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EFFECT OF PARTIAL AND FULL REPLACEMENT OF FINE AGGREGATE WITH GRANULATED BLAST FURNACE SLAG (GBFS)

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Abstract- Cement, sand and aggregates are vital materials in construction industry. Among these items, sand plays an important role in preparation of mortar and concrete. There is a high demand of natural sand in the developing countries like India as the infrastructure of these countries are rapidly growing. Due to continuous consumption, these countries are facing deficiency of these natural sands and also the use of these natural resources beyond a permissible level is posing a great threat to our environment which in turn affects the society that we live in. This issue makes us look for a substitute that can be used instead of the natural sands that are found in rivers. Granulated Blast Furnace Slag is widely used as the substitution of natural sand. It is an industrial by-product which successfully functions as an alternative of Granulated Blast Furnace (GBFS). This paper will make a comparative study for use of GBFS as a substitution for natural sands in plastering and masonry. The current study compares the mechanical properties of conventional concrete and concrete in which fine aggregate (crush sand) is replace with 30%, 50%, 80% and 100% of GBFS at a water cement ratio of 0.32 with PPC (Portland pozzolana cement).

Keywords: GBFS; PPC; Flexural Strength; Split Tensile Strength; Compressive strength.

I. INTRODUCTION

In the preparation of concrete, sand is the most important material used. Today, the world is facing a lot of environmental issues among which include erosion of rivers. This leads to scarcity of sand. Overconsumption of the natural sands due to higher demand owing to the rapidly developing infrastructure may also be counted as a factor for the scarcity of natural sand. It also leads to the increase of cost of sand. So, this makes it necessary to find another alternative of the natural sand so as to solve the problem of the shortage of sand and also to solve the problem cause by the price rise of sand. Engineers and researchers have introduced new types of materials which can replace natural sand and solve the problems caused by the scarcity of natural sand and also contribute to the improvement of the quality of our environment. Granulated Blast Furnace Slag is one such innovative material. It is a by-product of steel industry. The use of GBFS is useful on two different levels. First of all, it is advantageous to the environment as the industrial waste is being reused and the toxic substance contained in it is bound to the concrete permanently. It is also economical since natural sands are costlier due to scarcity.

II. OBJECTIVE

The objective of the current study is:

i. To study the effect of partial and full replacement of fine aggregate with Granulated blast furnace slag (GBFS) on strength and durability characteristics of high strength (M60) concrete.
ii. To find out the optimum percentage replacement of the aggregate by GBFS.
iii. To achieve sustainability in the environment by using industrial by-products rather than disposing them in landfills which causes so much environmental problems?

III. EXPERIMENTAL INVESTIGATIONS

A. Materials used

The materials used in this investigation are as follows:

a. Cement

Portland Pozzolana cement which is also commonly used as PPC, conforming to IS 1489 was used in this study. These types of cement are used by using pozzolanic materials as one of most important materials.

Table1.Properties of Cement

CEMENT	Test Value
1. Specific gravity	2.9
2. Fineness	331 m_2/kg
3. Initial setting time	135 min
4. Final setting time	190 min
5. Soundness (Le-chatelier)	0.5mm

b. Coarse Aggregate

Gravel was used as coarse aggregate for this investigation. The size of the gravel used is 20mm.

c. Fine Aggregate

- Crushed sand conforming to IS 383 was used. When an aggregate is sieved through 4.7 mm sieve and the aggregate passes through it, it is called fine aggregate.
- Granulated blast furnace slag (GBFS) is used as a replacement of fine aggregate.

Table2-Properties of Aggregates

	Fine aggregate(crushed sand)	Coarse Aggregate	GBFS
Specific Gravity	2.65	2.80	2.85
Grading Zone	II		II
Fitness modulus	2.67		2.86
Water absorption	4%	0.4%	1%

d. Micro Silica

Micro Silica also known as Silica fume, is an amorphous polymorph of silicon dioxide, silica. Silica fume is added to Portland cement concrete to improve its properties, in particular its compressive strength, bond strength, and abrasion resistance.

e. Chemical Admixtures

Super Plasticizers conforming to IS 9103:1999 was used. It is a chemical admixture which is used in concrete to increase the workability, with minimal use of water. Poly carboxylic ether(PBE) based super plasticizer was used from ECMAS.

B. Casting and curing of cubes, cylinder and beam

In this investigation, the mix design is carried out as per IS 10262:2009 for M60 grade of concrete with full and partial replacement of fine aggregate with GBFS. The composition of the concrete is as follows:

M60 Cement +Micro Silica +CA+FA(Crushed Sand) 100%
M60Cement+Micro Silica+CA+30% GBFS
M60 Cement+Micro Silica+CA+50% GBFS
M60 Cement+Micro Silica+CA+80% GBFS
M60 Cement+Micro Silica+ CA+100% GBFS

The concrete cubes, cylinder and beam are casted after mixing the concrete by hand or by mixing machine at the room temperature (27 +- 2 degree C). Potable water was used for preparing the concrete block. The concrete block was casted on different composition and the casted specimens were kept immersed in water for 7 days and 28 days, which is known as conventional concrete curing by immersion method in a curing tank.

C. Testing of concrete

The crushed sand is replaced by GBFS of 30%,50%,80% and 100% respectively in M60 grade concrete. Then the cubes, beams and cylinders are tested for the compressive strength, flexural strength and split tensile strength respectively for 7 days and 28 days.

The types of specimens used are:

1. Cubes of size 150*150*150 mm
2. Beams of size 100*100*500 mm
3. Cylinders of 150 dia *300 mm

i. Compressive strength test

The compressive strength of concrete is given in terms of the characteristic compressive strength of 150 mm size cubes tested at 7 days and 28 days. The characteristic strength is defined as the strength of the concrete below which not more than 5% of the test results are expected to fall.

ii. Flexural Strength Test

Concrete is relatively strong in compression and weak in tension. In reinforced concrete members, little dependence is placed on the tensile strength of concrete since steel reinforcing bars are provided to resist all tensile forces. However, tensile stresses are likely to develop in concrete due to drying, shrinkage, rusting of steel, temperature gradient and many other reasons. Therefore, the knowledge of tensile strength is important. A beam test is found dependable to measure the flexural strength properties of concrete.

iii. Split Tensile Test

The tensile strength of concrete is one of the basic and important properties. Splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete. The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. The concrete develops cracks when subjected to tensile forces. Thus, it is necessary to determine the tensile strength of concrete to determine the load at which the concrete members may crack.

IV. RESULTS AND DISCUSSIONS

A. Compressive Test Result Discussion

Table 3: Percentage increase in compressive strength of PPC concrete from target mean strength.

COMPOSTION	COMPRESSIVE STRENGTH (7 DAYS STRENGTH) (N/mm²)	Target Mean Strength Of 28 days	COMPRESSIVE STRENGTH (28 DAYS STRENGTH) (N/mm²)	% increase of Compressive Strength from 28daystarget mean strength
M60/PPC/100%CS	73.67	68.25	103.06	51.00
M60/PPC/30% GBFS	59.69	68.25	87.66	28.43
M60/PPC/50% GBFS	60.87	68.25	88.83	30.15
M60/PPC/80% GBFS	67.53	68.25	95.33	39.67
M60/PPC/100% GBFS	75.79	68.25	96.93	42.02

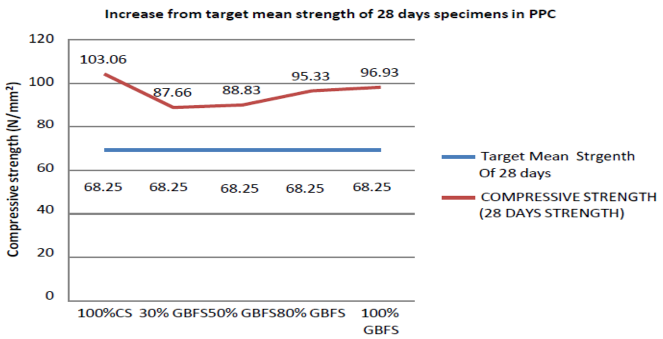

Fig1. - Percentage increase in compressive strength of PPC concrete from target mean strength.

B . Flexural test result discussions

Table 4 : Percentage increase in flexural strength with reference mix and target mean strength in PPC.

COMPOSTION	TARGET MEAN STRENGTH (0.7^f_{ck}) (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/PPC/100 %CS	5.42	6.19	-	14.20
M60/PPC/30 % GBFS	5.42	6.13	-0.96%	13.09
M60/PPC/50 % GBFS	5.42	6.21	0.32%	14.57
M60/PPC/80 % GBFS	5.42	6.88	11.14%	26.93
M60/PPC/100 % GBFS	5.42	7.47	20.67%	37.82

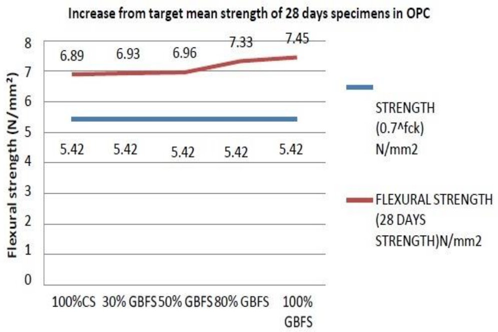

Fig 2 -Increase in flexural strength in PPC Concrete

C. Split Tensile Strength Test Result Discussions

Table 5: Percentage increase in Split Tensile Strength with reference mix and target mean strength in PPC.

COMPOSTION	TARGET MEAN STRENGTH (0.7^f_{ck}) (N/mm²)	SPLIT TESILE STRENGTH (28 DAYS STRENGTH) (N/mm²)	% increase of Split tensile Strength With reference sample	% increase in Strength from 28daystarget mean Strength
M60/PPC/100%CS	5.42	5.55	-	2.39
M60/PPC/30% GBFS	5.42	5.69	4.74%	4.98
M60/PPC/50% GBFS	5.42	5.72	5.53%	5.53
M60/PPC/80% GBFS	5.42	6.51	20.11%	20.11
M60/PPC/100% GBFS	5.42	5.81	7.19%	7.19

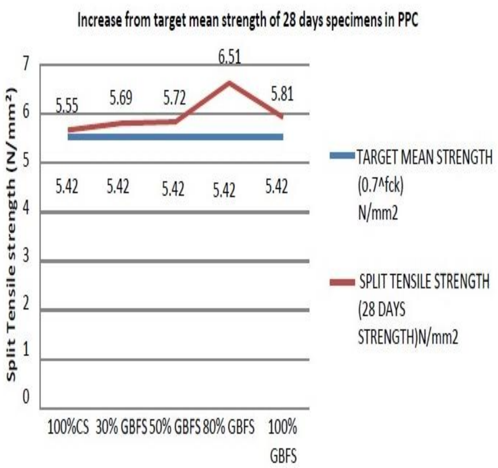

Fig: Increase in split Tesile strength of PPC concrete from target mean strength

WORKABILITY:

Table 6 : Percentage increase of Plasticizer in PPC

COMPOSITION	DESIGN SLUMP (mm)	SUPERPLASTIZIER (ml)			% increase of Superplasticizer	% increase of Superplasticizer with respect to design quantity
		Design quantity	Extra Quantity added	Total superplasticizer		
M60/PPC/100 %CS	100	2081.25	352.35	2433.60	-	16.92
M60/PPC/30% GBFS	100	2081.25	1115.79	3197.04	31.37	53.61
M60/PPC/50% GBFS	100	2081.25	1321.33	3402.58	39.81	63.48
M60/PPC/80% GBFS	100	2081.25	1468.15	3549.40	45.84	70.54
M60/PPC/100 % GBFS	100	2081.25	1614.96	3696.21	51.88	77.59

CONCLUSION

- The percentage increase in compressive strength is 42.02% at 28 days in PPC concrete by replacing 100% of the crushed sand with granulated blast furnace slag with respect to target mean strength [68.25 N/mm2].
- Percentage increase in flexural strength with respect to the reference mix [M60/PPC/100%CS] is 20.67% at 28 days in PPC concrete by replacing 100% of the crushed sand with granulated blast furnace slag.
- Percentage increase in split tensile strength with respect to the reference mix at 28 days is 20.11%, 7.19% in PPC concrete by replacing 80%, 100% of the crushed sand with granulated blast furnace slag respectively
- In PPC concrete by replacing 100% of the crushed sand with granulated blast furnace slag, there is an increase in superplasticizer addition by 51.88% 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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