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Effective Utilization of Slag Sand and Ground Granulated Blastfurnace Slag for the Production of Green and Sustainable Concrete

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ABSTRACT

Concrete can be made sustainable using alternatives to cement, fine aggregate, and coarse aggregate. In this study, slag sand is used as a complete replacement to natural sand and is physically characterized for its properties as per relevant IS codes of practices. Ground granulated blast-furnace slag is used as an alternative to cement, two replacement levels namely 30% and 60% for cement is carried out in this experimental investigation. Fresh concrete properties are determined by conducting compaction factor and slump tests, hardened properties namely compressive strength and split tensile strength at 7 days and 28 days are also determined. M20 grade concrete mix is proportioned as per IS: 10262-2009, all the alternatives have been tried, and test results for various combinations are compared.

Key words: *Sustainable concrete, Slag sand, Ground granulated blast-furnace slag, Strength studies.*

1. INTRODUCTION

Sustainability generally means having no negative impact on the environment. Green building refers to both a structure and processes that are environmentally responsible and resource-efficient throughout the building life cycle. Building materials typically considered as green includes products that are non-toxic, renewable, reusable, or recyclable.

900 kg of CO_2 are emitted for the production of every tonne of cement. Ground granulated blast-furnace slag (GGBFS) which is a waste from blast furnace in ironwork industry being used as an alternative to cement helps in effective utilization of industrial by-products which would otherwise end up in a landfill. Thus, saving land filling space and also reduces CO_2 emission thus lowering carbon footprint and greenhouse gas emission.

A lot of damage has been caused to the ecosystem by carrying out dredging operations on the sand beds leading to depletion of ground water level, lowers stream bottom, threat to nearby structures such as bridges due to undermining effect which may go up to its depth of excavation, bank erosion, and also leads to destruction of aquatic life. The recent controversy in India over sand mining has put spotlight on the need to substitute the natural fine aggregates. Slag sand is being used as an alternative to fine aggregate which in turn leads to effective utilization of industrial by-products.

2. LITERATURE REVIEW

In the work of Saxena *et al*. [1], the compressive strength was carried out on concrete cubes 150 mm size, with sand replaced by iron slag at 5 levels (0, 15, 30, 45, and 60%). Result shows that the iron slag added to the concrete has the greater strength than the plain concrete.

- In the work of Quasrawi *et al*. [2], the slag is used as fine aggregate replacing the sand in the mixes partially or totally. Ratios of 0, 15, 30, 50, and 100 %are used. Best results are obtained for replacement ratios of 30-50% for tensile strength and 15-30% for compressive strength.
- In the work of Kumar and Kumar [3], concrete M20 and M30 grades for 0, 25, 50, 75, and 100% replacement cubes were also prepared, respectively. Results show that blast furnace slag can be used as an alternative to natural sand up to 60-75% in mortar and concrete, respectively.

3. RESEARCH IMPORTANCE

As per literature review being done there are a lot of works which are being carried out on the concrete properties using slag sand alone. In this work, the properties of concrete when GGBFS and slag sand are being used in combination are determined. Since there is environmental issue in India against sand mining from river beds, cost of the sand which is one of the prime material for construction as shooed up, keeping

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in mind this burning issue complete replacement of slag sand is been carried out, which ensures reduced environmental impact, cost, and also effective utilization of industrial by-products.

4. MATERIALS USED

4.1. Cement

Birla Shakti cement (Ordinary Portland Cement [OPC]) of 53 grades. Testing has been carried out as per IS: 4031- 1988 [4]. It confirms to the specifications of IS: 12269-1987 [5]. The properties of cement is presented in Table 1.

4.2. Aggregates

Testing of aggregates for its properties are carried out as per IS: 2386-1963 [6]. The aggregates conforming to the specifications of IS: 383-1970 [7] is used. The properties of coarse and fine aggregates are presented in Tables 2 and 3.

4.2.1. Coarse aggregate

20 mm downsize aggregate 75%, and 12 mm downsize aggregate 25% which is locally available is used.

4.2.2. Fine aggregate

Slag sand obtained from JSW M/s Turangal, Bellary, is used. 50% of fine variety and 50% of coarse variety are used in combination. Locally available natural sand is also used in the work. Slag sand and natural sand confirming to Zone I are used.

4.3. Super Plasticizer

High-performance superplasticizer, based on modified polycarboxylic ether from a reputed manufacturer are used. The dosage of SP is varied to get the required slump and the same is mentioned.

5. MIX DESIGN

M20 grade of concrete was proportioned as per IS-10262:2009 [8]. Water cement ratio used is 0.55, and the proportion of mix is 1:2.38:2.54. The ingredients of concrete mix and their combinations are presented in Tables 4 and 5.

6. CASTING FOR CONCRETE

9 cubes of 100 mm size and 9 cylinders of size 100 mm×200 mm were cast for each concrete mix. Specimens were tested at 7 and 28 days of curing.

7. RESULTS AND DISCUSSION

7.1. Workability

When compared the concrete mixes done using slag sand and natural fine aggregate, slag sand produced harsh concrete because of its surface texture and hence used to consume more amount of superplasticizer to achieve the desired workability concrete mixes with 30% of GGBFS and 60% of GGBFS were observed to bleed and also used to set early in case of slag sand as fine aggregate, on the other hand, this was not observed when natural fine aggregate was used. The workability of various mixes in terms slump and compacting factor are presented in Tables 6 and 7. Work ability was measured using slump cone test. As per IS 1199:1959 [9] fresh properties of concrete are determined.

7.2. Fresh Density

Fresh density is carried out by using compaction factor test. Concrete mixes with slag sand were observed to flow discontinuous due to the harshness of mix and

Table 1: Properties of cement.

Properties	53 Grade OPC	As per IS: 12269-1987
Standard consistency	27.5%	-
Initial setting time, minutes	210	>30
Final setting time, minutes	280	<600
Sp. gravity	3.14	-
Compressive strength, MPa		
3 days	29.01	≥27
7 days	40.22	≥37
28 days	55.03	≥53

OPC=Ordinary Portland Cement

Table 2: Properties of coarse aggregate.

Properties	Coarse aggregate	As per IS: 383-1970
Specific gravity	2.51	-
Water absorption	0.35%	-
Impact value	31.11%	<45% for concrete
Crushing value	21.33%	<45% for concrete

Table 3: Properties of fine aggregates.

Properties	Slag sand	Natural sand
Specific gravity	2.58	2.65
Water absorption (%)	5.3	1.1
Loose bulk density, kg/m^3	1197.33	1405.33
Compacted bulk density, kg/m^3	1319.33	1561.33

Table 4: Ingredients of concrete mix per m^3.

Materials	Weight (kg)
Cementitious material	360
Coarse aggregate	915.25
Fine aggregate	856.9
Water	198

more friction which was generated with the apparatus inner surface for the concrete flow.

7.3. Compressive Strength

Compressive strength test has been carried out as per IS:516-1959 [10]. The well-established theory is that when GGBFS is used the initial strength of concrete would be less when compared with concrete prepared by cement alone. This trend prevailed in our study also with concrete mixes prepared using natural sand but for concrete with slag sand, the samples with 30% of GGBFS and 100% of cement gave comparable results, whereas sample with 60% of slag gave less compressive strength. The compressive strength of various mixes at 7 and 28 days are presented in Table 8 and as well as in Figure 1.

Table 5: Concrete mixes with following components in combination were prepared.

Type of sample	Cementitious		Fine aggregate		Coarse aggregate
	Cement	GGBFS	Natural fine aggregate	Slag sand	
S-1	100	-	100	-	100
S-2	70	30	100	-	100
S-3	40	60	100	-	100
S-4	100	-	-	100	100
S-5	70	30	-	100	100
S-6	40	60	-	100	100

GGBFS=Ground granulated blastfurnace slag

Table 6: Quantity of plasticizer used and slump results.

Particulars	Plasticizer in ml	Slump in mm
Sample 1	10	70
Sample 2	10	100
Sample 3	10	130
Sample 4	25	70
Sample 5	60	40
Sample 6	60	30

Table 7: Compaction factor for various samples.

Particulars	Compaction factor
Sample 1	0.93
Sample 2	0.93
Sample 3	0.99
Sample 4	0.95
Sample 5	0.93
Sample 6	0.92

7.4. Spilt Tensile Strength

Split tensile strength of cylinders is determined by conducting the test as per IS:5816-1999 [11]. The split tensile strength of various mixes at 7 and 28 days are presented in Table 9 and as well as in Figure 2.

8. CONCLUSION

Following few conclusions can be made from the study:

The addition of GGBFS decreased the compressive strength at 7 and 28 days. However, the reduction in compressive strength is not that appreciable keeping in mind the 30% and 60% replacement of cement. The strength obtained in sample 1 is that corresponds

Table 8: Compressive strength of various samples in MPa.

Particulars	Age of testing	
	7 days	28 days
Sample 1	33.10	49.36
Sample 2	26.07	41.19
Sample 3	22.13	37.60
Sample 4	32.07	45.52
Sample 5	31.83	44.87
Sample 6	25.98	35.98

Table 9: Spilt tensile strength of various samples in MPa.

Particulars	Age of testing	
	7 days	28 days
Sample 1	2.94	3.07
Sample 2	2.44	3.25
Sample 3	2.32	3.59
Sample 4	2.44	3.25
Sample 5	2.57	3.35
Sample 6	2.46	3.05

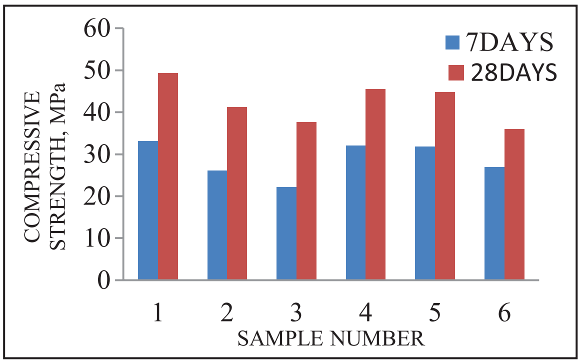

Figure 1: Variation of compressive strength of various samples at 7 days and 28 days.

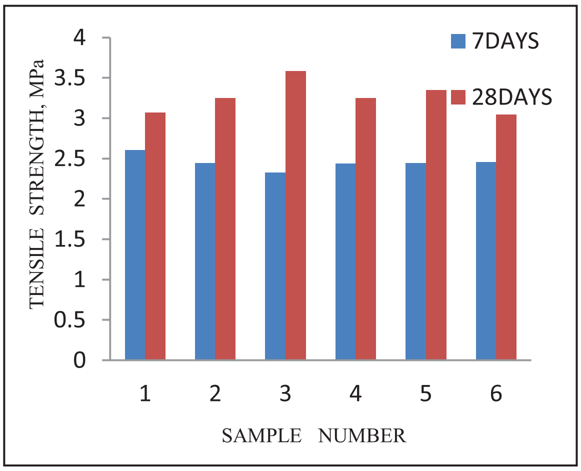

Figure 2: Variation of spilt tensile strength of various samples at 7 days and 28 days.

to M40 concrete. With the addition of 30% and 60% GGBFS, the grade has decreased close to M35 and M30, respectively. Replacing 100% natural sand by GBFS sand decreased the compressive strength marginally for the same slump, where the reduction in slump is compensated by increased the dosage of SP (S1 vs. S4). However, in the presence of slag powder, the slag sand performed more or less same as that of concrete containing natural sand. From this, it can be conceded that the strength of concrete with GBFS (slag) sand and in the presence of 30% and 60% cement replaced by GGBFS is marginally less compared to concrete with natural sand counterpart. From this, it is clear that the GBFS sand can be used as an alternative to natural sand for the production of concrete provided the loss in workability is adjusted using higher dosage of superplasticizer.

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***Bibliographical Sketch**

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