Experimental Investigation of Granulated Blast Furnace Slag and Quarry Dust as a Fine Aggregate in Cement Mortar

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Abstract— In this experimental work ninety-nine cubes has been prepared having dimension 70.7x70.7x70.7 mm are cast as per IS:4031 (2000). In this experimental investigation cement mortar mix 1:3 by volume were selected for 0%, 20%, 40%, 60%, 80% and 100% partially replacement of natural sand (NS) by Granulated blast furnace slag (GBFS) and quarry dust (QD) [3 cubes on each parameter respectively] for W/C ratio of 0.55 respectively. All the cubes were tested under compressive testing machine. To compare the average compressive strength of natural sand (NS) with granulated blast furnace slag (GBFS) and quarry dust (QD).

Key words: Granulated blast furnace slag, quarry dust, natural sand, compressive strength, mortar flow, workability

I. 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

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.

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 porosityand 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).

II. MATERIALS

A. Cement:

Ordinary Portland cement (53 grade) of Birla A-1 brand manufactured from a single batch will be used throughout the course of project. The physical properties of cement are given in table 1.

S.No	Properties	Result
1	Specific gravity	3.10
2	Normal consistency	32%
3	Initial setting time	45 min
4	Final setting time	210 min

Table 1: Properties of cement

B. Fine Aggregate:

The aggregate consists of well graded fine aggregate (shahpur sand) that passes a 4.75 mm sieve and salt-free source is used. The sand is selected from locally available river-beds and which is free from organic or other deleterious matter. The moisture content of the aggregate should be considered in the calculation of required water. The physical properties of fine aggregate are given in table 2.

S.No	Properties	Result
1	Specific gravity	2.66
2	Bulk density (loose condition)	1.290 gm/cc
3	Bulk density (compacted condition)	1.470 gm/cc
4	Fineness modulus	3.69

Table 2: Properties of fine aggregate

C. Water:

Potable water will be used in the investigation for mixing and curing.

D. Granulated Blast Furnace Slag:

GBFS used in this present investigation was procured form JSW steel plant, Bellary. The sieve analysis data and physical properties of Granulated Blast Furnace Slag (GBFS) fine aggregate used are shown in table.3 both natural sand and GBFS and belonged to zone II gradation mentioned on IS 383-1970.

S.No	Properties	Result
1	Specific gravity	2.85
2	Bulk density (loose condition)	1.340 gm/cc
3	Bulk density (compacted condition)	1.500 gm/cc
4	Fineness modulus	3.50

Table 3: Properties of GBFS

E. Quarry Dust:

Quarry Dust used in this present investigation was procured form local quarry plant (Gulbarga). The sieve analysis data and physical properties of QD are shown in table.4 QD belonged to Zone II gradation mentioned on IS 383-1970.

S.No	Properties	Result
1	Specific gravity	2.59
2	Bulk density (loose condition)	1.670 gm/cc
3	Bulk density(compacted condition)	1.805 gm/cc
4	Fineness modulus	3.623

Table 4: Properties of Quarry Dust

F. Mix Proportioning:

The mix design was done as per Is:10262(2009). The grade of mortar adopted for this study is M12 grade and water cement ratio as 0.55 for mortar. The mix proportion for mortar is 1:3

III. EXPERIMENTAL INVESTIGATION

The experimental program of this project is designed to investigate the use of Granulated blast Furnace Slag (GBFS) and Quarry Dust (QD) as partially replacement of fine aggregate in cement mortar. Before testing the specimen the cube where casted in wooden mould and the size of the cube is 70.7x70.7x70.7 mm [cast as per IS:4031 (2000)] mortar mix 1:3 was selected for 20,40,60,80 and 100% replacement of natural sand with Granulated Furnace Slag (GBFS) and Quarry Dust (QD) for constant W/C of 0.55 and all the cubes were casted and kept for curing at a period of 3,7 and 28 days after completion of curing period the cube were removed from the water and all the cubes where tested under a compressive testing machine. To investigate the mortar flow behavior and its compressive strength.

A. Casting And Curing Of Specimen:

1) Casting Of Cement Mortar Cube:

Moulds of size 70.7mmx70.7mmx70.7mm Cast as per IS:4031 (2000) are used for casting the cement mortar cube. The moulds were cleaned and one coat of cutting oil was applied on all the internal surfaces.

All the cube moulds were filled in 3 layers, the height of each layer was 1/3rd height of the mould and for each layer 25 blows were given with the help of tamping rod over the entire cross section of the mould uniformly. After filling and compacting the mould, the top surface was made smooth.

A total No of 99 cubes are casted. The proportion of materials which is used in the present study was 1:3 mix proportion of mortars prepared by replacement of natural sand by GBFS and QD particles and are designated as GBFS0, GBFS20, GBFS40, GBFS60 GBFS80, GBFS100 and QD0, QD20, QD40, QD60, QD80, QD100 for the cement mortar mix 1:3 with 0.55 w/c ratio. In all the designations 0, 25, 50, 75 and 100 indicates the % of GBFS and QD in cement mortar. Three cubes on each parameter respectively by GBFS and QD replacement. A casting of specimen is shown in fig 3.1 After 24 hours the sample were demoulded as shown in fig 3.2.

Fig. 3.1: Casting of Specimen

Fig. 3.2: Casting of Specimen

2) Curing Of Specimen:

The curing of specimens is done by pounding method of curing. Specimens are removed from the moulds and are placed in tank containing water for required No of days of curing. After the curing period specimens are taken out from the tank and the surface moisture is removed by wiping the surface with the cloth. Curing periods of 3 days, 7 days and 28 days were used in the investigation.

B. Testing Of Specimen:

1) 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 3.5, 3.6, 3.7 & 3.8. The flow of cement mortar decreased substantially for GBFS and QD 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.

Fig. 3.5: Measurement of Flowability

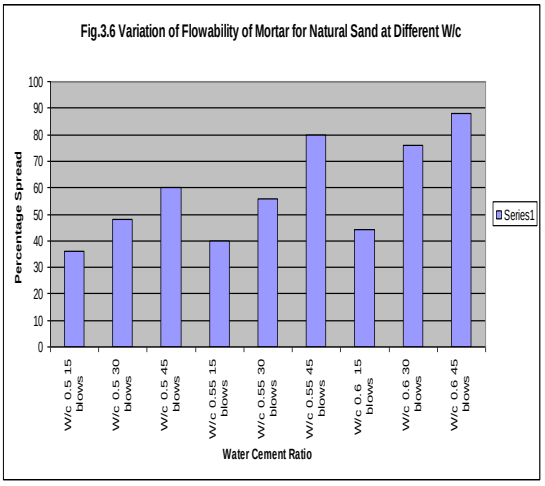

Fig. 3.6:

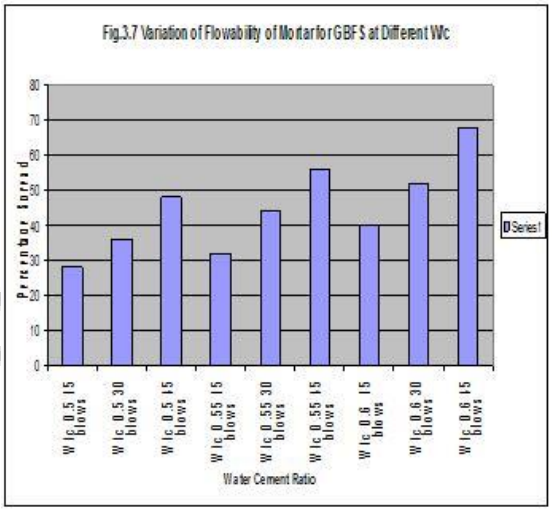

Fig. 3.7:

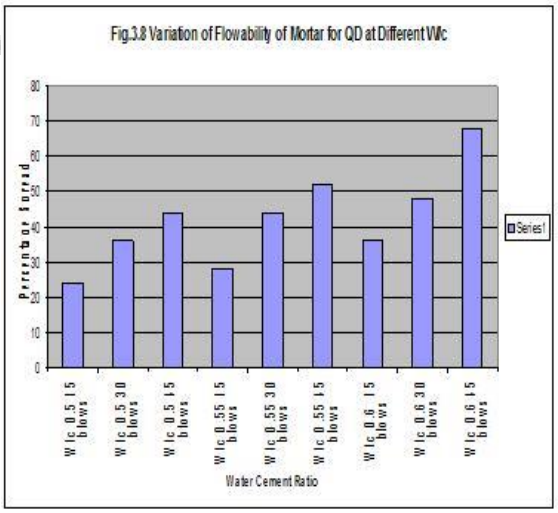

Fig. 3.8:

2) Cube Compression Test:

In this test cube specimens were used using for determining the characteristic compressive strength. The cube was tested in a compression testing machine of capacity 2000KN is shown in fig 3.9. The load was applied in such a way that, the two opposite side of the cube were compressed (top and bottom surface). The compressive strength was calculated by dividing the load by area of specimen. Compression test is shown in fig 3.10. i.e., Cube compressive strength (Fc) = ultimate load/ cross section area of cube

Fig. 3.9: Compressive testing machine

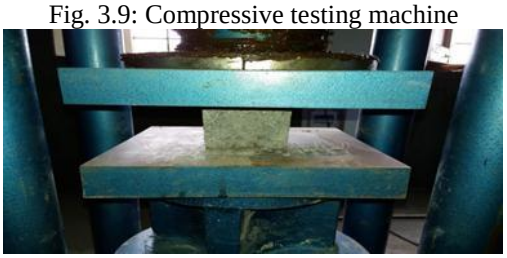

Fig. 3.10: Compressive testing machine

IV. RESULTS AND DISCUSSION

In the current investigation studies on strength and durability properties of cement mortar with different replacement levels of natural sand by GBFS and QD, were carried out.

A. Compressive Strength:

The result of compressive strength test are tabulated in Table 4.1. From the result it was observed that the compressive strength of the cement mortar increases with increase in the replacement level of sand by GBFS and QD up to 60% .

GBFS For 3 days curing period, the strength of the cement mortar is increased about 1.970%, and 16.73% and 19.32% and 5.27% for 20%, 40%, 60% and 80% and decreased about 14.31% for 100% replacement level respectively when compared with that of conventional cement mortar.

And QD For 3 days curing period, the strength of the cement mortar is increased about 2.73%, and 6.58% and 15.69% for 20%, 40%, and 60% and decreased about 13.163% and 29.68% for 80% and 100% replacement level respectively when compared with that of conventional cement mortar.

GBFS For 28 days curing period, the strength of the cement mortar increased about 1.29% and 5.79% and 10.58% and 0.96% for 20%, 40%, 60% and 80% and decreases about 4% for 100% replacement level respectively when compared with that of conventional cement mortar. At 60% replacement levels of sand the compressive strength of both GBFS cement mortar and conventional cement mortar were similar. From the results the optimum sand replacement level with GBFS was found to be 60%. The variation of the compressive strength with the age of the curing period and variation of the replacement proportion are shown in Fig 4.1.and Fig 4.2 respectively.

And QD For 28 days curing period, the strength of the cement mortar increased about 0.14% and 2.02% and 3.14% for 20%, 40% and 60% and decreases about 7.48% and 21.28% for 80% and 100% replacement level respectively when compared with that of conventional cement mortar. At 60% replacement levels of sand the compressive strength of both QD cement mortar and conventional cement mortar were similar. From the results

the optimum sand replacement level with QD was found to be 60%. The variation of the compressive strength with the age of the curing period and variation of the replacement proportion are shown in Fig 4.3and Fig 4.4 respectively. The failure pattern of cubes is shown in the fig 4.5

Average Compressive Strength at 3,7 and 28 days for natural sand and GBFS sand at w/c of 0.55

Combination	Compressive Strength, N/mm^2		
	3 Days	7 Days	28 Days
0% GBFS + 100% NS	22.940	30.626	41.970
20% GBFS+ 80% NS	23.401	32.041	42.520
40% GBFS +60% NS	27.551	34.626	44.553
60% GBFS + 40% NS	28.435	36.871	46.938
80% GBFS + 20% NS	24.218	28.844	42.380
100% GBFS + 0% NS	20.068	22.789	40.340

Table 4.1: Average Compressive strength

Average Compressive Strength at 3,7 and 28 days for natural sand and QD sand at w/c of 0.55

Combination	Compressive Strength, N/mm2		
	3 Days	7Days	28 Days
0% QD + 100% NS	216.940	39.310	48.970
20% QD+ 80% NS	22.585	30.204	39.931
40% QD +60% NS	27.211	31.701	41.836
60% QD + 40% NS	24.558	33.129	43.333
80% QD + 20% NS	20.272	27.891	39.047
100% QD + 0% NS	17.687	20.272	34.605

Table 4.2: Average Compressive strength

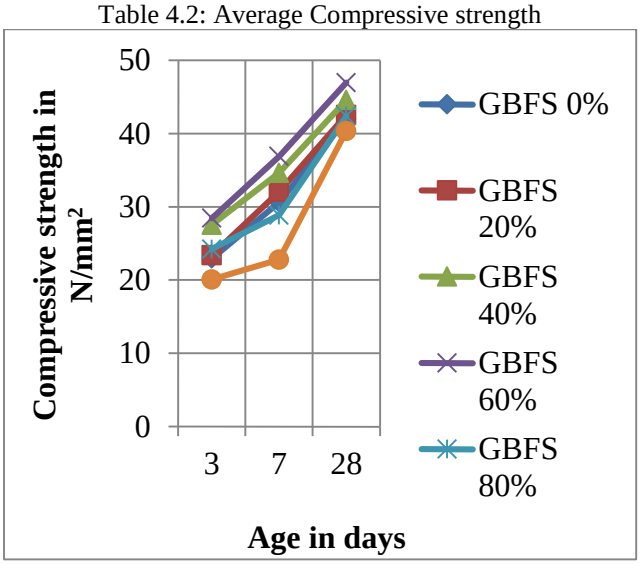

Fig. 4.1: compressive strength V/s Age in Days

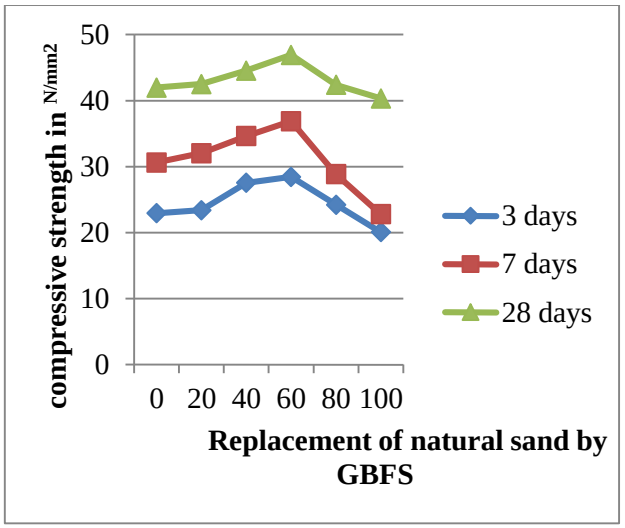

Fig. 4.2: compressive strength V/s Replacement of Natural sand by by GBFS

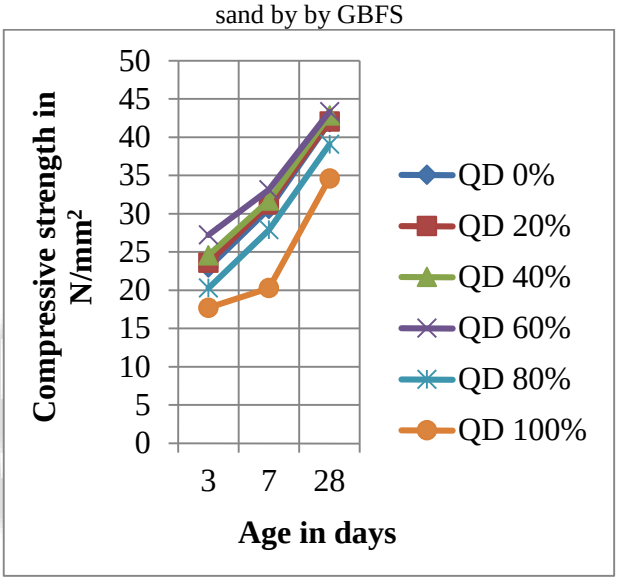

Fig. 4.3: compressive strength V/s Age in days

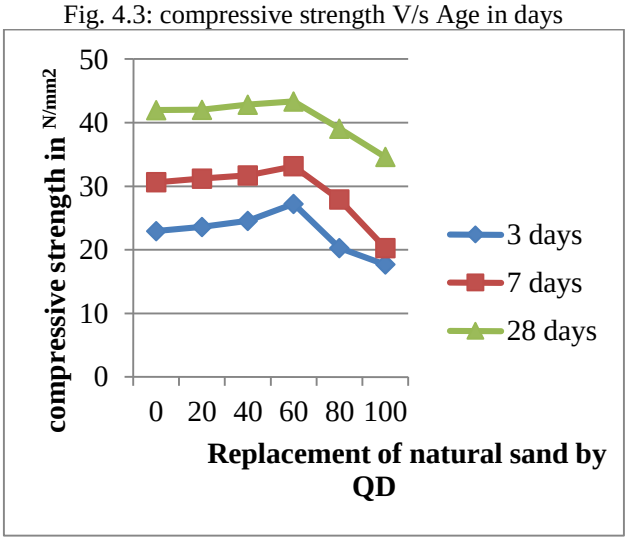

Fig. 4.4: compressive strength V/s Replacement of Natural sand by QD

Fig. 4.5: Failure pattern of cubes

V. CONCLUSIONS AND FURTHER SCOPE

A. Conclusions:

The experimental results obtained show that partial replacement of ordinary sand by granulated blast furnace slag and quarry dust gives better results over the verified range from 0, 20, 40, 60, 80 & 100 % replacement. The conclusions are drawn as below.

- Compressive strength values showed increase up to 60% sand replacement level by GBFS and QD respectively. At 60% sand replacement level mechanical properties were identical to that of conventional cement mortar. Beyond 60% all the strength values showed decrease when compared with that of conventional cement mortar.
- The maximum percentage increase in compressive strength of GBFS at 60% sand replacement was 10.58%. for 28 days.
- The maximum percentage increase in compressive strength of QD at 60% sand replacement was 3.145%. for 28 days.
- The compressive strength compression between GBFS and QD values showed increase up 60% sand replacement by GBFS is 7.43% that of quarrydust.
- • It can be concluded that concrete mix with sand replacement by GBFS and QD will be an economical and environmentally sustainable option.
- For structural purpose we can use 100% replacement of GGBS Sand.

B. Further Scope:

- Long term strength studies up to 60 days and 90 days for GGBS and QD cement mortar can be carried out.
- Durability studies can be carried out for GGBS and QD cement mortar.
- Strength can be increased by using different super plasticizers in GGBS and QD cement mortar.

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