—**In this paper, an experimental investigation on the effect of Isfahan Ground Granulate Blast Furnace Slag (GGBS) on the compressive strength development of self-consolidating concrete (SCC) and normal concrete (NC) was performed. For this purpose, Portland cement type I was replaced with GGBS in various Portions. For NC and SCC Mixes, 10*10*10 cubic cm specimens were tested in 7, 28 and 91 days. It must be stated that in this research water to cement ratio was 0.44, cement used in cubic meter was 418 Kg/m³ and Superplasticizer (SP) Type III used in SCC based on Poly-Carboxylic acid. The results of experiments have shown that increasing GGBS Percentages in both types of concrete reduce Compressive strength in early ages.

Keywords**—**Compressive strength, GGBS, normal concrete, self-consolidating concrete.

I. Introduction

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 used in manufacturing concrete, ground granulated slag is a latent hydraulic binder that 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 slag [1], [2]. A technical advantage of slag concrete relates to lower heat of hydration, which is of particular importance for massive concrete elements, increase the durability of reinforced concrete in the marine environment and increase long-term strength, compared to plain PC concrete [3]. A study by Vejmelkova et al. [4] shows that some of the positive characteristics of slag concrete can be obtained even at low replacement level as 10% or 20%. Macke chine et al. [1] state that common drawbacks of south African slag concrete relate to low early strength and increase plastic shrinkage cracking. Oner and Akyuz [9] reported that optimum percentage of GGBS replacement with cement for maintaining the maximum compressive strength is in the range of 55-59%. Globally the most common type of slag used in concrete is ground granulated blast furnace slag (GGBS), which is produced when pig iron is manufactured in a blast furnace. In the manufacturing process, the iron oxide is reduced to metallic iron using. As a fluxing agent, limestone or dolomite, which combines the silica and alumina constituents in the ore to form a molten slag, which is then further treated to produce the finely ground slag applied in the manufacture of concrete. A more environmentally friendly process to produce iron is the corex process, in which coke ovens and blast furnace are replaced with direct reduction shaft and a melter-gasifier. This process yields a quenched slag, called ground granulated corex slag (GGCS) as a byproduct. Changes in the manufacturing process inevitably result in subtle differences in chemical and physical properties of slags produced by either the blast furnace or corex process. GGBS activation is usually negotiated with ASTM C989 and reported as SAI index. According to this test, the compressive strength relation of 5*5*5 cubic cm mortar mix design with 100% cement shows the SAI index [8]. This index is reported as 80, 100 and 120 based on ASTM C989, which shows the low, medium and high activation of slag. Compressive strength decreases with the increase of slag content at an early age, as is the case of vibrated concrete but at later ages (56 and 90 days) the strength is comparable to that of reference concrete [7].

Syamak Tavasoli is from Bu-Ali Sina University, Islamic Republic of Iran (e-mail: s.tavasoli@basu.ac.ir).

II. Testing Program and Procedures

This study examines the compressive strength of concrete mixture with a water-cement ratio of 0.44. In selected specimens, 20%, 30%, 35%, 50% and 65% of the cement (by weight) was replaced with GGBS.

A. Testing Procedure

The compressive strength of 10*10*10-cubic cm, stored at standard condition of 90% humidity and $23 \pm 2°C$ temperature, was tested at 3, 7, 28, 91 days.

B. Material

1. Cement

The cement used in this study was ordinary Portland cement (OPC) type $I-425$ purchased from Hegmatan Cement Company. This product is widely used in Hamedan province construction projects.

2. Sand

Sand used in this experiment was purchased from Shensa Company-Saveh-Iran. Fineness Modules of this type of sand is 3.7, and the Aggregates grading is shown in Fig. 1.

3. Gravel

Gravel in this test was provided from Jahad mine in Hamedan province. Aggregate grading is shown in Fig. 2.

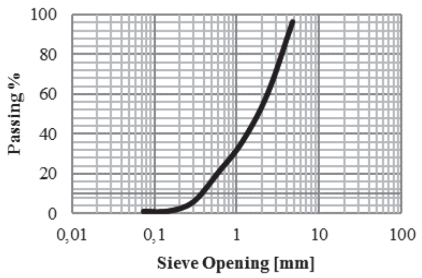

Fig. 1 Sand grading

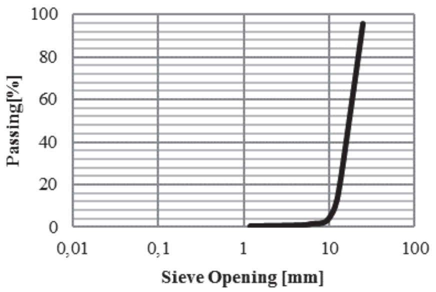

Fig. 2 Gravel grading

4. GGBS

The GGBS used in this study purchased from Isfahan Foolad Company and was ground in the Abeyek experimental and development Institute. Blain of used GGBS is $400^{m^2}/_{Kg}$. Based on the test performed SAI of this type of GGBS has Grade 80, which means low activation slag.

5. Silica Fume

The silica fume supplied from Azna-Lorestan Fero-Silica Company.

6. Super Plasticizer

Superplasticizer used in this experiment was based on polycarboxylic acid provided by LG Company with the name of WBK50-P.

C. Mixing Portions

In mixing Composition of SCC, EFNARC standard used to verify the concrete produced in tests [6]. Super-plasticizer used in SCC mixes was also diluted in water before added to the concrete mixture for better distribution of admixture. Coarse Aggregate and Fine Aggregates Portion was 20% to 80% [5]. Normal Concrete Mixing Portions was designed based on Iran National Mixing Composition. Coarse Aggregate and Fine Aggregate Portion was 40% to 60%.

III. Results and Discussion

In Fig. 3 Effect of different GGBS percentage replacement on the Compressive strength of normal Concrete and Self-Compacting Concrete at age 7-Day is Observed. It is clear that in each percentage of GGBS replacement, the Compressive strength of SCC mixes is more than NC mixes. The reason is to improve paste structure and the transitional zone between Aggregate and Paste. Moreover, it's clear that increase in GGBS Percentage will reduce the 7-day compressive strength in SCC and NC.

In Fig. 4, the procedure of gaining 28-day compressive strength of Concrete samples with different GGBS Percentage replacement can be observed. It is considered that up to 35% of GGBS replacement in SCC and SCC 28-day compressive strength reduce with the same Procedure and have same 28-day compressive strength. But when the GGBS Percentage increases over than 35%, the 28-day compressive strength of NC samples has shown more reduction than SCC's. So that increase in GGBS Percentage replacement up to 65% will reduce the 49% of compressive strength at the age of 28-Day. It must be stated that this increase in GGBS Percentage will reduce 28% of the 28-day compressive strength of SCC.

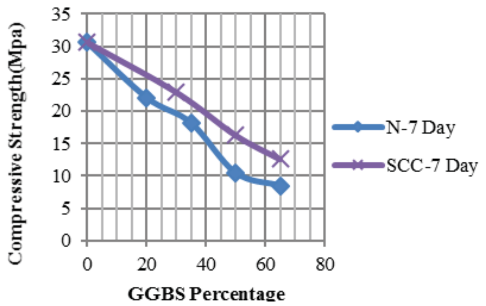

Fig. 3 The Comparison of Compressive Strength with GGBS Percentage in Normal and SCC mixes at the age of 7 days

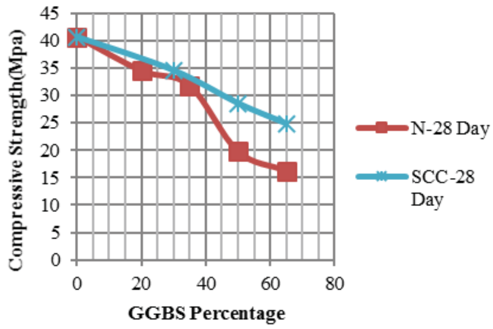

Fig. 4 The Comparison of Compressive Strength with GGBS Percentage in Normal and SCC mixes at the age of 28 days

In Fig. 5 the Effect of GGBS replacement on the 91-day Compressive strength of mix designs can be observed. GGBS replacement Percentage increase in SCC causes Compressive strength reduction continually. Although in NC with 20% GGBS Compressive strength increases up to 2.8% than Non-GGBS mix designs, 91-day compressive strength in NC with more than 20% GGBS decreases. In Fig. 6 compressive strength procedure of NC and SCC mix design without GGBS is shown.

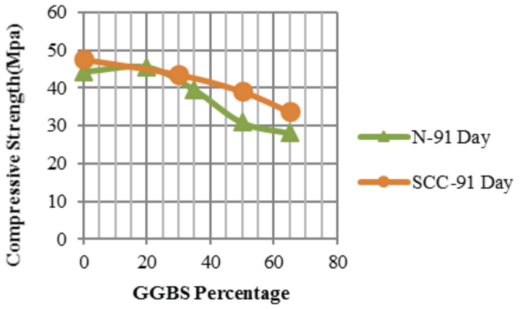

Fig. 5 The Comparison of Compressive Strength with GGBS Percentage in Normal and SCC mixes at the age of 91 days

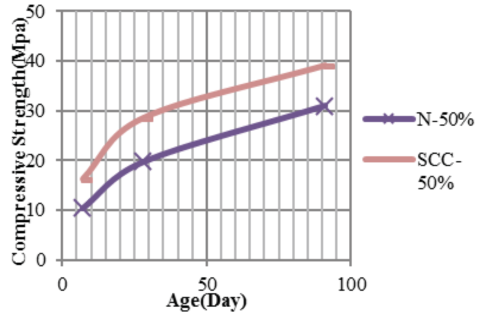

Fig. 7 The Comparison of Compressive Strength with Age of Concrete in 50% Normal and SCC mixes

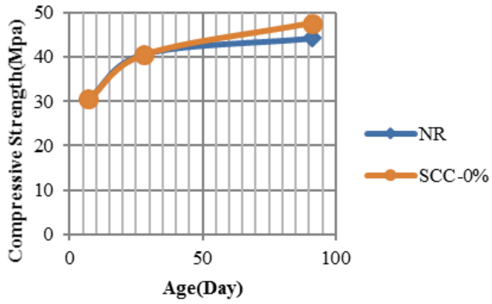

Fig. 6 The Comparison of Compressive Strength with age of Concrete in 0% Normal and SCC mixes

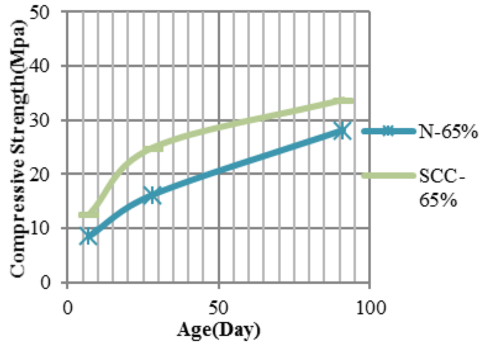

Fig. 8 The Comparison of Compressive Strength with Age of Concrete in 65% Normal and SCC mixes

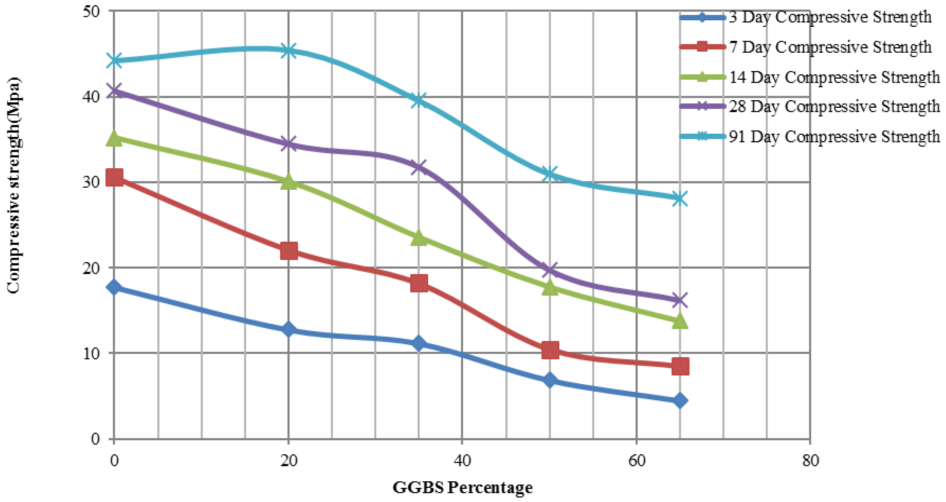

Fig. 9 Compressive strength development of NC by GGBS replacement percentage

It seems that the Compressive strength of both NC and SCC until 28-day age is equal but after this age compressive strength of SCC grows faster. Based on Figs. 5 and 6, it is clear that the 50% and 65% GGBS replacement show higher compressive strength in SCC than NC.

It can be seen in Fig. 7 that increase of Compressive strength in NC and SCC mixes with 50% GGBS replacement, performed with the similar slope during 91-day but the quantity of SCC compressive strength is more than NC's. Fig. 8 shows Compressive strength induction of SCC and NC mixes with 65%GGBS replacement during 91-day. This Figure also shows that the SCC mixes has more compressive strength than NC mixes. Although in samples with 50% GGBS graph slopes are parallel, in 65% GGBS samples are not. In Fig. 9, NC compressive strength development with different GGBS replacement Percentage is observed. On the basis of this Figure, adding GGBS cause reduction in compressive strength of samples. Development of compressive strength in samples included with GGBS in early ages because of Calcium Hydroxide in concrete is coming down. Only in 20% replacement of GGBS, it can be seen that compressive strength in 91-day age has 2.8% increase more than reference samples.

Replacement of 50% GGBS reveals 65% and 52% reduction in 7-day and 28-day compressive strength of normal concrete. Replacement of 65% GGBS is also in NC causes 72.2% and 60.7% reduction in compressive strength of 7-day and 28-day in comparison to reference mix design. Because of sharp reduction in early age and later age compressive strength of samples with 50% and 65% GGBS, it seems that replacement of more than 35% GGBS in NC do not have a desirable result.

In Fig. 10, SCC compressive strength based on the percentage replacement of slag is visible. In general, the addition of slag cause reduction in compressive strength such as NC concrete at all age groups. In all ages, Strength reduction of SCC concrete occurs with the same slope.

Fig. 11 shows the strength development of normal concrete samples with replacement of slag. According to this Figure using slag cause reduction in compressive strength at all ages. Only at the age of 91 days, we have seen a growth rate of 2.5% compared to the OPS concrete.

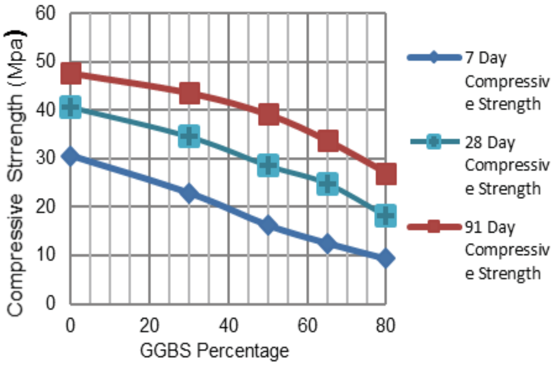

Fig. 10 Compressive strength development of RCC by GGBS replacement percentage

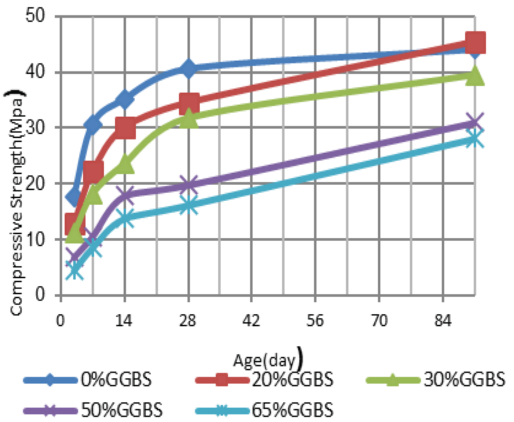

Fig. 11 Compressive strength development of NC by ages

Fig. 12 shows the strength development of SCC concrete with different percentage of slag using slag reduce strength at all ages.

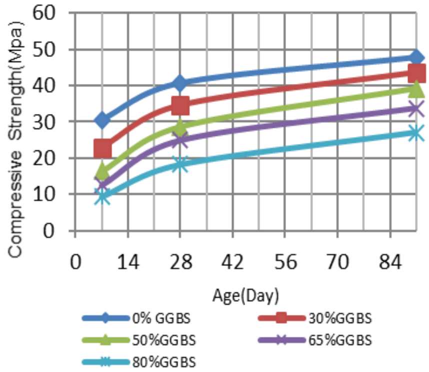

Fig. 12 Compressive strength development of RCC by ages

IV. Conclusion

1. Generally, the use of slag caused a reduction in early age strength in both SCC and NC concrete.
2. Using slag in concrete sample cause reduction in the amount of Calcium Hydroxide. This phenomenon reduces strength, especially in early ages.
3. Only in 20% replacement of GGBS in NC, it can be seen that compressive strength in 91-day age has 2.8% increases more than reference samples. Because of cement reduction, we have observed a reduction in all cases.
4. Increasing GGBS replacement Percentage generally causes a reduction in compressive strength of 7, 28, and 91-day age in SCC samples.
5. Better curing condition causes the development of compressive strength in a later age of both SCC and NC samples.

Acknowledgment

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References

[1] A. J. J. H. Mackechnie JR, "Structural and Durability properties of concrete made with Corex slag," South Africa: University of Cape Town, 2003.
[2] S.C Pal, A Mukherjee, S.R Pathak "Investigation of Hydraulic activity of ground granulated blast furnace slag in concrete," Cement and Concrete Research, vol. 33, pp. 1481-6, 2003.
[3] A.M. Alshamsi "Microsilica and ground granulated blast furnace slag effects on Hydration temperature," Cement and Concrete Research, vol. 27, pp. 1851-9, 1997.
[4] Eva Vejmelková, Milena Pavlíková, Zbyněk Keršner, Pavla Rovnaníková, Michal Ondráček, Martin Sedlmajer, Robert Černý "High-Performance Concrete containing lower slag amount: A complex view of Mechanical and Durability properties," Construction Building Material, vol. 23, pp. 2237-45, 2009.
[5] "Specification and Guidelines for self-compacting concrete," EFNARC, Norfolk, 2002.
[6] E. P. Group, "Self-Compacting Concrete," EFNARC, 2005.

[7] E.-H. K. S. K. Othmane Boukendakdji, "Effects of Ground Granulated blast furnace slag and superplasticizer type on the properties and Compressive strength of Self-compacting concrete," Cement and Concrete Composites, vol. 34, pp. 583-590, 2012.
[8] ASTM C989, "Standard specification for ground granulated blast furnace slag, for use in concrete and mortars," Annual book of ASTM standards, 1994.
[9] A. O. a. S. Akyuz, "An experimental study on the optimum usage of GGBS for the Compressive strength of concrete.," Cement and Concrete Composites, vol. 29, pp. 505-514, 2007.