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Research Paper

USE OF GRANULATED BLAST FURNACE SLAG AS FINE AGGREGATE IN CEMENT MORTAR

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This paper investigates the possibility of utilizing Granulated Blast Furnace Slag (GBFS) as a sand substitute in cement mortar, in order to reduce environmental problems related to aggregate mining and waste disposal. In this investigation, cement mortar mix 1:3 and GBFS at 0, 25, 50, 75 and 100% replacement to natural sand for constant w/c ratio of 0.5 is considered. The work is extended to 100% replacements of natural sand with GBFS for w/c ratios of 0.4 and 0.6. The flow characteristics of the various mixes and their compressive strengths at various ages are studied. From this study it is observed that GBFS could be utilized partially as alternative construction material for natural sand in mortar applications. Reduction in workability expressed as flow can be compensated by adding suitable percentage of super plasticizer.

Keywords: Granulated blast furnace slag (GBFS), Compressive strength, Workability, Mortar flow, Super plasticizer

INTRODUCTION

Aggregates have a significant influence on both rheological and mechanical properties of mortars and concrete [Neville]. Their specific gravity, particle size distribution, shape and surface texture influence markedly the properties of mortars and concrete in the fresh state. On the other hand, the mineralogical composition, toughness, elastic modulus and degree of alteration of aggregates are generally found to affect the properties of mortars and concrete in the hardened state [Mehta].

In India, natural river sand (fine aggregate) is traditionally used in mortars and concrete. However, growing environmental restrictions to the exploitation of sand from riverbeds have resulted in a search for alternative sand, particularly near the larger metropolitan areas. This has brought in severe strains on the availability of sand forcing the construction industry to look for an alternative construction material. Thus manufactured fine aggregates appear as an attractive alternative to natural fine aggregates for cement mortars and concrete.

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Manufactured sand is totally different from natural river sand. The surface characteristics are different. Most of the artificial sand is irregular and more porous. Grading will vary over wide range resulting in internal porosity and reduction in workability of mortar or concrete. A number of studies have dealt with the influence of both grading and particle shape of the fine aggregate in mortars and concrete. For good quality manufactured sand at a given water/cement ratio, it has been found that concrete made with manufactured sand achieved compressive strength equal to or higher than concrete made with natural sand, reducing the void content of the aggregate, thereby lubricating the aggregate system without increasing the water requirement of the mixture (Ind Manoj and Pal, 1998 and Suhas, 2012).

To understand the variations in mixing water requirements, many earlier researchers have investigated the effect of particle shape of both fine and coarse aggregates on water demand on concrete. They have found that the shape of the fine aggregate has a more significant impact on water demand than the shape of the coarse aggregate. Further, within the permitted standard limits, the particle size distribution of the fine aggregate was found to have a greater influence in the properties of concrete than that of the coarse aggregate. As a result, the choice of the appropriate type of fine aggregate for a given application is of primary importance as far as properties of mortars and concrete are concerned (Gonçalves *et al*., 2007).

Various types of slag from copper and steel industry are being used in mortar and concrete (Pundhir *et al*., 2005, Khalifa *et al.,* 2011, Mohammed Nadeem and Pofale, 2012, and Tamilarasan and Perumal, 2012). The use of Granulated Blast-Furnace Slag (GBFS) as an aggregate in cement mortar and concrete provides environmental as well as economic benefits. Many steel industries in India are supplying GBFS as an alternative to sand.

In addition there are many other alternative materials for aggregates derived from construction and demolition wastes, recycled aggregates and quarry wastes. These aggregates are successfully utilized in concrete production which can also help to conserve natural materials and to reduce the cost of waste treatment prior to disposal (Nataraja *et al.,* 2001).

OBJECTIVES OF WORK

Present experimental work explores the possibility of using GBFS as replacement of natural sand in mortar. In this work, cement mortar mix 1:3 was selected for 0, 25, 50, 75 and 100% replacements of natural sand with GBFS for constant w/c ratio of 0.5 and also work has been carried out for 100% replacements of natural sand with GBFS for w/c ratios of 0.4 and 0.6. Mortar flow behavior and its compressive strength are investigated.

MATERIAL PROPERTIES

Cement

Ordinary Portland Cement 43 grade (OPC 43) was used throughout the investigation. The cement used has been tested for various properties as per IS: 4031 (1988) and found to be conforming to various specifications of IS: 8112 (1989). The physical properties of cement are given in Table 1.

Table 1: Properties of Cement			
S. No.	**Descriptions**	**Test Values**	**IS: 8112-1989 Requirements**
1.	Fineness, Blain's Value, m^2/kg	255	More than 225
2.	Normal consistency (%)	30.5	No standard value
3.	Setting time (min)		
	Initial setting time	125	Not less than 30
	Final setting time	285	Not more than 600
4.	Soundness		
	Le-chatelier method (mm)	1	10
	Autoclave expansion, %	Nil	0.8
5.	Compressive strength, MPa		
	3 days	32.5	23
	7 days	41.6	33
	28 days	50.8	43

Fine Aggregates

The fine aggregates used for this work were natural river sand and GBFS. Natural sand confirms to grading zone II and GBFS confirms to grading zone III as per IS: 383 (1970). The physical properties of sand such as sieve analysis, specific gravity, bulk density, etc., were determined as per IS: 2386 (1963).

Physical Properties

The properties of fine aggregate used are given in Table 2.

Sieve Analysis

Sieve analysis (or gradation test) is a practice or procedure used to assess the particle size distribution of a granular material. Gradation affects many properties of an aggregate. With

Table 2: Properties of Fine Aggregates		
Fine Aggregates	**Natural Sand (NS)**	**GBFS**
Specific Gravity (ssd)	2.69	2.63
Bulk density (ssd), kg/m^3	1603	1430
Water absorption, %	0.45	2.56
Fineness Modulus	2.51	2.37
Fines through 75 μ, %	0.6	6.14

careful selection of the gradation, it is possible to achieve high bulk density, high physical stability and low permeability. Figure 1 shows the sieve analysis of fine aggregates determined as per IS: 383 (1970).

Superplasticiser

In the present investigation Conplast SP 430 super plasticizing admixture is used, which complies with IS:9103:1979. Conplast SP 430 is based on sulphonated naphthalene polymers and is supplied as a brown liquid instantly dispersible in water. It has been specially formulated to give high water reduction upto 25% without loss of workability. Its specific gravity is 1.145 (at 30 °C) and chloride content is Nil. Air entrainment is approximately 1%.

Casting for Mortar Cubes

The proportion of materials which is used in the present study was 1:3. Tables 3 and 4 illustrate the mix proportions of mortars prepared by replacement of natural sand by GBFS particles. The replacement was taken as 0, 25, 50, 75 and 100% for 1:3 mortar mixes proportions for 0.5 water-cement ratio (w/c) and 100% replacement of GGBS for water-cement ratio (w/c) of 0.4 and 0.6 respectively. For each mix mortar cubes of size 70.7 x 70.7 x 70.7 mm are cast as per IS: 4031 (2000). After 24 h the sample was demoulded and cured for the period of 3, 7 and 28 days. At the end of each curing period, a total of three specimens

Figure 1: Sieve Analysis of Natural Sand and GGBS Sand

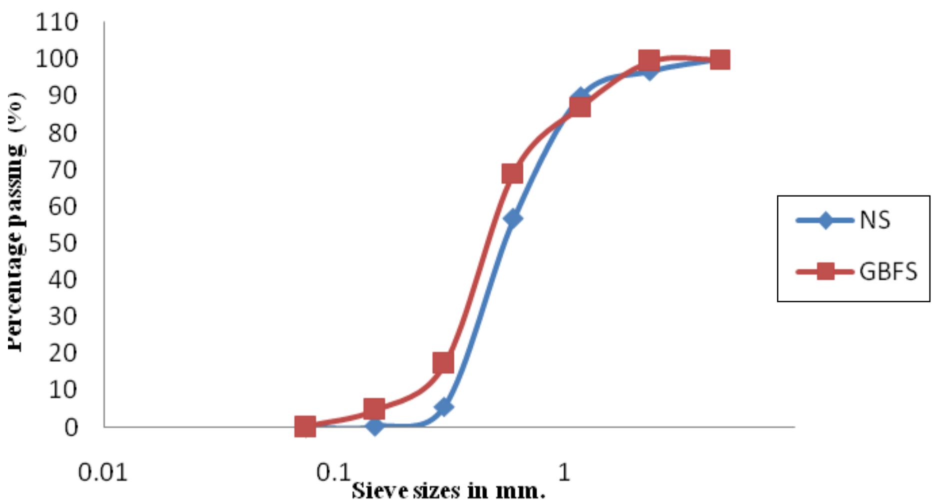


Table 3: Proportions of Constituent Materials Used for Cement Mortar

Combination	Cement (g)	Natural Sand (g)	GBFS (g)	Water (w/c=0.4)	Water (w/c=0.5)	Water (w/c=0.6)
Control mix (0% replacement)	200	600	0	80	100	120
100% replacement of natural sand with GBFS	200	600	0	80	100	120

Table 4: Proportions of Constituent Materials Used for Cement Mortar

Combination	Cement (g)	Natural Sand (g)	GBFS Sand (g)	Water (mL)(w/c-0.5)
25% replacement of natural sand with GBFS	200	450	150	100
50% replacement of natural sand with GBFS	200	300	300	100
75% replacement of natural sand with GBFS	200	150	450	100

were tested to know the compressive strength as per IS: 516 (1959).

Flowability of Cement Mortar

Workability of fresh cement mortar was measured by using standard flow table apparatus as per IS: 5512 as shown in Figure 2. The flow of cement mortar decreased substantially for GBFS mortar for all replacement levels. As the finer material increases, more is the surface area and hence more water is required for wetting the surface. For the given fixed quantity of water as the finer material increases the workability decreases. The workability can be increased by adding suitable dosage of chemical admixture.

Figure 2: Measurement of Flowability

Author please chk Results and Discussion

TEST RESULTS AND DISCUSSION

The result of the investigation for the replacements of natural sand with GBFS was discussed. The replacement was taken as 0, 25, 50, 75 and 100% for 1:3 mortar mixes proportions for 0.5 w/c and 100% replacement of GGBS for w/c of 0.4 and 0.6 respectively.

Effect of GBFS on Compressive Strength of Cement Mortar

The compressive strength development of cement mortar containing different percent replacement of GBFS and for different w/c ratios is shown in Figures 3 to 5. Tables 5 and 6 shows compressive strength at 3, 7 and 28 days for natural sand and GBFS sand at different w/c ratios and also different replacement of natural sand by GBFS sand at constant w/c of 0.5. Figure 4 shows that, significant amount of decrease in compressive strength of cement mortar made with GBFS, when compared with strength of control mix (Figure 3). Figure 4 also shows that, the compressive strength of cement mortar for 0.4 w/c ratio is less compared with the strength of water cement ratios 0.5 and 0.6. This is because of insufficient water in the mix for compaction, too much of flaky particle in GBFS and also may be because of the improper bond between cement paste and aggregate. From Figure 5 it can be observed that, the compressive strength of cement mortar for replacement of natural sand by GBFS up to 75% was closer to that of reference mix.

Figure 3: Showing Variation of Compressive Strength at 3, 7 and 28 Days for Natural Sand

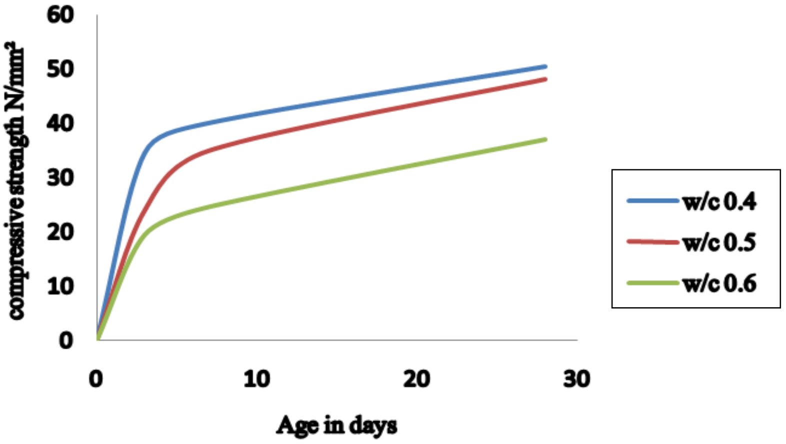


Figure 4: Variation of Compressive Strength at 3, 7 and 28 Days for GBFS Sand

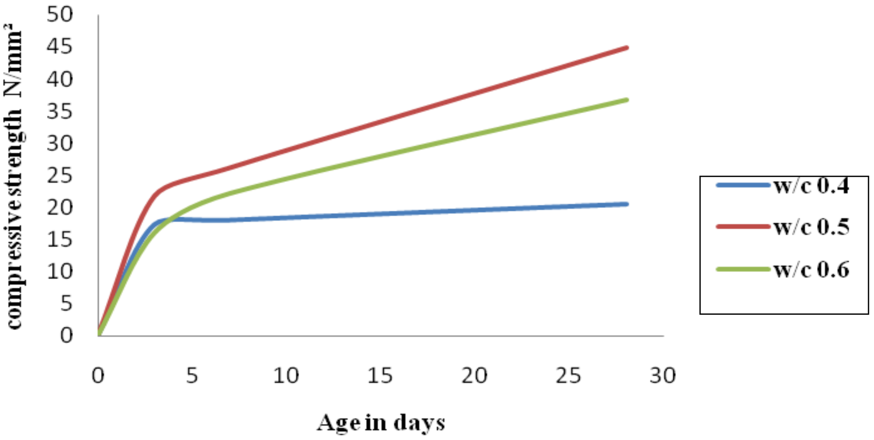


Figure 5: Variation of Compressive Strength at 3, 7 and 28 Days for Different Replacement of Natural Sand by GBFS Sand at w/c of 0.5

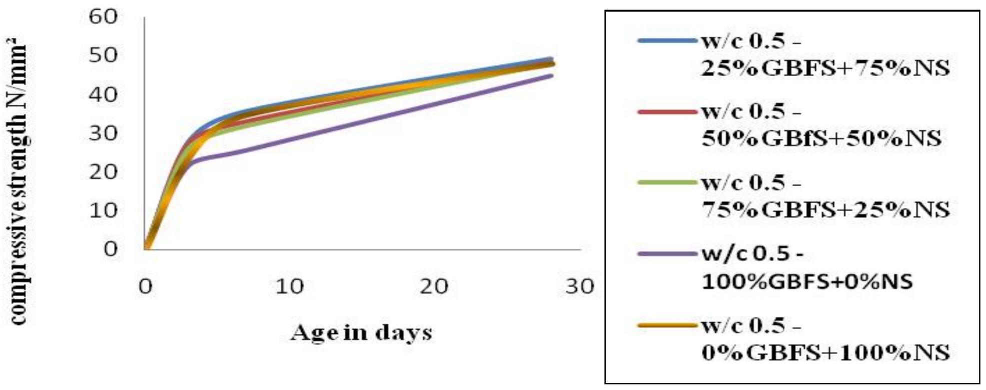


Table 5: Compressive Strength at 3, 7 and 28 Days for Natural Sand and GBFS Sand at Different w/c

Combination	Water-Cement Ratio (w/c)	Compressive Strength (N/mm²)		
		3 days	7 days	28 days
Cement+100% NS	0.4	34.61	40.13	50.53
Cement+100% NS	0.5	23.94	34.91	48.02
Cement+100% NS	0.6	19.53	24.67	37.11
Cement+100% GBFS	0.4	17.41	18.11	20.62
Cement+100% GBFS	0.5	21.73	26.13	44.80
Cement+100% GBFS	0.6	16.01	22.13	36.67

Table 6: Compressive Strength at 3, 7 and 28 Days for Different Replacement of Natural Sand by GBFS Sand at w/c of 0.5

Combination	Compressive Strength, N/mm²		
	3 days	7 days	28 days
25%GBFS+75%NS	27.73	35.6	49.07
50%GBFS+50%NS	27.47	33.11	48.41
75%GBFS+25%NS	26.01	31.87	48.11
100%GBFS+0%NS	21.73	25.61	44.81
0%GBFS+100%NS	23.94	34.91	48.02

Figure 6: Variation of Flowability of Mortar for Natural Sand at Different w/c

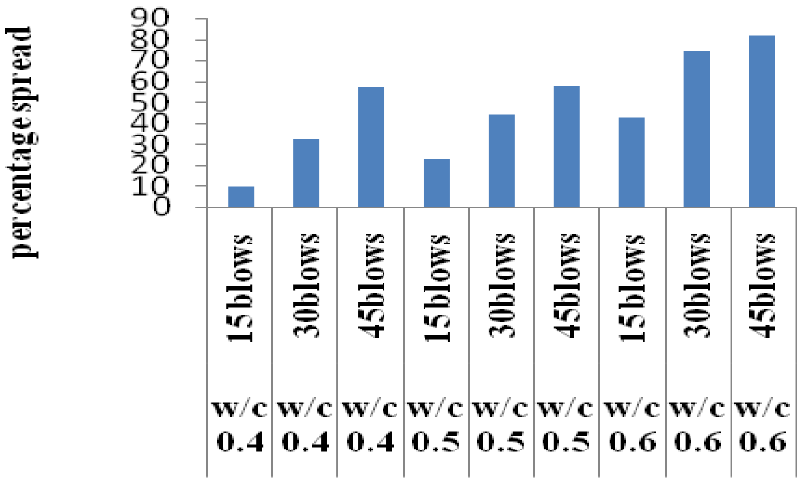


Figure 7: Variation of Flowability of Mortar for GBFS Sand at Different w/c

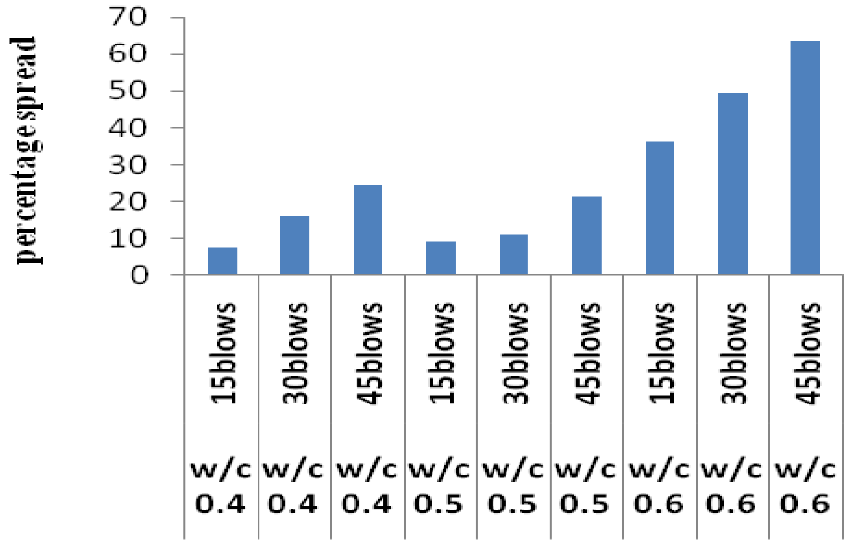
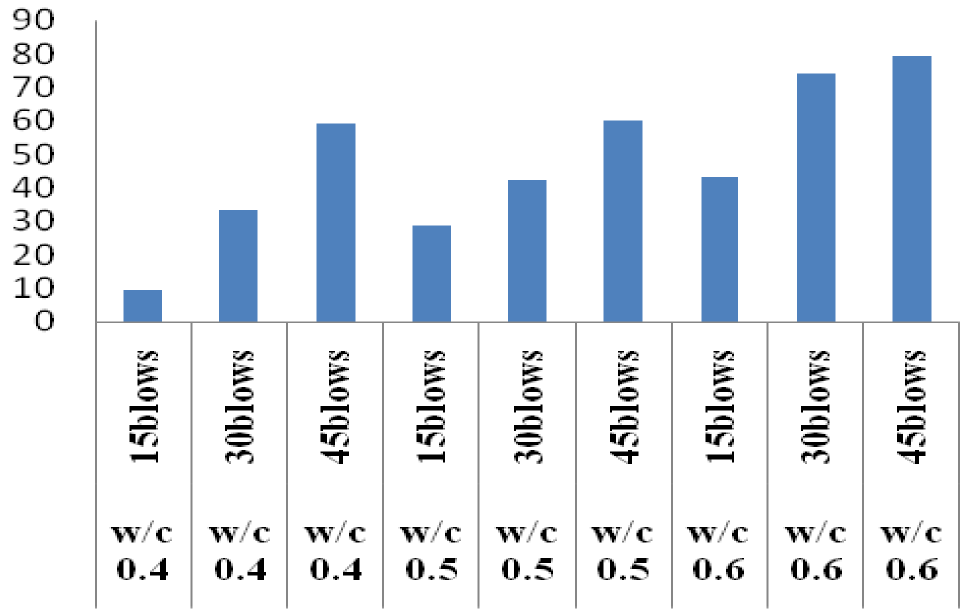


Figure 8: Variation of Flowability of Mortar for GBFS Sand at Different w/c by Adding 1% of Superplasticizer



The variation of flowability containing different percent replacement of GBFS and for different w/c ratios is shown in Figure 6 to 8. The results indicated that the use of GBFS at any level of replacement as a fine aggregate in cement mortar will significantly reduce the flowability of cement mortar. This flowability can be increased by adding certain dosage of superplasticiser (FOSROC). From Figure 8 it was observed that by adding 1% of superplasticizer by weight of cement, it was possible to get workability closer to that of reference mix.

CONCLUSION

The data obtained shows that the compressive strength of cement mortar increases as the replacement level of GGBS increases. This increase is not substantial. However for 100% replacement the strength decreases marginally compared to 100% natural sand. This trend is true for all ages of testing. From this it is clear that GGBS sand can be used as an alternative to natural sand from the point of view of strength. Use of GGBS up to 75% can be recommended.

It is also observed that the flow of mortar decreases as the percentage of GGBS increases. The decrease in flow for 25% is marginal and for higher percentages the flow decreases substantially. Using suitable dosage of chemical, the flow can be maintained.

By adding 0.5% to 1% of superplasticizer, it was possible to get workability closer to reference mix. Finally we can conclude that GBFS can be used as partial replacement (0 to 75%) for natural sand in cement mortar without scarifying workability in terms of flow using suitable dosage of super plasticiser.

As the sand is artificial, its long term performance from the point of view of durability is very important and further studies in this direction is in progress. The shape characterization is also an important factor and studies in this direction are also planned considering different types of manufactured sand that are available in our palace.

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