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Performance of M60 Grade Concrete with Full and Partial Replacement of Crushed Sand by Granulated Blast Furnace Slag (GBFS) in OPC Concrete

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ABSTRACT: The over usage of manufactured sand (crushed sand)in construction has so many rocks which takes millions of years to form again. The construction industry is forced to look for replacement of fine aggregate. We can balance the ecology on the earth by using replacement of fine aggregate by industrial byproduct. It further reduces the pollution effect on the environment by increasing the usage of industrial byproducts in our construction industry. In this context we conduct a study to check feasibility of use of GBFS (Granulated Blast Furnace Slag) as alternate to manufactured sand in OPC Concrete.This experimental study focuses on investigating behavior of M60 grade of concrete by full and partial replacement of fine aggregate by Granulated blast furnace slag (GBFS). Cubes, cylinders and beams are tested forcompressive strength, split tensile strength and flexural strength respectively after 7 days and 28 days curing. In this study replacement percentage of fine aggregate by GBFS is 30%, 50%, 80% and 100%. When the test results of full and partial replacement by GBFS with 100% crushed sand in the concrete are compared, it shows that with increase in percentage of GBFS the mechanical properties and resistance to sulphate attack has significantly increased.

KEYWORDS: ecology, byproduct, Granulated Blast Furnace Slag

I. INTRODUCTION

Cement, sand and aggregate are essential needs for any construction industry. Sand is a major material used for preparation of mortar and concrete and plays a most important role. In general consumption of natural sand is high, due to the large use of concrete and mortar. Hence the demand of natural sand is very high in developing countries to satisfy the rapid infrastructure growth. The developing country like India facing shortage of good quality natural sand and particularly in India, natural sand deposits are being used up and causing serious threat to environment as well as the society. Rapid extraction of sand from riverbed causing so many problems like losing water retaining soil strata, deepening of the riverbed sand causing bank slides, loss of vegetation on the bank of rivers, disturbs the aquatic life as well as disturb agriculture due to lowering the water table in the well etc. are some of the examples.

As the deposits of natural sands have been slowly been depleted, it has become necessary and economical to produce manufactured fine aggregate (MFA) or crushed sand or robo sand. Crushed sand is a fine aggregate processed from quarried stone that is crushed and classified to obtain a controlled gradation and a cubical to angular particle shape.
In the present scenario, the usage of crushed sand is also one of the environmental concerns leading to the depletion of rock formations. As the formation of rock takes millions of years to form again, therefore the construction industry is forced to look for alternative materials in the form of fine aggregate.

Preventing the depletion of natural resources and enhancing the usage of industrial by-products which causes so many environmental problems has become a challenge to the scientist and engineers. A number of studies have been conducted concerning the protection of natural resources, prevention of environmental pollution and contribution to the economy by using these industrial by-products.

The two major by-products of industry are slag and fly ash. In India, the annual production of fly ash is about 170 million tons, but about 35 percent of the total is being utilized, which is very low. Owing to its ultra-fineness,

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pozzolaniccontribution and other properties, the use of fly ash makes a cost of disposal and to reduce environmental pollution, it is an imperative to increase the quantity of fly ash utilization. Similarly, the Steel industry in India is producing about 24 million tons of blast furnace slag and 12million tons of steel slag.

Granulated Blast Furnace Slag (GBFS):

Granulated Blast Furnace Slag is a by-product of the steel industry. It is defined as "the non-metallic by-product consisting essentially of calcium silicates and other bases that is developed in a molten condition simultaneously with iron in a blast furnace." The iron ore, which is made up of iron oxides, silica, and alumina, comes together with the fluxing agents; molten slag and iron are produced. The molten slag then goes through a particular process depending on what type of slag it will become. Granulated blast furnace slag (GBFS) is produced when molten slag is quenched rapidly using water jets, which produces a granular glassy aggregate. This glassy aggregate with little fines used as fine aggregate replacement in the present investigation. The use of slag in making concrete or mortar by partial/full replacement of fine aggregate not only provides economy in cost of construction but also solves the problem of disposal of slag.

Presently, use of slag in India is to the tune of 25 to 30 % by cement industry rest is mostly unused.

II. METHODOLOGY

The methodology of the present study is to compare the mechanical properties of conventional concrete and concrete in which fine aggregate (Crushed sand) replaced with 30%, 50%, 80% and 100% of GBFS at water cement ratio of 0.32 with both OPC (Ordinary Portland cement) and PPC (Portland pozzolana cement). This study also involves the comparison with respect to workability of 100mm slump and durability criteria.

Materials

The materials used in this investigation are as follows,

Cement OPC (ordinary Portland cement), Flyash, Micro Silica, Crushed Sand, Coarse Aggregate(20 mm, 12.5 mm) Granulated Blast Furnace Slag, Super Plasticizer (PCE Based), Water.

Materials Properties

Table 1: Properties of Ordinary Portland Cement

CEMENT	Results obtained
1. Specific gravity	3.15
2. Fineness	2.95 %
3. Initial setting time	145 min
4. Final setting time	215 min
5.Soundness (Le-chatelier)	0.6mm
6.Compressive strength for 3 days	32 MPa (min 27MPa)
7.Compressive strength for 7 days	50 MPa (min 37MPa)
8.Compressive strength for 28 days	70 MPa (min 53MPa)

Table 2 Properties of Fine Aggregate (Crushed Sand)

FINE AGGREGATE	Results obtained
1. Specific gravity	2.65
2. Fineness modulus	2.67
3. Water absorption	4%

Table 3: Properties of Coarse Aggregate

COARSE AGGREGATE	Results obtained
1. Specific gravity	2.80
2. Impact value	9.22
3. Crushing value	0.815
4. Water absorption	0.04%

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Table 4: Properties of Granulated Blast Furnace Slag

Granulated Blast Furnace Slag(GBFS)	Results obtained
1. Specific gravity	2.85
2. Fineness modulus	2.86
3. Impact value	9.22
4. Crushing value	0.815
5. Water absorption	1%

Primary tests on materials
Tests on cement
Specific gravity of cement, Fineness of Cement, Initial and Final Setting of Cement, Soundness, Compressive strength test.
Test on fine and coarse aggregates
1. Sieve analysis, Specific gravity of aggregates, Water Absorption, Crushing and Impact values of Coarse aggregates.
Tests on Hardened Concrete
1. Compressive Strength Test
2. Flexural Strength Test
3. Split Tensile Test

III. RESULTS AND DISSCUSSIONS

COMPRESSIVE STRENGTH TEST RESULT

Table 5 Percentage increase in compressive strength of OPC concrete from target mean strength.

Composition	Target Mean Strength Of 7 Days	Compressive Strength For 7 Days	Target Mena Strength For 28 Days	Compressive Strength for 28 days	% increase of compressive strength from 28 days target mean strength
M60/OPC/100%CS	46.58	55.79	68.25	83.61	22.50
M60/OPC/30% GBFS	46.58	70.54	68.25	85.6	24.77
M60/OPC/50% GBFS	46.58	70.64	68.25	86.62	26.91
M60/OPC/80% GBFS	46.58	72.23	68.25	87.26	27.85
M60/OPC/100% GBFS	46.58	74.74	68.25	94.63	38.65

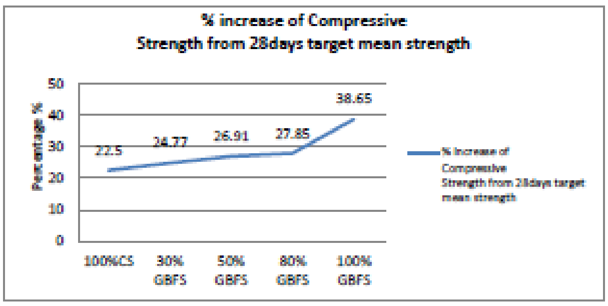

Fig 1: Percentage increase in compressive strength of OPC concrete from target mean strength

1.In**M60/OPC/100%GBFS**the percentage increase of compressive strength from 28 days target mean strength is38.65% and is high, compared with other proportions.

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2. From the above graph we can understand that the initial strength (7 days strength) achieved are more in partial and full replacement of fine aggregate with GBFS.

3. It is observed that the Target Mean strength i.e., 46.58 N/mm2 for7 days cured specimens and 68.25N/mm2 for 28 days cured specimens has been achieved in OPC concrete in all proportions.

FLEXURAL STRENGTH TEST RESULT

Table 6: Percentage increase in flexural strength with reference mix and target mean strength

COMPOSTION	TARGET MEAN STRENGTH (0.7^fck) (N/mm2)	FLEXURAL STRENGTH (28 DAYS STRENGTH) (N/mm2)	% increase of Flexural Strength With reference sample	% increase of Flexural Strength from 28daystarget mean strength
M60/OPC/100%CS	5.42	6.89	-	27.12
M60/OPC/30% GBFS	5.42	6.93	0.58%	27.85
M60/OPC/50% GBFS	5.42	6.96	1.01%	28.41
M60/OPC/80% GBFS	5.42	7.33	6.38%	35.23
M60/OPC/100% GBFS	5.42	7.45	8.12%	37.45

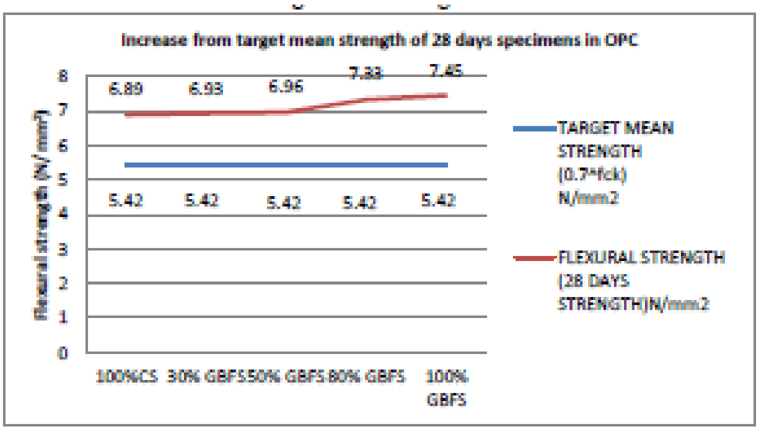

Fig2: Increase in Flexural strength of OPC concrete from target mean strength

1.From the above table, the flexural strength of OPC concrete has achieved the target mean strength of 0.7√fck i.e., 5.42 N/mm2 in all the proportions
2. The strength obtained is going on increasing as replacement of GBFS is increasing, by fulfilling the target mean strength criteria
3. The percentage increase of flexural strength from the reference is also following the increasing trend.

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SPLIT TENSILESTRENGTH TEST RESULT

Table 7: Percentage increase in compressive strength of OPC concrete from target mean strength.

Composition	Target Mean Strength (0.7^Fck) (N/Mm2)	Split Tensile Strength (28 Days Strength) (N/Mm2)	% increase in Split tensile Strength With reference sample	% increase in Strength from 28daystarget mean Strength
M60/OPC/100%CS	5.42	5.45	-	0.55
M60/OPC/30% GBFS	5.42	5.66	3.09%	4.40
M60/OPC/50% GBFS	5.42	5.50	-0.18%	1.47
M60/OPC/80% GBFS	5.42	5.74	7.69%	5.90
M60/OPC/100% GBFS	5.42	5.91	10.88%	9.04

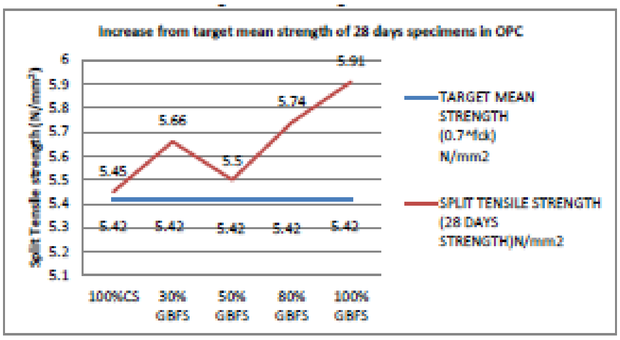

Fig 3: Increase in Split Tensile strength of OPC concrete from target mean strength

1. From the above table, the spilt tensile strength of OPC concrete has achieved the target mean strength of 0.7√fck i.e., 5.42 N/mm2.

2. The strength obtained first increased in 30% replacement and then decreased in 50% replacement then goes on increasing up to 100% replacement, by fulfilling the target mean strength criteria.

IV. CONCLUSIONS

The following conclusions were drawn based on the experimental results obtained.

- The maximum **compressive strength** of 94.63 N/mm2 at 28 days was obtained in OPC concrete by replacing 100% crushed sand with granulated blast furnace slag.
- Percentage increase in **flexural strength** with respect to the reference mix [M60/OPC/100%CS] is 8.12% at 28 days in OPC concrete by replacing 100% crushed sand with granulated blast furnace slag.
- Percentage increase in **split tensile strength** with respect to the reference mix is 10.88% at 28 days in OPC concrete by replacing 100% of the crushed sand with granulated blast furnace slag.
- In OPC concrete, when crushed sand is replaced with 100% granulated blast furnace slag, there is a decrease in workability which is adjusted by increasing the **superplasticizer** by 54.40% with respect to reference mix to get 100mm slump.
- Therefore, It is recommended that 100% crushed sand can be replaced by Granulated Blast Furnace Slag (GBFS) in high grade concrete (M60). The decrease in workability can be adjusted by increasing the dosage of superplasticizer.

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