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Use of Blast Furnace Slag as an Alternative of Natural Sand in Mortar and Concrete

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ABSTRACT: Construction Industry plays a crucial role in the economic development of any country. In India Construction industry is the second largest after agriculture, contributes about 11% in the GDP. Construction industry is directly related with the consumption of cement in the world. India is the second largest cement producer in the world after China. Sand is a major material used for preparation of mortar and concrete and plays a important role in mix design. Sand is required about two times the volume of cement used in concrete construction. Hence the demand of natural sand is very high in developing countries to satisfy the rapid infrastructure growth. As demand of natural sand is increasing day by day there is a need to find the new alternative material to replace the river sand, such that excess river erosion and harm to environment is prevented. In present study alternatives of natural sand, blast furnace slag were evaluated for their suitability of replacing natural sand for making mortar and concrete. Blast furnace slag as by–product, which is a non–biodegradable waste material from that only a small percentage of it is used by cement industries to manufacture cement.. Mortar with proportions (1:4) for 0%, 25%, 50%, 75% and 100% replacement and concrete of M-20 and M-30 grades for 0%, 25%, 50%, 75% and 100% replacement cube were also prepared respectively. From this study it is observed that Blast furnace slag can be used as an alternative to natural sand up to 60% and 75% in mortar and concrete respectively.

KEYWORDS: Concrete, Natural sand, Blast furnace slag, compressive strength.

I.INTRODUCTION

Aggregate is the main constituent of concrete, occupying more than 70% of the concrete matrix. The global consumption of natural sand is very high, due to the extensive use of concrete. In general, the demand of natural sand is quite high in developing countries to satisfy the rapid infrastructural growth, in this situation developing country like India facing shortage in good quality natural sand. Particularly in India, natural sand deposits are being depleted and causing serious threat to environment as well as the society. Increasing extraction of natural sand from river beds causing many problems, loosing water retaining sand strata, deepening of the river courses and causing bank slides, loss of vegetation on the bank of rivers, exposing the intake well of water supply schemes, disturbs the aquatic life as well as affecting agriculture due to lowering the underground water table etc are few examples. In past decade variable cost of natural sand used as fine aggregate in concrete increased the cost of construction. In this situation research began for inexpensive and easily available alternative material to natural sand. (Jadhava and Kulkarni, 2012). Khajuria and Siddique (2014) shows that the iron slag added to the concrete had greater strength than the plain concrete. Sudarvizhi and Ilangovan (2011) observed that upto 80% replacement, CS and FS can be effectively used as replacement for fine aggregate. Sankh et al. (2014) presents the different alternatives to natural sand in preparation of mortar and concrete. The paper emphasize on the physical and mechanical properties and strength aspect on mortar and concrete. Nataraja et al. (2013) observed that GBFS could be utilized partially as alternative construction material for natural sand in mortar applications.

II. MATERIALS

CEMENT

The cement used was Ordinary Portland cement (Birla gold, 43 Grade). It was tested as per Indian standard specification (IS: 8112-1989).

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Table 1: Properties of ordinary Portland cement

S. No.	Descriptions	Test Values	IS: 8112-1989
1.	Fineness, Blain's Value, m^2/kg	260	More than 225
2.	Setting time (min) Initial setting time Final setting time	 90 247	 Not less than 30 Not more than 600
3.	Soundness, Le-Chatelier method (mm)	1	10
4.	Compressive Strength After 3 days: After 7 days:	 21 Mpa 36 Mpa	 72 ± 1 h, Min 23 168 ± 2 h, Min 33

FINE AGGREGATE

Locally available Mahanadi sand was tested for its suitability as fine aggregate as per IS: 383-1970. Results of the tests are as summarized in Table 2.

Table 2: Physical properties of natural sand

S. No.	Properties	values	Range as per code IS: 383-1970
1	Specific gravity	2.71	2.30-2.90
2	Bulk density (kg/m^3)	1503	1280-1920
3	Fineness Modulus	2.83	2.10-3.20
4	Water absorption (%)	1.32	0-8

COARSE AGGREGATE

Well graded aggregates available at crusher stone nearby plant in jagdalpur, Chattisgarh (India) was tested for its suitability for this study as per IS: 383 -1970 (Reaffirmed 1997).

Table 3: Physical properties of coarse aggregate

S. No.	Properties	Values	Range as per code IS: 383-1970
1.	Aggregate Impact Value	14.40 %	Not more than 45%
2.	Aggregate Abrasion Value	18.03 %	Not more than 50%
3.	Aggregate Crushing Value	17.25 %	Not more than 45%
4.	Fineness Modulus	6.54	5.50-8.00

BLAST FURNACE SLAG

The non-metallic product, consisting essentially of silicates and alumina silicates of calcium and of other bases that is developed in a molten condition simultaneously with iron in a blast furnace.

1. Air-cooled blast-furnace slag is the material resulting from solidification of molten blast-furnace slag under atmospheric conditions; subsequent cooling may be accelerated by application of water to the solidified surface.
2. Expanded blast-furnace slag is the lightweight, cellular material obtained by controlled processing of molten blast furnace slag with water, or water and other agents, such as steam or compressed air, or both.
3. Blast-furnace slag is the glassy granular material formed when molten blast-furnace slag is rapidly chilled, as by immersion in water (Virgalitte et al., 2000).

Blast furnace slag (4.75mm to 75 micron) was collected from jindal Steel Plant located at bhilai, Chhattisgarh for replacement to natural sand. The physical properties of blast furnace slag is shown in Table 4

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Table 4: Physical properties of blast furnace slag

S. No.	Properties	Values	Range as per code IS: 383-1970
1	Specific gravity	2.52	2.30-2.90
2	Bulk density (kg/m^3)	1305	1280-1920
3	Fineness Modulus	2.40	2.10-3.20
4	Water absorption (%)	2.59	0-8

It can be observed from table 4, that physical properties of blast furnace slag are within permissible limit as per IS: 383-1970.

III. OBJECTIVES

1. To study the effect of partially replace fine aggregates with blast furnace slag and find its effect on the strength characteristics of concrete and mortar.
2. Study of strength properties of mortar and concrete at the ages of 3,7 days and 7, 28 days respectively for 0%, 25%, 50%, 75% and 100% replacement of natural sand.
3. Comparative study of strength properties results of both the grades (20 M Pa, and 30 M Pa) of concrete and mortar with proportion (1:4) containing natural sand and blast furnace slag.

IV. COMPRESSIVE STRENGTH OF MORTAR WITH NATURAL SAND

For determining the Compressive strength, first the standard cubes of mortar (7.07 cm) size were casted with the natural sand. Table 5 show the 3 and 7 days strength of mortar cubes of 1:4 proportions casted with 0.82 W/C ratios of natural sand and blast furnace slag.

Table 5: Comparison of mortar strength of blast furnace slag with natural sand

S. No.	Combination	C/S Proportion	BFS Compressive Strength, (Mpa)	
			3 Days	7 Days
1	0% GBFS +100% NS	1:4	2.94	4.11
2	25% GBFS+ 75% NS	1:4	3.23	3.83
3	50% GBFS + 50% NS	1:4	3.49	4.31
4	75% GBFS + 25% NS	1:4	2.99	3.51
5	100% GBFS + 0% NS	1:4	2.16	3.14

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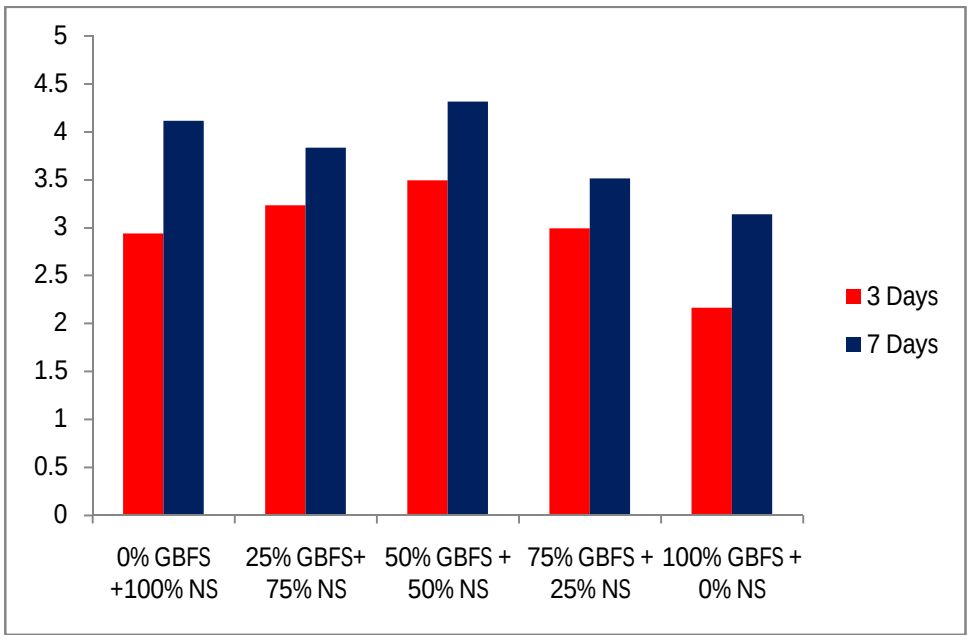

Figure 1: Comparison of blast furnace slag mortar compressive strength (1:4) at 3 and 7 days with natural sand.

V. COMPRESSIVE STRENGTH OF CONCRETE WITH NATURAL SAND

Standard mix proportions for commonly used M-20 and M-30 grade concrete were selected. Standard concrete cube of 15 cm were prepare with natural sand and their 7 and 28 days strength was determined. Table 4.13 shows the compressive strength of M-20 and M-30 grade concrete after 7 and 28 days. This compressive strength was compared with the compressive strength of cubes prepared with the blast furnace slag.

Table 6: Comparison of compressive strength of natural sand and blast furnace slag

			M-20		M-30	
Replacement (%)	**W/C ratio**	**Slump (mm)**	**compressive strength at 7 Days, N/MM^2**	**compressive strength at 28 Days, N/MM^2**	**compressive strength at 7 Days, N/MM^2**	**compressive strength at 28 Days, N/MM^2**
0% GBFS + 100%NS	0.5	100	21.17	28.16	29.91	38.03
25% GBFS + 75%NS	0.5	100	20.20	27.12	29.16	37.79
50% GBFS + 50% NS	0.5	100	22.61	31.50	32.92	41.40
75% GBFS + 25% NS	0.5	100	24.89	32.67	33.74	42.50
100% GBFS + 0% NS	0.5	100	19.90	27.03	28.14	36.23

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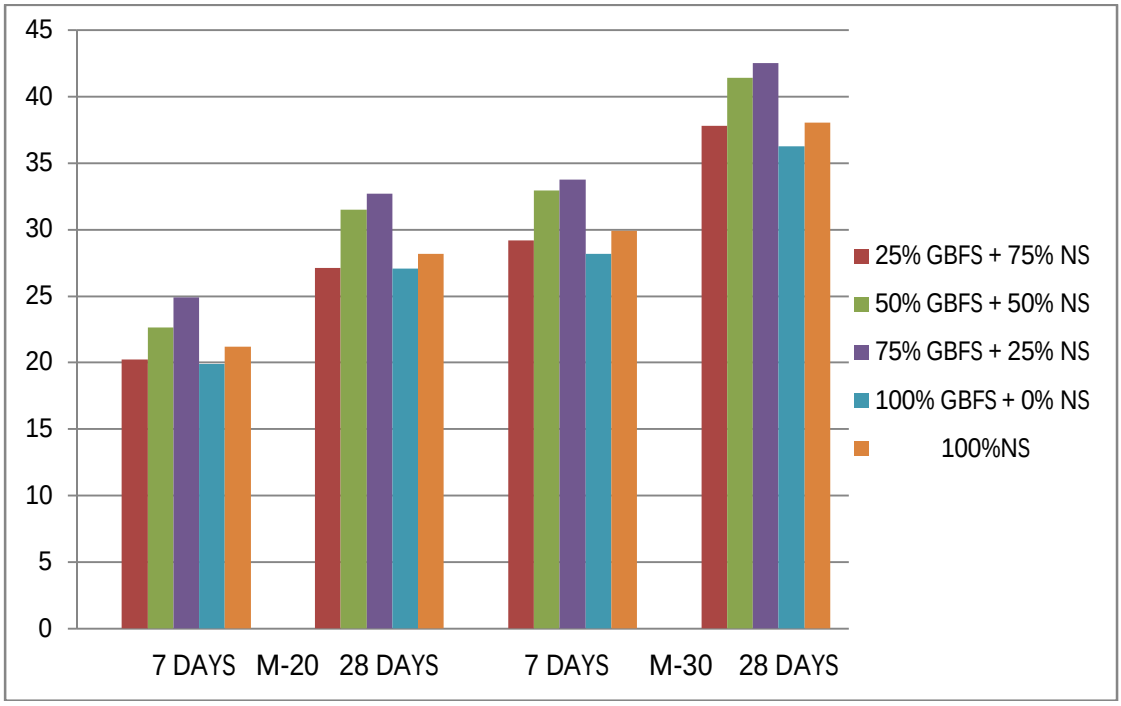

Figure 2: Comparison of blast furnace slag concrete compressive strength at 7days and 28 days with natural sand.

VI. CONCLUSIONS

1. Using of blast furnace slag as a replacement of fine aggregate will might prove an economical and environmentally friendly solution.

2. Chemical Composition with respect to Silica, Aluminium, Oxygen, Calcium and magnesium are nearest to normal sand in Blast furnace slag.

3. At 100% replacement of natural sand, compressive strength decreases when compared with the cubes prepared with 100% natural sand only.
4. Blast furnace slag can be used as alternative of fine aggregates in making mortar up to 60% replacement, which reduces the consumption of natural sand.
5. When blast furnace slag was examined as replacement of natural sand for making concrete, compressive strength of cubes (28 days) is comparable with that of the cubes prepared with natural sand up to 75% replacement. Beyond this, compressive strength decreases with increase in the replacement.

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