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Influence of Granulated Blast Furnace Slag on Compressive Strength of Concrete

Rakesh Kumar Patra[1] and Bibhuti Bhusan Mukharjee[2]

[1,2]VSSUT, Burla
E-mail: [1]rkp306@gmail.com, [2]bibhuti.2222@gmail.com

Abstract—*In this present research work the effect of Granulated blast furnace slag (GBS) as a replacement of fine aggregate (FA) on the compressive strength (C S) of concrete is investigated. The compressive strength result of 150 mm cubes with 4 different percentages (20%, 40%, 60%, and 80%) of GBS is reported. The compressive strength is observed after 7, 28 and 90 days of curing period and compared with the control mix. It is revealed from the investigation that addition of GBS increases the strength of concrete with the increase in percentage of additives.*

1. INTRODUCTION

Concrete has a wide range of usage in the area of construction & it is a basic construction material that requires attention and diligence at every stage, from production to implementation. Concrete has an important place among materials that form the basis of modern societies. Concrete based on industrial by-product materials such as slag can play a vital role in the context of sustainability and environmental issues. Compressive strength is a most important property to check the quality of concrete. Also other properties are directly or indirectly related to the compressive strength. Different types of admixtures are used to enhance the strength of concrete (Neville 2009). Such as industrial waste products as a replacement of fine aggregate, recycled concrete aggregates as replacement of coarse aggregate and cement replacements. Ground granulated blast furnace slag is widely used as the replacement of cement in concrete (Binci et al. 2012). Also granulated blast furnace slag is also used in case of concrete as a replacement of fine aggregate (Binci et al. 2007). GBS is mainly available in crystalline form. As it is a cementitious material it shows pozzolanic reaction in the later curing ages which increase the strength of concrete (Hanifi et al. 2008). Also addition of GBS as fine aggregate replacement showed higher early age strength than the control mix as confirmed by the previous stusies. The strength of concrete increases upto 60% addition of GBS (Hanifi et al. 2008).

The utilization of industrial waste products is beneficial to the society. As it reduces environmental pollution and also the addition of GBS shows positive effect on the strength of concrete. It reduces many problems of construction industry such as in environmental pollution, shortage of natural aggregates, and shortage of dumping yards etc. Concrete with different percentage addition of GBS shows less porosity than the normal concrete. As the fibers of steel present in GBS fills the porous structure of concrete it leads to increased compressive strength than the normal concrete and

also increasing the density of concrete. As the literature showed that addition of 100% GBS showed reduction of compressive strength (Zeghichi 2006). The increase in compressive strength is upto 60% replacement level.

The influence of GBS on the compressive strength of concrete is rarely investigated in the literature. Hence detailed experimental program for development of compressive strength is carried out in this research paper.

2. EXPERIMENTAL PROGRAM

OPC cement of grade 43 with specific gravity 2.97 and consistency 31% is used in the concrete. Natural river sand is used as fine aggregate. GBS collected from Rourkela steel plant is used as replacement of fine aggregate. Coarse aggregate (CA) of nominal size 20 mm is used in the experimental program. The detailed properties of GBS as well as natural aggregates are given in Table 1.

Table 1: Properties of aggregates and GBS

Property	Natural FA	Natural CA	GBS
Bulk density (compact) (kg/l)	1.615	1.622	1.250
Bulk density (Loose) (kg/l)	1.462	1.394	1.157
Specific gravity (SSD)	2.63	2.85	2.56
Water absorption (%)	0.4	0.8	1.2

Concrete mixes are prepared with 20%, 40%, 60%, and 80% replacement level of GBS with fine aggregate. Two w/c ratios are taken i.e. 0.45 and 0.5. Slag is replaced by weight of fine aggregate. The 150 mm cubes are prepared and tested after the curing ages of 7, 28, and 90 days. The cubes are tested in 2000

KN capacity compressive strength machine and the rate of loading is maintained throughout the program as per BIS specification (IS: 516, 1959). Details of concrete mix are given in the Table 2 and Table 3.

Table 2: Proportion of mixture per cubic meter of concrete for w/c ratio 0.45

Mix Designation	Cement (kg)	CA (kg)	FA (kg)	% replacement	GBS (kg)
WS1	438	1161	625	0	0
WS2	438	1161	500	20	125
WS3	438	1161	375	40	250
WS4	438	1161	250	60	375
WS5	438	1161	125	80	500

Table 3: Proportion of mixture per cubic meter of concrete for w/c ratio 0.5

Mix Designation	Cement (kg)	CA(kg)	FA (kg)	% replacement	GBS (kg)
WS6	394	1169	658	0	0
WS7	394	1169	526	20	132
WS8	394	1169	394	40	264
WS9	394	1169	264	60	394
WS10	394	1169	132	80	526

3. RESULT AND DISCUSSION

The slump value of different mixes is given in Table 4. It is observed from the table that workability of concrete decreases with increase in GBS content. The optimum value of workability is obtained at 40% replacement level for both the w/c ratios.

Table 4: Workability of different concrete mix.

Specimen designation	Workability(mm)
WS1	103
WS2	87
WS3	68
WS4	47
WS5	27
WS6	98
WS7	78
WS8	53
WS9	40
WS10	23

The compressive strength results of concrete after 7, 28 and 90 days of curing is given in Fig. 1-3. Fig. 1 represents the compressive strength of 150 mm cube after 7 days of curing at different w/c ratio. At water/cement ratio 0.5 the compressive strength for control mix was found to be 23.85 MPa. For 20% replacement it was found to be 25.67 MPa which is 7.63% higher than the control mix. For 40% and 60% replacement it was found to be 26.03 and 26.92 MPa which are 9.14%, 12.87% higher than the control mix respectively. In case of 80% replacement the compressive strength was decreased to 22.37. For water/cement ratio 0.45 compressive strength of control mix was found to be 24.62 MPa. At replacement level of 20%, 40%, 60% the compressive strength was found to be 27.92, 29.2, 30.22MPa which are 13.4%, 18.6%, 22.74% higher than the control mix respectively with same trend as of water/ cement ratio 0.5. At 80% replacement level the compressive strength was decreased to 24 MPa. An increasing trend in compressive strength is observed up to 60% replacement level which is decreased at replacement level of 80% same as in case of 100 mm cube strengths.

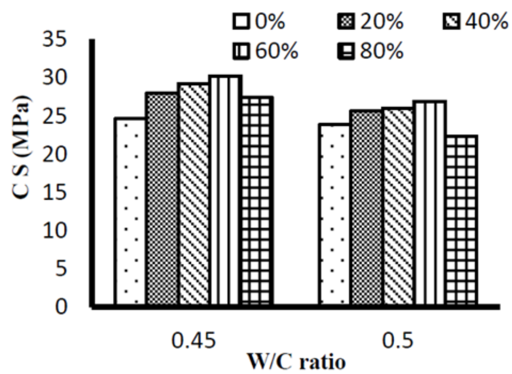

Fig. 1 variation of 7 days compressive strength

Fig. 2 represents the compressive strength of 150 mm cube at 28 days of curing at different w/c ratio. At water/cement ratio 0.5 the compressive strength of control mix was found to be 37.77 MPa which is 58.36% more than the control mix at 7 days. The compressive strength of concrete at 20%, 40%, 60% was 38.33, 38.55, 40.78 MPa which is 49.31%, 48.09%, 51.48% higher than the compressive strength of concrete at 7 days of curing and 1.48, 2.1, 7.96% higher than the control mix respectively. At 80 % replacement the compressive strength was decreased to 37.92 MPa which is 69.5%% higher than the concrete at 7 days of curing. At water/cement ratio 0.45 the control mix had a compressive strength of 38.92 MPa which is 58.1% higher than the control mix at 7 days of curing. The compressive strength of concrete at 20%, 40%, 60% was 39.5, 40.55, 41.03 MPa which is 41.47%, 38.86%, 35.77% higher than the compressive strength of concrete at 7 days of curing and 1.5, 4.18, 5.42% higher than the control mix respectively. At 80% replacement the compressive strength was 38.18 MPa which is 39.29% higher than the concrete at 7 days of curing. It is observed that at 28 days all the mixes attains the target strength. But the strength increases up to 60% replacement level which decreases at 80% replacement (Binci et al. (2012)).

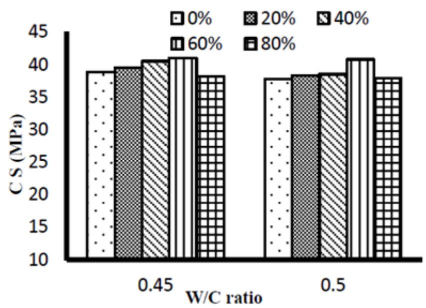

Fig. 2 Variation of 28 days compressive strength

Fig. 3 represents the compressive strength of 150 mm cube at 90 days of curing at different w/c ratio. At w/c ratio 0.45 the compressive strength of control mix is 46.97 MPa. The compressive strength at 20%, 40%, 60%, 80% replacement level is 48.023, 49.87, 51.53, 45.43 MPa respectively which are 21.5%, 23%, 25.5%, 19% higher than the compressive strength at 28 days of curing respectively at w/c ratio 0.45. Similarly the control mix has a compressive strength of 44.94 MPa at w/c ratio 0.5. The compressive strength is 46.38, 47.3, 50.87, 45.23 MPa at 20, 40, 60, 80% replacement level which are 21%, 22.7%, 24.5%, 19.3% higher than the compressive strength of 28 days at w/c 0.5 respectively. It is observed that the compressive strength is increasing with respect to time. Also the compressive strength is increasing upto 60% replacement level in both the w/c ratios. The compressive strength is higher for 60% replacement level for both the w/c ratios which is decreasing at 80% replacement level in both the w/c ratio. I.e. the compressive strength follows the same trend as in 28 days of curing for both w/c ratios.

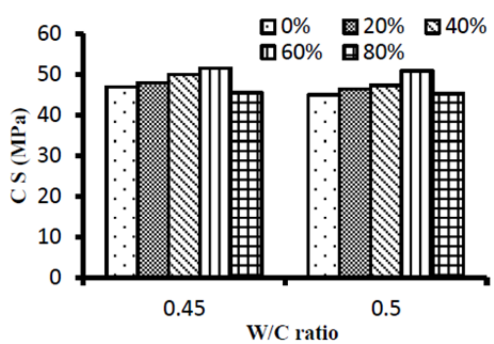

Fig. 3 Variation of 90 days compressive strength

The compressive strength development of all the 10 mixes from 7 to 90 days is given in the fig. 4. The development of compressive strength is increasing with the increase of curing ages. After 28 days of curing it attains the target strength. The compressive strength shows an increasing value upto 60% of replacement ratio. The increase in percentage of compressive strength is more at the later ages.

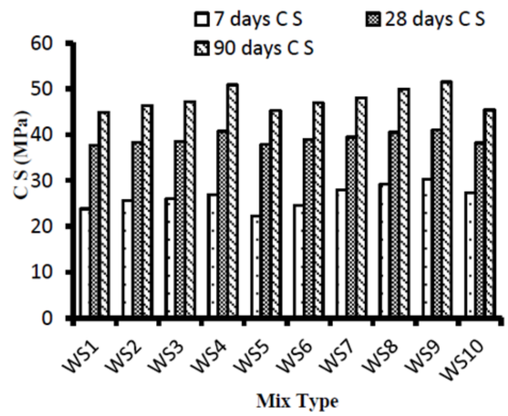

Fig. 4 Comparative study of compressive strength result

4. CONCLUSION

The influence of GBS on the strength properties of concrete was investigated in the present work and following conclusions were drawn.

The compressive strength of concrete increases with increase in the additive percentage.

- The percentage increase in the compressive strength is more in case of 90 days curing than 28 days curing
- The pozzolanic reaction caused by GBS leads to increased compressive strength of concrete at the later ages.
- The fibrous structure of GBS fills the pores of concrete which increases the density of concrete.
- The slump value of concrete decreased with the increase in GBS% due to higher water absorption of GBS.

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