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OPTIMISATION OF CONCRETE INCORPORATING PARTIAL REPLACEMENT OF CEMENT BY GGBFS AND NATURAL SAND BY GBF SLAG SAND

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Abstract— Since the past decade, sustainable and eco-friendly living has been a topic of concern to people from all walks of life. However, not much effort has been made towards putting an effective solution on ground for the fast depleting river beds despite the fact that sand plays a very vital role in the construction industry. Also global warming caused due to the emission of CO_2 during the hydration process of cement concrete caused a main concern. Further, this paper re-affirms the scope for use of industrial by-products in the manufacture of concrete in all possible aspects including practicability, economic feasibility and ecological benefits. GGBFS (Ground Granulated Blast Furnace Slag) and GBF Slag Sand is one such waste product of the iron manufacturing industry, whose use and production has increased many folds during last decades is used in this experimental work as alternative binder and filler materials for Ordinary Portland Cement (OPC) and River Sand respectively in concrete. M40 grades of concrete was considered for a water content (w/c) 0.4 and slag sand replaced by 40%,50%&60% with river sand and GGBFS replacements of 30%, 40%, 50% with cement to investigate the properties of compressive strength, split tensile strength, flexural strength of concrete mix. And also optimization of concrete has been checked to get the required target mean strength. The optimum strength of concrete was obtained for the mix having 40% GGBS and 50% Slag sand (58.41 N/mm^2).

***Keywords*— GBF Slag Sand, GGBFS, Workability, Density, Compressive Strength, Flexural Strength, Split tensile Strength, Modulus of Elasticity**

I. INTRODUCTION

Sustainable concrete is the main emphasis given to the present generation to produce concrete so as to overcome the scarcity of natural river sand and the environmental destruction (i.e. global warming) caused due to the emission of CO_2 during the hydration process of cement concrete. Hence, a concrete that can be sustained for a very long period of time and for the future generations to come is to be focused and stressed on. Concrete, that is most versatile building material used all over the globe in the construction industry has to be eco-friendly, economical and sustainable in terms of technical and non-technical aspects. Isayuksela [1], he presents investigation of how the usage of bottom ash (BA), granulated blast furnace slag (GBFS), and combination of both of these materials as fine aggregate in concrete affects the concrete durability. Veena G. Pathan [2], made an experimental investigations carriedout to evaluate effects of replacing GGBS as cement in concrete to with respect to workability and compressive strength. Concrete mix with 40% replacement of cement with GGBFS gave higher compressive strength. Mohammed Nadeem [3], Experimental investigation of using slag as an alternative to normal Aggregates (course and fine) in concrete. He present results of experimental investigations carried out to evaluate effects of replacing aggregate (coarse and fine) with that of slag on various concrete properties. Sreekrishnaperumal Thanga [4] Based on experiments replacing natural sand by furnace slag and welding slag found out that Different fine aggregate replacements have been studied by substituting 5%, 10%, and 15% of slag the welding and furnace slag‘s . It was concluded that the optimum compressive strength of concretes after 28 days has been found to be 41 N/mm2 for 5% welding slag and 39.7 N/mm2 for 10% furnace slag replacements.

II. Experimental programme

A. Materials Used:

In present work various materials is used with their respective properties namely: OPC 43 Grade, GGBS, Fine aggregates: Natural River sand and Slag sand (SS), coarse aggregate, Super-plasticizer, and Water

1) Cement:

Ordinary Portland cement of 43 grades conforming to IS: 12269-1987 has been used. The physical properties of the cement obtained on conducting appropriate tests as per IS: 12269-1987.

Table 1: Basic properties of cement

Properties	Cement
Specific gravity	3.1
Standard consistency	31%
Initial setting time	38min
Final setting time	480min
Fineness	5.3%

2) GGBS:

GGBS used in this experimental work is procured from JSW Cements. The physical were: Specific Gravity=2.90, Standard Consistency= 34%, Initial setting time= 180 minutes as per IS: 4031- 1988.

3) Fine Aggregates:

Locally available clean river sand passing through IS-480 sieves have been used. The results of sieve analysis conducted as per the specification of IS: 383-1970. The fine aggregate was of Zone II, Fineness Modulus =2.60, Specific Gravity= 2.66 and loose bulk density of 1.47 g/cc.

4) Slag Sand:

The Granulated Blast Furnace Slag used in the present investigation was collected from JSW steel plant, district of Bellary. The tests on granulated blast furnace slag were carried out as per IS: 383-1970. Slag sand was of Zone 2. Fineness Modulus = 2.63, Specific gravity = 2.63, loose bulk density of 1.43 g/cc.

5) Coarse Aggregates:

The coarse aggregate used is crushed (angular) aggregate conforming to IS 383: 1970. The maximum size of aggregate considered is 20mm IS sieve passing and minimum size of aggregate considered is 12.5mm IS sieve passing. The results of sieve analysis conducted as per the specification of IS: 383-1970. Fineness Modulus =7.30, Specific Gravity= 2.60.

6) Water:

Clean potable water is used for casting and curing operation for the work. The water supplied in the campus is of the potable standard of pH value= 7.50 are used.

7) Super Plasticizer:

To improve the workability of fresh concrete sulphonated naphthalene based super plasticizer i.e., Conplast SP 430 was used supplied by FOSROC chemicals, 0.75% (max 2%) dosages was used to increase the workability of concrete.

B) Mix Proportion:

Concrete mix design of M40 grade was designed conforming to IS: 10262-2009 is prepared and trial mixes were attempted to achieve workable concrete mix. Cubes of standard size 100x100x100mm, Beam of size 500x100x100mm and cylinders of diameter 100mm and height 200mm were casted and cured at room temperature. Cubes were tested at 7 and 28 days, cylinders and beams were tested for 28 days.

Table 2: Concrete mix design

Unit of batch	Water (Litters)	Cement (Kgs)	FA (Kgs)	CA (Kgs)	Super plasticizer
Cubic meter of concrete	168	425	685	1127	3.2
Ratio of ingredients	0.4	1	1.61	2.65	0.75%

Table 3: Mix Proportions in Kg/M3

Mix	Cement	GGBFS	River sand	GBF Slag	Coarse aggregate	Water (lts)	Super Plasticizer
CM	425		685		1127	170	3.19
M1	297.5	127.5	685		1127	170	3.19
M2	255	170	685		1127	170	3.19
M3	212.5	212.5	685		1127	170	3.19
M4	425		411	274	1127	170	3.19
M5	425		342.5	342.5	1127	170	3.19
M6	425		274	411	1127	170	3.19
M7	297.5	127.5	411	274	1127	170	3.19
M8	297.5	127.5	342.5	342.5	1127	170	3.19
M9	297.5	127.5	274	411	1127	170	3.19
M10	255	170	411	274	1127	170	3.19
M11	255	170	342.5	342.5	1127	170	3.19
M12	255	170	274	411	1127	170	3.19
M13	212.5	212.5	411	274	1127	170	3.19
M14	212.5	212.5	342.5	342.5	1127	170	3.19
M15	212.5	212.5	274	411	1127	170	3.19

C) Fresh Concrete Properties:

The test results showed that slump flow has slightly reduced has Slag sand content varied but improved as the GGBS content is increased. The slump value is increased compared to the control mix, however all the concrete mixes were homogeneous and cohesive in nature also the slump had shear type of failure as the GGBS content was increased. No segregation and bleeding in any of the mixes were observed.

Fig 1*:* Slump test

D) Hardened Concrete Properties:

Compressive strength, splitting tensile strength and modulus of rupture of different mixes were determined.

III. TEST ON HARDEN CONCRETE

A) Compressive Strength:

The cubes of size 100mm×100mm×100mm are casted for various percentages of GGBS by (0%, 30%, 40% and 50%) and Slag sand (SS) 0%, 40%,50% & 60% The cubes are cured and tested for 7 and 28 days. Testing was made in 2000kN testing machine with loading rate of 140kg/cm/m^2. The average of 3 cubes for each curing and each replacement is noted down to get the compressive strength of concrete.

B) Split Tensile Strength:

The splitting tensile strength is well known indirect test used for determining the tensile strength of concrete as it is one of the most important fundamental properties of concrete. Three cylinders of size 100mm diameter and 200m in length are casted for various percentages of GGBS by (0%, 30%, 40% and 50%) and Slag sand (SS) 0%, 40%,50% & 60% and cured for 28 days for each replacement of GGBS and Slag sand (SS). Testing was made in 2000kN testing machine at rate of loading as (1.2 to 2.4) (π/2) l*d, N/min. The average of three cylinders for each replacement is noted down to get the strength spilt tensile of concrete.

C) Flexural Tensile Strength:

Flexural strength is defined as a materials ability to resist deformation under load. Three beams of size 100mm×100mm×500mm are casted for various percentages of GGBS by (0%, 30%, 40% and 50%) and Slag sand (SS) 0%, 40%,50% & 60% and cured for 28 days for each replacement of GGBS and Slag sand (SS). Testing was done under two point loading in flexural testing machine.

IV. Results and discussions

A) Compressive Strength:

The results of compression are shown in graphical form in the figure 5, 6 and 7.

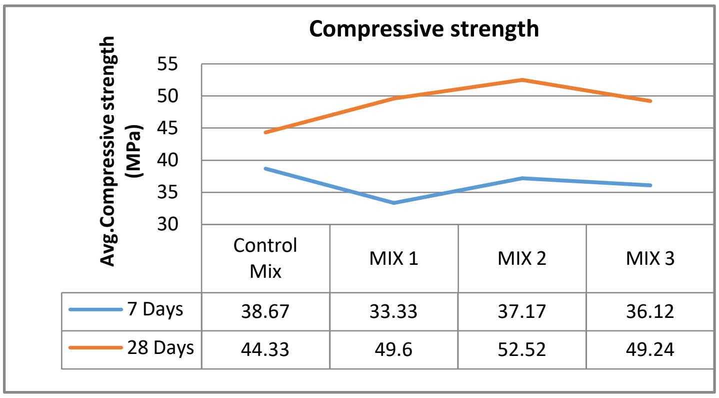

Fig 5: Compressive strength of GGBS concrete of 7th and 28th day.

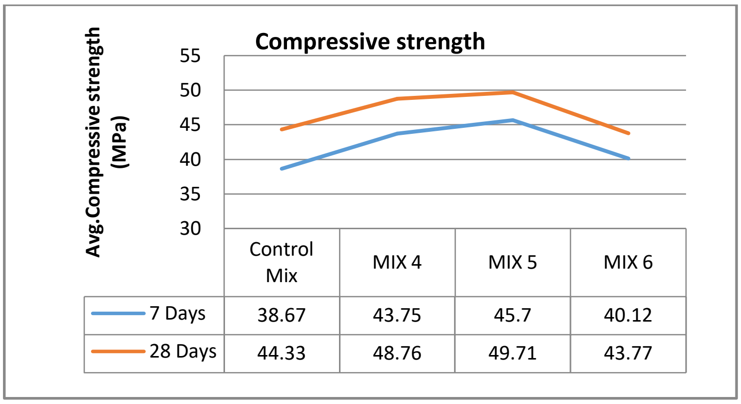

Fig 6: Compressive strength of Slag sand concrete of 7th and 28th day.

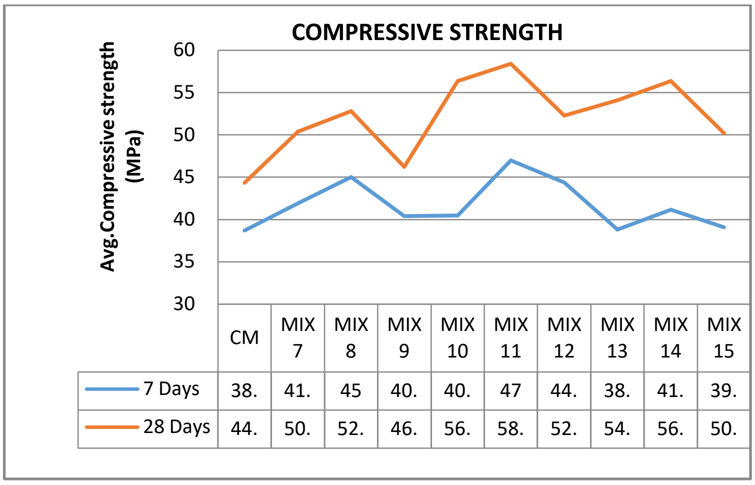

Fig 7: Compressive strength of concrete with GGBS and Slag sand of various proportions.

The optimum percentage level of 40% GGBS replacement to weight of cement has shown higher results when compared to control mix, similarly 50% GBFS has shown higher strength. When both are used in a mix, the mix having 40% GGBS and 50% GBFS i.e., M11mix has shown higher strength.

B) Split tensile strength:

The results of split tensile strength are shown in graphical form in the figure 8, 9 and 10.

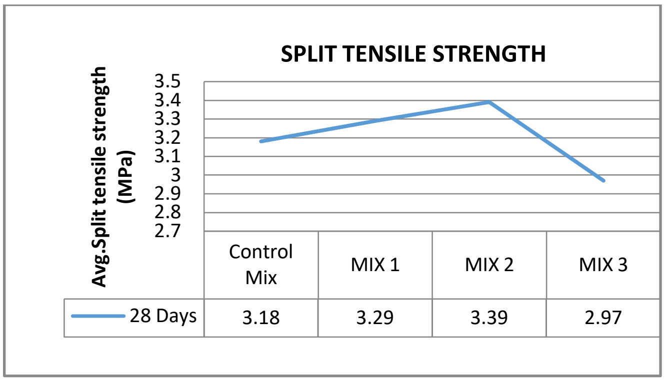

Fig8: Split tensile strength of GGBS concrete of 28^{th} day.

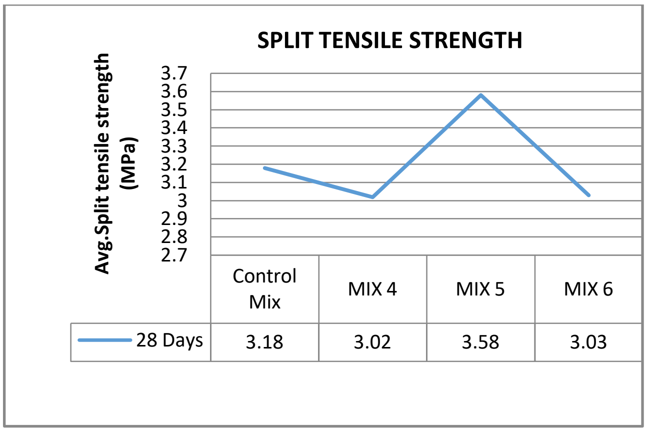

Fig 9: Split tensile strength of Slag sand concrete of 28^{th} day.

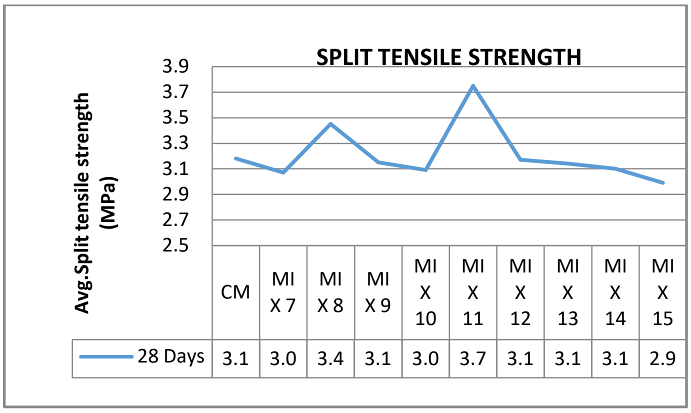

Fig 10: Split tensile strength of concrete with GGBS and Slag sand of various proportions.

It is observed that there is an increase in split tensile strength at 40% GGBS replacement, and 50% GBFS replacement and mix 11, having 40% GGBS and 50% GBFS at 28 days strength.

C) Flexural strength:

The results of flexural strength are shown in the graphical form in figure 11, 12 and 13.

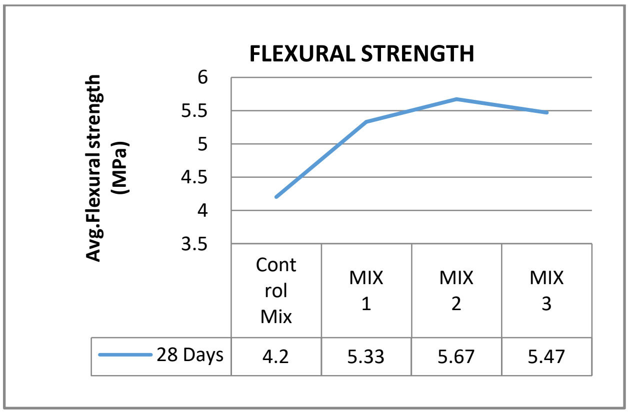

Fig 11: Flexural strength of GGBS concrete of 28th day.

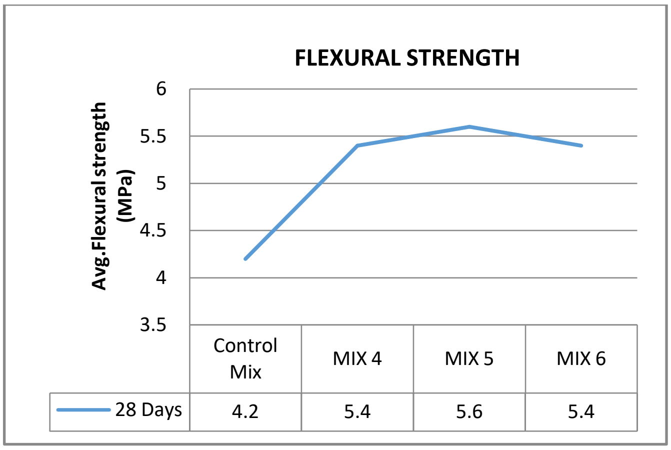

Fig 12: Flexural strength of Slag sand concrete of 28th day.

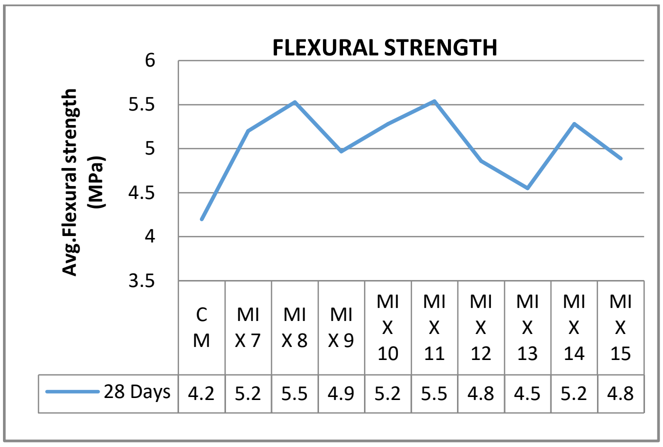

Fig 13: Flexural strength of concrete with GGBS and Slag sand of various proportions.

It is observed that there is an increase in flexural strength at 40% GGBS replacement, and 50% GBFS replacement and mix 11, having 40% GGBS and 50% GBFS at 28 days strength.

V. CONCLUSION

An attempt was made to establish the suitability on use of GFS Slag sand as a replacement to natural sand, and GGBS as a replacement to cement. From the above results the following conclusions can be drawn

1. The concrete designed for M40 grade has resulted in substantial higher strength compared to the target value. Even with the addition up to 50% of GGBS as a replacement to cement, Hence to an extent of 60% of slag can be used in concrete without sacrificing on workability.
2. The strength of concrete with GBF Slag sand has resulted the slightly higher strength compared to natural sand. However, the workability of concrete has decreased marginally.
3. The compressive strength is found to maximum at 40% GGBS and 50% GBF Slag sand, same in case of split tensile strength and flexural strength. When both are replaced in a mix the optimum dosage also found to be same.
4. The concrete containing above industrial by products found to be more durable due to enhanced pozzolanic activity of slag at relatively low w/c of 0.45 from the point of severe exposure condition. The concrete so produced is categorized as high strength concrete as the 28 days strength is in excess of 58 MPa. However durability studies such as acidattack, chemical attack and rapid chloride permeability test should be conducted to substantiate the above facts.
5. The slag sand improves the density making it lighter compared to the conventional concrete. Also, the slag sand saves the natural resource i.e. natural river sand by 50% making a sustainable concrete.
6. The use of GGBS and Slag Sand in the present research work reduces the cost by 15% making a concrete sustainable, economical, eco-friendly pertaining to the CO_2 emission due to heat of hydration by OPC and saving the natural resource i.e. natural river sand which is at scares forever.

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