STRENGTH AND DURABILITY PROPERTIES OF CONCRETE INCORPORATING GRANULATED BLAST FURNACE SLAG

[PAPER ID: ICITER-D177]

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ABSTRACT:

The effect of granulated blast furnace slag on the properties of concrete has been investigated in this paper. Granulated blast furnace slag (GBS) has been used 20%, 40%, 60%, 80% as replacement of fine aggregate in this study. Two water /cement ratios 0.45 and 0.5 are maintained. The compressive strength, water absorption, density and porosity in terms of volume of voids have been investigated after 28 days of curing. The compressive strength increases with the increase in GBS%. Moreover, the density of concrete increases with the increasing percentage of GBS.However, porosity and water absorption of concrete decreased after 28 days of curing.

INTRODUCTION:

Concrete is the most used construction material now-a-days. With this increase of construction work the availability of natural aggregates decreases day by day. Also The worldwide consumption of sand as fine aggregate (FA) in concrete production is very high, and several developing countries have encountered some strain in the supply of natural sand in order to meet the increasing needs of infrastructural development in recent years. Hence to mitigate these needs of construction industry alternate materials such as industrial waste products which are granulated blast furnace slag, cenosphere, flay ash are used in the construction industry (Neville 2000). Granulated blast furnace slag is the industrial waste product of steel and iron industry. When the slag is allowed to cool slowly, it solidifies into a grey, crystalline, stonymaterial. This material is known as air cooled slag. This forms the material used as a concrete aggregates. From the previous studies it is observed that use of GBS as replacement of fine aggregate increases the strength properties of concrete (Binci et al. 2008). The abrasion resistance of concrete increased due to the addition of GBS (Binci et al. 2008). Due to the fibrous structure of GBS it filled the pores of concrete. This leads to decrease in water absorption and porosity of concrete specimens (Binci et al. 2012).

The utilization of industrial waste resolves most of the problems of the society such as environmental pollution, dumping yard, less requirement of natural aggregates. Thus concrete with different percentage of GBS is proved to be more effective in strength as well as durability properties than the normal concrete. Moreover fewer studies have been found on the effect of GBS on durability properties also with the strength properties. Therefore detailed experimental programme is carried out to investigate the effect of GBS on concrete.

EXPERIMENTAL PROGRAMME:

GBS used in the present research work was collected from Rourkela steel plant. Ordinary Portland cement (OPC) of grade 43 was used. The consistency and specific gravity of cement was found to be 31% and 2.97. Coarse aggregate (CA) of nominal size 20 mm was used in the research work. River sand was used as the natural fine aggregate (FA) in the research work. The detailed properties of the aggregates used were given in Table- 1.

Table- 1 Properties of natural 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 were prepared with two water/cement ratios 0.45 and 0.5. Four different percentages of GBS 20%, 40%, 60%, 80% were replaced by natural sand. Slag was replaced as the weight of fine aggregate. Cubes of size 150 mm were prepared and cured in water for 28 days. After 28 days of curing the compressive strength and the durability properties such as porosity, density and water absorption were tested. 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). The detailed of concrete mixes were given in the following Table- 2 and 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

RESULT AND DISCUSSION:

The compressive strength of concrete is tested after 28 days of curing and the result is expressed in the fig- 1. Also the durability properties such as water absorption, porosity and density of concrete specimen were presented in fig- 2 to 4 respectively.

It is observed from the figure-1 that 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)).

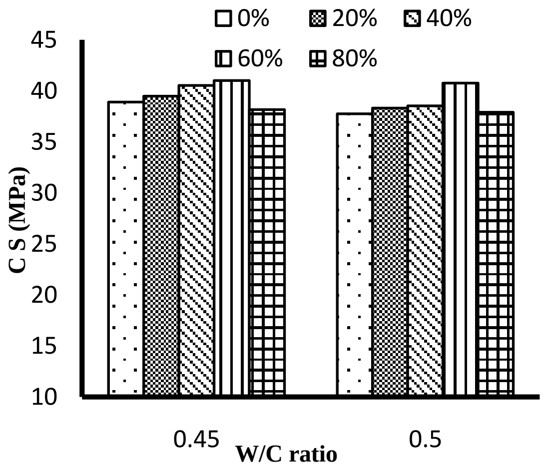

Fig. 1 Variation of 28 days compressive strength

Fig. 2 represents water absorption of concrete specimens with different percentage of GBS and different w/c ratios. At 0% replacement level the water absorption of control mixes are 5.29% and 5.48% respectively. At 20% replacement it decreases to 4.803% and 5.216% for w/c ratios 0.45 and 0.5 respectively. For 40% replacement level it further decreases to 4.3% and 4.59% for w/c ratios 0.45 and 0.5 respectively. At replacement level of 60% and 80% water absorption are 3.93%, 4.176% and 3.34%, 3.56% for w/c ratio 0.45 and 0.5 respectively. It is observed from the figure that water absorption of specimens with w/c ratio 0.5 is more than the specimens with w/c ratios 0.45. This is due to the presence of more pores in case of specimens with w/c ratio 0.5. This reduction in w/c ratio leads to the increase in density of concrete specimen which further leads to increase of strength of concrete specimens. The difference in water absorption is more in case of 20% replacement level.

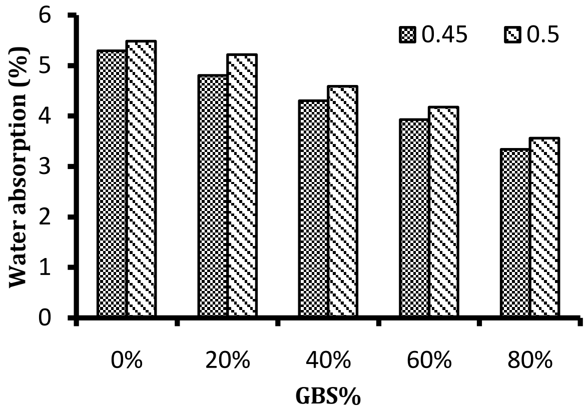

Fig. 2 Water absorption of concrete mixes at different percentage of GBS

Fig. 3 represents the volume of voids (%) present in the concrete specimen at different w/c ratio and different GBS% at 28 days of curing. The control mix has 10.67% and 11.13% volume of voids at w/c ratio 0.45 and 0.5 respectively. At 20% replacement level the volume of voids is 9.97% and 10.59% for w/c ratio 0.45 and 0.5 respectively. At 40% replacement level it is 9.07% and 10.17% for w/c ratio 0.45 and 0.5 respectively. For 60% and 80% replacement level it is 8.74%, 8.91% and 7.53%, 7.66% for w/c ratio 0.45 and 0.5 respectively. It is observed from the figure that the volume of voids is more in case of w/c ratio 0.5 and less in case of w/c ratio 0.45. Due to this the strength of concrete specimens is more in case of w/c ratio 0.45 and less in w/c ratio 0.5 as observed above. Similarly the water absorption is less in case of specimens of w/c ratio 0.45 than specimens at w/c ratio 0.5. Also the density of concrete is more in case of w/c ratio 0.45 than specimens of w/c ratio 0.5 which leads to increase in strength of specimens of w/c ratio 0.45.

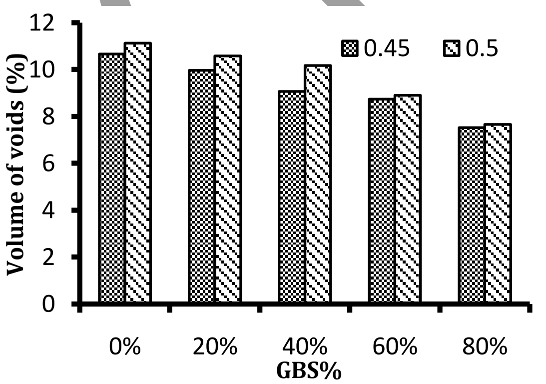

Fig. 3Volume of voids of concrete mixes at different percentage of GBS

Fig. 4 represents density of concrete mixes with different percentage of GBS% and different w/c ratios. At 0% replacement level the density of the concrete specimen is 2290.69 kg/m³ and 2283.82 kg/m³ for w/c ratio 0.45 and 0.5 respectively. At 20% replacement level density of concrete mixes are 2302.79 kg/m³ and 2291.17 kg/m³. At 40% and 60% replacement level the densities are 2323.063 kg/m³, 2308.007 kg/m³ and 2338.77 kg/m³, 2323.12 kg/m³ for w/c ratio 0.45 and 0.5 respectively. At 80% replacement level density is 2348.56 kg/m³ and 2335.18 kg/m³ at w/c ratio 0.45 and 0.5 respectively. The difference in density of concrete between two w/c ratio is higher in case of 60% replacement level and lower in case of the control mix. In all the additive percentage level density is more in case of w/c ratio 0.45 than w/c ratio 0.5. This results in increased strength of concrete specimens as observed above. It is also observed that concrete mixes with w/c ratio 0.45 has higher density which is due to lower pore percentage in the specimen. The density of concrete mixes lies between 2000 kg/m³ - 2400 kg/m³ which are the range of density of normal concrete.

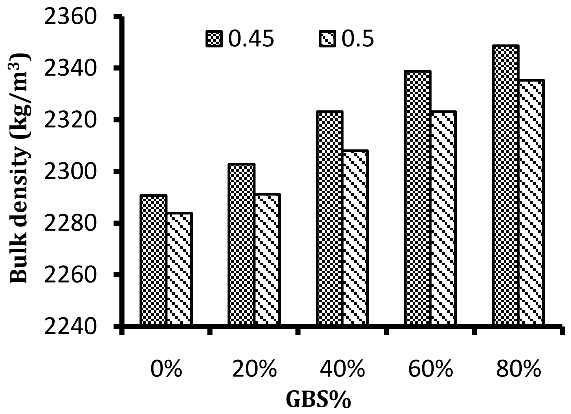

Fig. 4Bulk density of voids of concrete mixes at different percentage of GBS

CONCLUSION:

In this study, the effects of GBS, as fineaggregate in concrete at variousreplacement ratios, on concrete durability and compressive strength are investigated and following conclusions are drawn.

- Incorporation of GBS decreases the voids content percentage of concrete specimens.
- The decrease in voids leads to decrease in water absorption of concrete with the increase in GBS%.
- The incorporation of GBS increases the density of concrete with the increasing amount of GBS.
- In addition to above the compressive strength of concrete increases with the increase in GBS%.

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