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Influence of Strength Properties of Concrete with Incorporation of Granulated Blast Furnace Slag

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Abstract—*Influence of the strength properties of concrete with the addition of different percentage of granulated blast furnace slag (GBS) is investigated in this paper. GBS is incorporated by natural fine aggregate with 4 different percentage 20%, 40%, 60% and 80%. Concrete mixes are prepared with two water/cement ratios 0.45 and 0.5. The strength properties such as compressive strength, splitting tensile strength and flexural strength are investigated and compared to the normal concrete. It is observed from the investigation that incorporation of GBS shows a positive effect on the strength properties of concrete. The compressive strength, splitting tensile strength and flexural strength shows an increasing value with the increase in the GBS%.*

1. INTRODUCTION

Concrete has a wide range of usage in the area of construction and it is a basic construction material which requires attention and diligence at every stage, from production to application. Compared to other building materials, concrete is a widely used construction material, because it can take any shape made up by formwork. Moreover it is economical and durable, requires less energy in production, and can be produced anywhere. In addition to this due to the increasing requirement of aggregates industrial waste are used as replacement of aggregates. On the other hand, industrial by-product materials such as slag have been shown to release up to 80% less greenhouse gas emissions. The blast furnace slag is a by-product obtained in the manufacture of pig-iron in the blast furnace. This is mainly the combination of the earthly constituents of iron ore with the limestone flux. The molten slag firstly chilled very rapidly either by pouring into a large excess of water, or by subjecting the slag stream to jets of water (Zeghichi 2006). Addition of GBS decreased the pores of concrete which improved compressive strength of concrete (Binci et al. 2008). In addition to compressive strength the splitting tensile strength and flexural strength of concrete increased with the increase in the GBS content irrespective of the water/cement ratio of the concrete mix (Topcu and Boga 2010). Addition of GBS upto 60% replacement level showed a positive effect on GBS%. The flexural strength of concrete increased upto 60% replacement level of GBS with natural fine aggregate (Khatib and Hibbert 2005).

Utilization of industrial wastes helps to resolve many problems of environmental pollution. It also helps to decrease the problem of dumping yard for the industrial waste disposal. It also decreases the use of natural aggregates. Hence concrete with different percentage of GBS is proved to be effective and showed higher strength than the normal concrete. Therefore a detailed study of concrete properties by addition of different percentage of GBS is investigated in the current research paper.

2. EXPERIMENTAL PROGRAMME:

Ordinary Portland cement (OPC) of grade 43 with specific gravity and consistency value 2.97 and 31% respectively was used in the present study. Coarse aggregate of nominal size 20 mm was used and river sand was used as the natural fine aggregate. Slag is collected from Rourkela steel plant was used in this study. The detailed properties of slag natural aggregates 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

Water/ cement ratio was taken as 0.45 and 0.5. Four different percentages 20%, 40%, 60%, and 80% of GBS were replaced by the natural fine aggregates. Cubes of size 150 mm × 150 mm × 150 mm cylinders of size 150mm × 300 mm and prisms of size 100 mm × 100 mm × 400 mm were casted and cured for 28 days. The compressive strength and splitting tensile strength of concrete were measured in the compressive testing machine of 2000 kN capacity and the flexural strength was measured in the universal testing machine with 100 kN capacity. 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

3. RESULT AND DISCUSSION:

The compressive strength, splitting tensile strength and flexural strength are measured after 28 days of curing and the results are given in the Fig- 1, 2 and 3 respectively.

Fig- 1 represents the compressive strength of 150 mm cubes at 28 days of curing at different w/c ratio. At water/cement ratio 0.5 the compressive strength of control mix is 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 has 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 is 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.

Fig- 2 represents the splitting tensile strength of cylinder specimen (150×300 mm) at 28 days of curing at different w/c ratios. At water/cement ratio 0.5 the tensile strength of control mix was found to be 2.94 MPa. The splitting tensile strength of concrete at 20%, 40% and 60% is 3.25, 3.32, 3.6 MPa which is 10.54%, 12.9%, 22.44% higher than the control mix respectively. At 80 % replacement the splitting tensile strength decreases to 3.11 MPa. At water/cement ratio 0.45 the control mix has a splitting tensile strength of 2.81 MPa which is 4.62% lower than the control mix of water/ cement ratio 0.5. The splitting tensile strength of concrete at 20%, 40%, 60% is 3.34, 3.49, 3.86 MPa which is 18.86%, 24.19%, 37.36% higher than the control mix respectively. At 80% replacement the compressive strength is 3.24 MPa. It is observed that the splitting tensile strength is increasing for both the w/c ratios. It is highest in case of 60% replacement level which is 22.44% and 37.36% higher than the control mix for w/c ratio 0.5 and 0.45 respectively. It is observed that the splitting tensile splitting tensile strength of concrete mixes increases with increase in GBS% up to 60% replacement level. But it decreases at 80% replacement level which is 10.67% and 10.01% higher than the control mix for w/c ratio o.5 and 0.45 respectively.

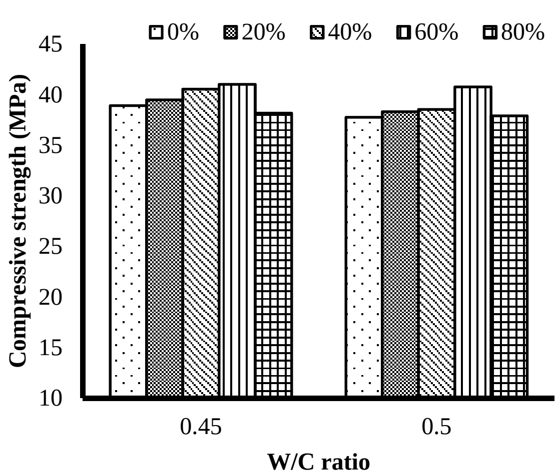

Fig- 1 Variation of compressive strength of cubes

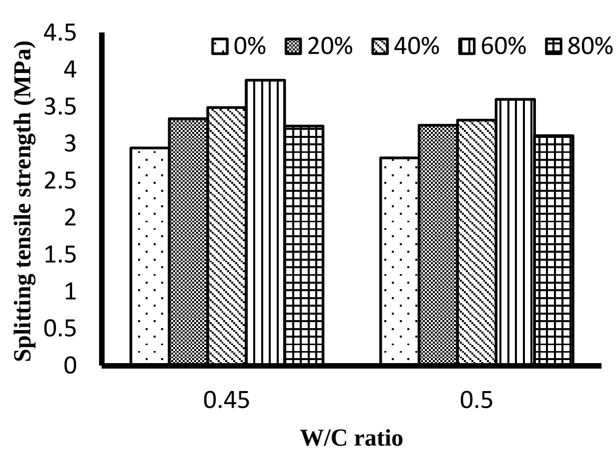

Fig- 2 Variation of splitting tensile strength of cylinders

Fig- 3 represents the flexural strength of concrete prisms (100×100×400 mm) at 28 days of curing at different w/c ratio. The control mix has a flexural strength of 4.84 and 4.34 MPa at w/c ratio 0.45 and 0.5 respectively. At 20% replacement level the flexural strength is 5.14 and 4.86 MPa for w/c ratio 0.45 and 0.5 which are 6.19% and 11.98% higher than the control mix respectively. The flexural strength is 5.315, 5.63 and 4.92 MPa for replacement level 40%, 60% and 80% which are 9.81%, 16.32%, and 1.65% higher than the control mix respectively at w/c ratio 0.45. Similarly at w/c ratio 0.5 the flexural strength is 4.97, 5.15 and 4.46 MPa which are 14.51%, 18.66% and 2.76% higher than the control mix for replacement level 40%, 60% and 80% respectively. Form the figure it is observed that the flexural strength increases with increase of replacement percentage upto 60% replacement level, which decreases at 80% replacement level. Also the strength is more in case of w/c ratio 0.45 rather than w/c ratio 0.5. Flexural strength development of mixes also follows the same trend as in case of compressive strength development. Due to the pozzolanic behaviour of GBS with increase in replacement percentage it gives the strength to the concrete.

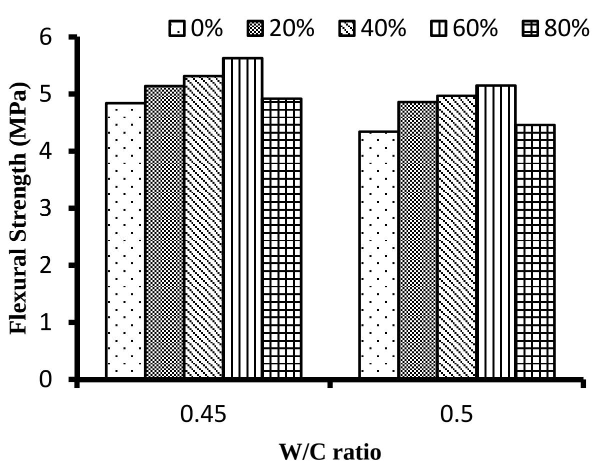

Fig- 3 Variation of flexural strength of prisms

4. CONCLUSION:

In the present study the effect of GBS as fine aggregate replacement on the strength properties of concrete is investigated and the following conclusions are illustrated.

- Concrete with GBS content showed higher strength than the natural concrete.
- Compressive strength of concrete showed highest value at 60% replacement level.
- Similar results were observed in case of splitting tensile strength as well as flexural strength.
- Hence concrete with different percentage of GBS can be useful for construction work.

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