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Replacement of Fine Aggregate by Granulated Blast Furnace Slag (GBFS) in Cement Mortar

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***Abstract*--The demand of natural sand is very high in developing countries to satisfy the rapid infrastructure growth. The developing country like India is facing shortage of good quality natural sand. Natural sand deposits are being used up and causing serious threat to environment as well as the society. This situation led us to explore alternative materials to replace river sand. Granulated Blast furnace Slag (GBFS) a waste industrial by product is one such material identified for replacement of natural sand. This paper highlights upon the comparative study for the utilization of GBFS as replacement of natural fine aggregate in construction applications (Masonry & plastering). In this investigation, Portland Pozzolana Cement (PPC) is used. Cement mortar mix of 1:3 by weight is selected for 0, 50, 60, 70, 80, 90 & 100% replacements of natural sand with GBFS. W/C ratio of 0.5 is taken for the investigation. The study gives a comparison between the GBFS mortar and cement mortar considering the strength. The partial replacement of sand with GBFS increases the strength of mortar than that of cement mortar.**

Keywords: GBFS; PPC; Flowability test; Compressive strength.

I INTRODUCTION

Sand is a most important material used for preparation of mortar and concrete. Nowadays there is a scarcity of river sand due to erosion of rivers and also due to other environmental issues. Due to the increasing popularity of concrete buildings, the demand for sand is increasing which increases the cost of sand and leads to scarcity of sand. Due to non-availability river sand, it is essential to find the new alternative material to replace the river sand. However, by use of the waste materials, the environmental impact can be reduced and this is known as waste hierarchy .The total amount of the by-products generated by the industry worldwide every year exceeds 900 million tones[1]. Many of the by-products contain toxic elements which are harmful if not disposed in safe manner. The cement and concrete industry provides a safe place for these by-products because most of the toxic metals can be permanently bound into the Portland slag cement hydration products. Fly ash (FA) is utilized as pozzolanic material in the cement worldwide which is one of the byproducts of thermal power plants. Researchers and engineers have come out with their own ideas to decrease or fully replace the use of river sand and use recent innovations such as Manufactured sand (M-sand), Granulated Blast furnace Slag (GBFS), stone crusher dust, Quarry dust, Washed bottom ash, sheet glass powder etc.

II OBJECTIVES

The aim of this study is to determine the strength of cement mortar, replacing fine aggregate with Granulated Blast furnace Slag (GBFS) by various percentages such as 0%, 50%, 60%, 70%, 80%, 90%, and 100%.

III EXPERIMENTAL INVESTIGATIONS

A. Materials used

The key materials used in this study were cement, sand, GBFS and water.

a. Cement

Portland Pozzolana cement (PPC) confirming to IS 1489(Part 1):1991 was used. The properties are determined as per relevant IS standards. The physical properties of cement are given in Table1.

Table 1.Physical properties

Description	Test value
Specific gravity	2.4
Normal consistency (%)	31.5
Initial setting time(min)	45
Fineness (%)	5.5

b. Sand

Sand is a material which is locally available. Natural sand confirms to grading zone II as per IS 383:1970. The physical properties of sand such as fineness, specific gravity, etc. are determined as per IS:2386-1963. The physical properties of sand used are given in Table 2.

c. Granulated Blast Furnace Slag (GBFS)

The GBFS was collected from Manalco Traders pvt limited, Calicut, Kerala. GBFS confirms to grading zone II as per IS 383:1970. The physical properties of sand such as fineness, specific gravity, etc. are determined as per IS:2386-1963. The physical properties of GBFS used are given in Table 2.

Table 2:Properties of fine aggregate

Fine aggregates	Natural Sand	GBFS
Specific gravity	2.7	2.89
Grading Zone	II	II
Fineness modulus	4.54	3.45
Uniformity coefficient	2.77	2.70

d. Water

The potable water from well is used for mixing and curing the mortar.

B. Casting and Testing of cubes

Cement mortar cubes was cast in 70.6mmx70.6mmx70.6mm moulds. Mixing has been carried out at room temperature (27±2ºC).Potable water was used for preparing the cement mortar cubes. 63 mortar cubes were cast with the proportion of 1:3(1 part of cement and 3 part of sand) for water cement ratio of 0.5. Three sets of cubes were cast to determine the compressive strength of cement mortar at 7, 28, and 90 days.

Table 3: Proportions of constituent materials for different replacement levels

Mix ID	Combination
M1	Cement + 0%GBFS + 100%Sand
M2	Cement + 50%GBFS + 50%Sand
M3	Cement + 60%GBFS + 40%Sand
M4	Cement + 70%GBFS + 30%Sand
M5	Cement + 80%GBFS + 20%Sand
M6	Cement + 90%GBFS + 10%Sand
M7	Cement + 100%GBFS + 0%Sand

All specimens were prepared in accordance with Indian Standard Specifications IS 516-1959 On an average 3 specimens were tested for each mix.

C. Flowability test

ASTM C 1437, the Standard Test Method for Flow of Hydraulic-Cement Mortar, determines how much a mortar sample flows when it is unconfined and consolidated. Mortar is placed inside 100mm tall conical brass mould. When the mould is removed, the mortar is vibrated at 1.67 Hz as the flow table rises and drops 15 times in 15 seconds. The mortar changes from a conical shape with a 120mm base to a "pancake." Mortar flow is reported as a percentage based on the change in diameter from 120mm to the final diameter of the mortar "pancake."

D. Compressive strength

The Compressive strength of mortar cubes for various mix proportions as per IS 516:1959. The compressive strength development of cement mortar containing different replacement percentage of GBFS at 7, 28, 90 days curing is determined.

IV RESULTS AND DISCUSSIONS

A. Flowability test

The flow values of cement mortar containing different replacement percentage of GBFS is shown in Table 4.

Table 4: Flow values

Mix ID	Flow value at 15 blows (%)	Flow value at 30 blows(%)	Flow value at 45 blows (%)
M1	21.7	39.2	50
M2	22.5	62.5	85.8
M3	34.2	70	88.3
M4	22.5	53.3	85
M5	37.8	51.7	76.7
M6	22.5	57.5	80
M7	29.2	75.8	89.2

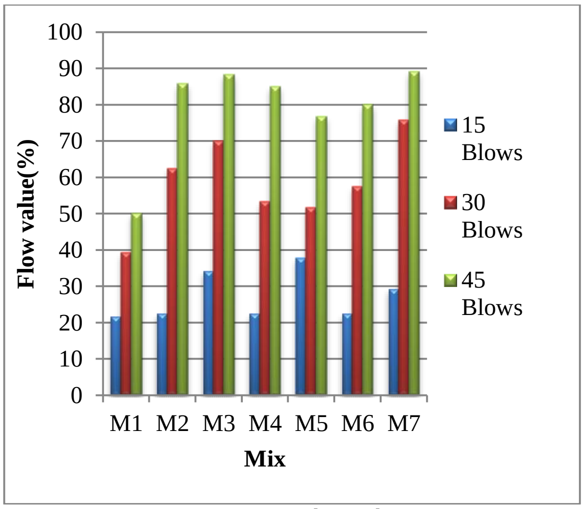

Fig 1.Mix Vs Flow Value

The flow value goes on increasing up to 60% replacement than cement mortar, and then it decreases up to 80% replacement. Further replacement of sand leads increase in flow value. Maximum flow value is at 100% replacement.

B. Compressive strength:

The compressive strength development of cement mortar containing different replacement percentage of GBFS at 7, 28, 90 days curing is shown in table 5.

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Table 5: Compressive strength at 7,28 and 90 days for different replacement of natural sand by GBFS

Mix ID	Compressive Strength (MPa)		
	7 days	28 days	90 days
M1	17.89	23.24	31.61
M2	18.75	26.60	34.56
M3	18.25	22.79	26.12
M4	17.50	21.68	24.46
M5	17.47	21.38	23.95
M6	16.40	20.37	21.11
M7	15.79	18.56	20.39

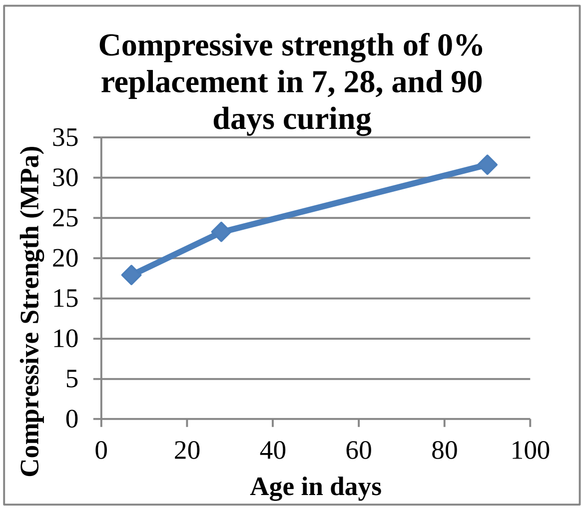

Fig 2.Compressive strength of 50% replacement

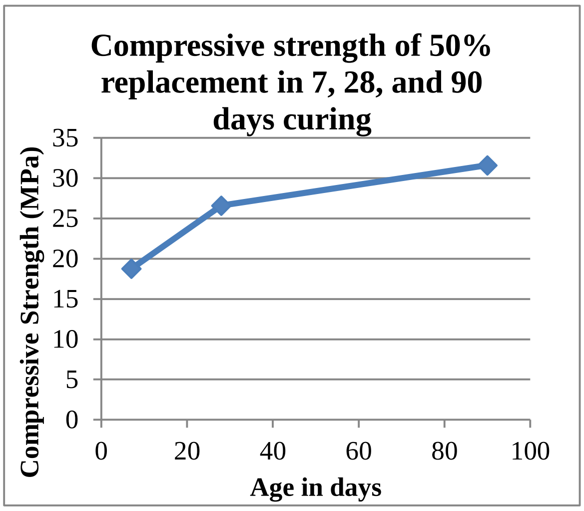

Fig 3.Compressive strength of 50% replacement

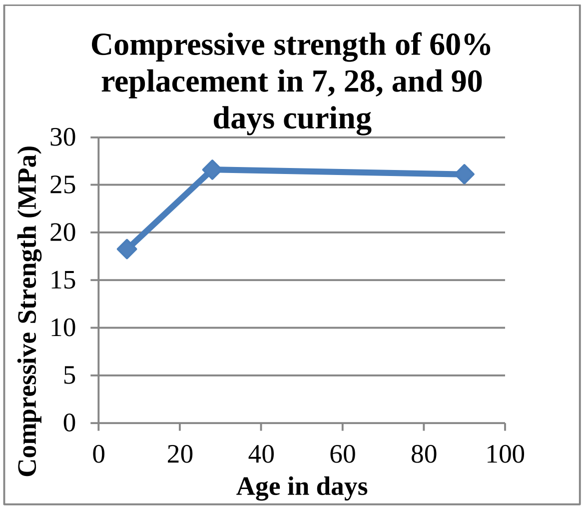

Fig 4.Compressive strength of 60% replacement

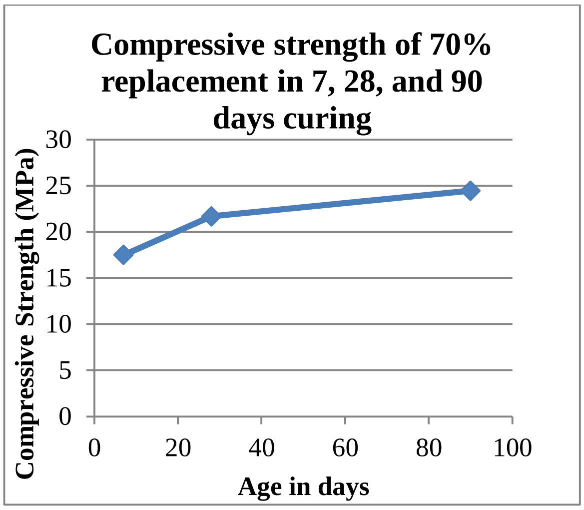

Fig 5.Compressive strength of 70% replacement

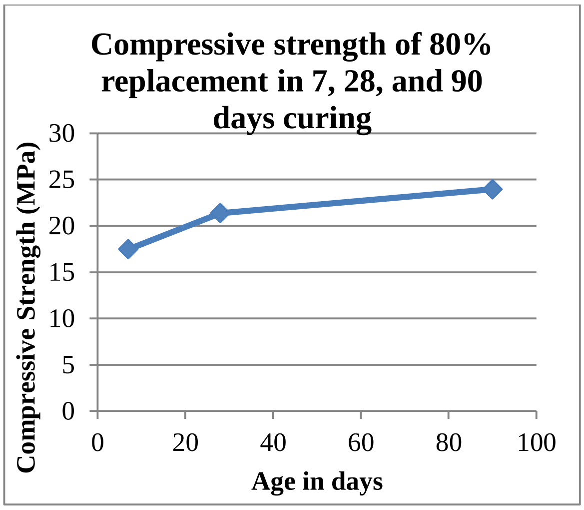

Fig 6.Compressive strength of 80% replacement

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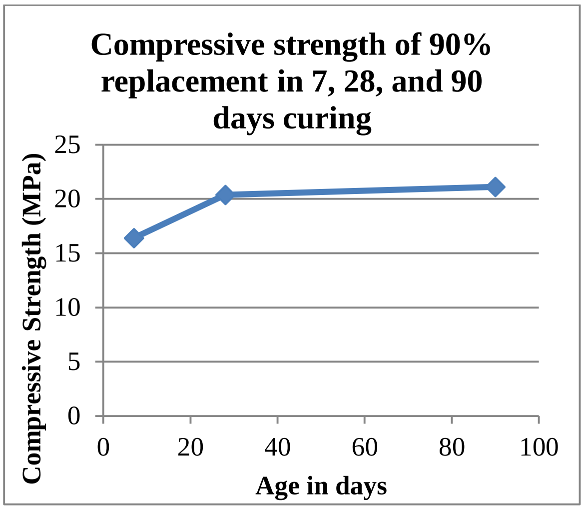

Fig 7.Compressive strength of 90% replacement

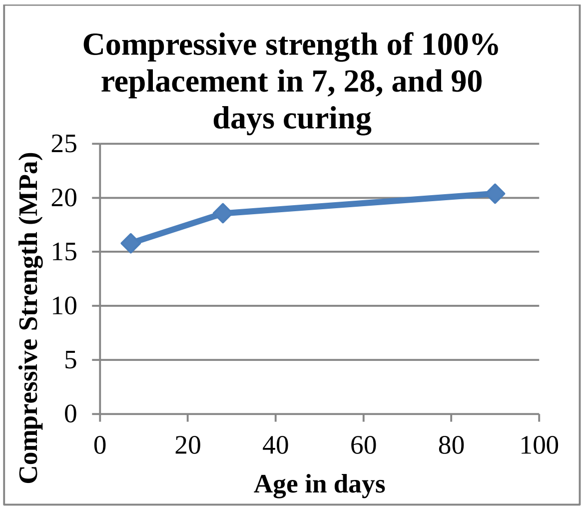

Fig 8.Compressive strength of 100% replacement

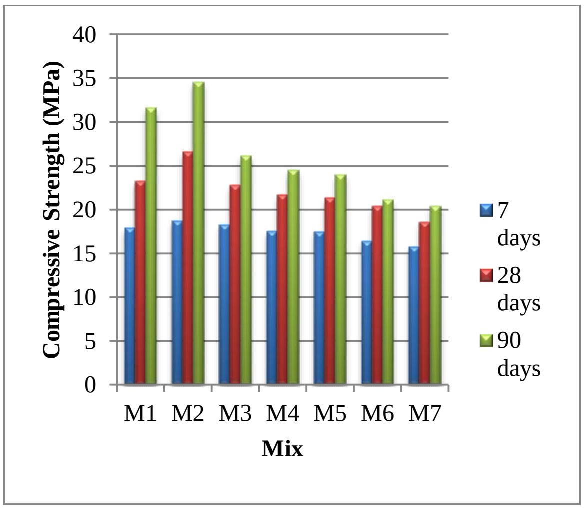

Fig 9.Mix Vs Compressive strength

50% replacement of natural sand with GBFS give better compressive strength than that of cement mortar. For 50% replacement the compressive strength is increased by 9.53%. There is reduction in compressive strength by 13.8, 5.11, 2.24, 7.56, and 5.34% for 60, 70, 80, 90, and 100% replacement respectively. It shows that, significant amount of decrease in compressive strength of cement mortar made with GBFS when compared with cement mortar.

V CONCLUSIONS

- In mortar, 50 to 80% replacement was found favorable to increase the flow properties with maximum flow value at 50% replacement. It is lower in 90% replacement compared to cement mortar.
- The compressive strength is maximum at 50%.Further increase in replacement percentage leads a reduction in compressive strength.
- Hence 50% GBFS can be used as fine aggregate without affecting any properties of mortar.

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