© 2015 IJSRSET | Volume 1 | Issue 5 | Print ISSN : 2395-1990 | Online ISSN : 2394-4099
Themed Section: Engineering and Technology

An Experimental Investigation on Strength Properties of Cement Concrete Modified with Ground Granulated Blast Furnace Slag

Dr. V. Bhaskar Desai , C. Chaitanya lakshmi
Department of Civil Engineering, JNTUA College of Engineering, Anantapuramu, Andhra Pradesh, India

ABSTRACT

In the present scenario there is necessity for finding alternate artificial fine aggregates making use of waste materials from the industries. An attempt has been made to use Ground Granulated Blast Furnace Slag (GGBFS) as the basic ingredient in preparing GGBFS modified concrete and in this process along with the mechanical properties Mode-II fracture properties are studied. By varying the percentages of GGBFS as fine aggregate in concrete replacing the conventional fine aggregate in percentages of 0, 20, 40, 60, 80 and 100 by weight, the properties such as compressive strength, split tensile strength, flexural strength, In-plane shear strength etc., are studied and analysis of hardened samples has been done through X-Ray Diffraction technique. This study is expected to through some light on better understanding of the "Strength properties of GGBFS modified concrete."
Keywords: Compressive Strength, Split Tensile Strength, Flexural Strength, In-Plane Shear Strength , X-Ray Diffraction Test

I. INTRODUCTION

This research work determines the effect of partial substitution of fine aggregates by GGBFS on the mechanical properties of concrete. The inclusion of Slag in concrete not only helps in reducing greenhouse gases but also helps in making use of environmentally friendly material such as GGBFS which is very effective in reducing the expansion. Aggregates have significant influence on mechanical properties of mortars and concrete. Their specific gravity, particle size distribution, shape and surface texture influence markedly the properties of mortars and concrete in the fresh state.

II. METHODS AND MATERIAL

A. Review Of Literature

Experimental Studies were conducted on Concrete Replacing Fine Aggregate with Blast Furnace Slags (BFS) by J. Selwyn Babu and Dr. N. Mahendran (13). In this study the mix was designed as per IS 10262-1982 to have a characteristic compressive strength of 20 N/mm2. Based on the mix design the cement content was identified as 383 kg/m3. The water cement ratio was taken as 0.5. No superplasticiser was used in this study. The results obtained encourage the use of blast furnace slag in concrete as a partial replacement to fine aggregate up to 25%. The maximum compressive strength of 40.69 N/mm2 was obtained by replacing 25% of fine aggregate with BFS. Workability was found to be a problem with the fresh concrete, and hence usage of superplasticiser was recommended. The usage of BFS is found to reduce the cost of concrete by 8 to 10%.

Bhaskar Desai, et.al. (39,40) studied the properties like compressive strength, mode-II fracture by using DCN specimen and the fracture toughness values in Mode-II (KIIC) were calculated from the theoretical equations suggested by the earlier researchers and are compared with those obtained from load verses deflection (p-δ) diagrams.

Patnaikuni Chandan Kumar, et.al. (44) studied the X-ray diffraction studies on rice husk ash (RHA) concrete samples heated at 300˚C and 1000˚C. These results were compared and observed that at 300˚C the inner surface of the specimen shows an extra compound, Copper Iron Lead Telluride Cu3FePbTe4 along with SiO2, Al5Fe2ZnO4 which was present on the surface also and it has been presumed that it might be responsible for imparting additional strength upto 7.5% in RHA concrete.

B. Experimental Program

i. Materials Used

The key materials used in this study are cement, sand, crushed stone, GGBFS. The cement used is an ordinary Portland cement of grade 53 with a specific gravity of 3.05. The fine aggregate confirms to grading zone II as per IS 383-1970 is used in the present research. The specific gravity of the fine aggregate is 2.6. The coarse aggregate used is crushed stone with a maximum size of 20mm. GGBFS is collected from Karnataka state kalyan steel factory in koppal, Karnataka near Hospet. The specific gravity of GGBFS is 2.15.

ii. Physical Properties

Various tests have been conducted on fine aggregate in the laboratory as per the procedure given in IS 383 (1970) and presented in table 1.

TABLE 1: The properties of fine aggregate are as fallows

Fine Aggregates	Natural Sand (NS)	GGBFS
Specific Gravity	2.6	2.15
Bulk density kg/m3	1525	1375.6
Water absorption,%	0.6	2.6
Fineness Modulus	4	5.53
% bulking of fine aggregate	17	21

The coarse aggregate used is crushed (angular) aggregate conforming to IS 383: 1970. The maximum size of aggregate considered is 20mm. The test results are tabulated below.

TABLE 2: The properties of Coarse aggregate

Coarse Aggregates	
Specific Gravity	2.72
Water absorption,%	0.3
Fineness Modulus	2.78
Aggregate crushing test,%	12.2
Aggregate impact test ,%	17.801

Cement: Ordinary Portland cement of 53 grades conforming to IS: 12269-1987 has been used. Specific gravity is found to be 3.05.

iii. Mix Proportion

The mix proportions are done for M_{20} grade of concrete giving w/c ratio of 0.55 by using IS-10262-2009 method of mix design. Total six mixes are made by replacing fine aggregate with GGBFS keeping w/c ratio as constant (control mix) by 0, 20, 40, 60, 80 and 100 % replacements given in table 3.

TABLE 3: Replacement proportions of fine aggregates

Mix No.	GGBFS-%	Natural sand-%
1	0	100
2	20	80
3	40	60
4	60	40
5	80	20
6	100	0

TABLE 4: Mix proportions of control mixes

% GGBFS	**Water Lit/m^3**	**Cement Kg/m^3**	**F.A Kg/m^3**	**C.A Kg/m^3**
0	197.16	1	1.94	3.16

iv. Casting and Testing of Specimens

Casting and testing of specimens is carried out as per IS relevant codes for compressive strength for cube of size (150mmx150mm)& cylinder of size (150mmx300mm), flexural strength for prism of size(500mm x 100mm x 100mm), modulus of elasticity cylinder of size (150mm x 300mm), split tensile strength for cylinder of ize(150mmx300mm) & in-plane shear strength for cube of size (150mmx150mm). Each time 24 specimens are cast out of which 12 specimens with $\frac{a}{w}$

ratios 0.3, 0.4, 0.5, and 0.6, 3 no of plain cubes, 6 cylinders and 3 plain beams. Plate 4.5 shows the arrangement of different notches to suit $\frac{a}{w}$ ratios 0.3, 0.4, 0.5, and 0.6. Totally 144 specimens are cast. For all test specimens, moulds are kept on the vibrating table and the concrete is poured into the moulds in three layers each layer being compacted thoroughly with tamping rod to avoid honey combing. Finally all specimens are vibrated on the table vibrator after filling up the moulds up to the brim. The vibration is effected for 7 seconds and it is maintained constant for all specimens and all other castings. The steel plates forming notches are removed after 3 hours of casting carefully and neatly finished. However the specimens are demoulded after 24 hours of casting and are kept immersed in a clean water tank for curing. Plate 6 shows the specimens in curing pond. After 28 days of curing the specimens are taken out of water and are allowed to dry under shade for few hours.

III. RESULTS AND DISCUSSION

1. Compressive strength of Cube and Cylinder

The results of compressive test of cubes and cylinders are tabulated in table 5 and figure 1&2 shows the variation of compressive strength versus percentage of slag replacing the natural fine aggregate for various mixes considered. Each result presented is the average of three specimen results. From the figure 1 it can be observed that due to the increase in percentage of slag replacement the cube compressive strength gets increased upto 20% replacement i.e 37.71 N/mm^2 with a 6.4% increase wrt that of control mix without slag i.e 35.4 N/mm^2 and later for the replacement of GGBFS beyond 20%, the compressive strength results decrease continuously. But even at the 60% replacement of natural fine aggregate, it is observed that the strength is marginally decreased. From the figure 2 it can be observed that due to the increase in percentage of slag replacement the cylinder compressive strength gets increased upto 20% replacement i.e 21.7 N/mm^2 with 2.3% increase over that of control mix i.e 21.22 N/mm^2 and later for the continuous replacement of GGBFS beyond 20%, the compressive strength results decrease continuously. But even with 60% replacement of natural fine aggregate it is observed that the strength is marginally decreased.

2. Split tensile strength:

The split tensile strength is well known indirect test used for determining the tensile strength of concrete. For each mix three cylinders of size 150mm diameter and 300mm in length are cast and tested. Each split tensile strength results is the average of 3 test results. The results are presented in table 6. The variation of split tensile strength versus percentage of replacing fine aggregate with GGBFS is presented in figure 3. From the figure it can be observed that due to the increase in percentage of slag replacement the split tensile strength gets increased upto 20% replacement i.e 3 N/mm^2 with 6% increase over that of control mix i.e 2.83 N/mm^2 and later for the continuous replacement of GGBFS beyond 20%, the split tensile strength results decrease continuously. Even with 60% replacement of natural fine aggregate it is observed that the strength is marginally decreased.

3. Flexural Strength

Flexural strength is defined as a material ability to resist deformation under flexural load. Three beams of size 100mm×100mm×500mm are cast for various percentages of GGBFS and testing is done under two point loading in flexural testing machine. The modulus of rupture is calculated. The results are tabulated in table 7. The variation of flexural strength versus percentage of replacement of fine aggregate with GGBFS is presented in figure 4. From the figure it can be observed that due to the increase in percentage of slag replacement, the flexural tensile strength gets increased upto 20% replacement i.e 4.02 N/mm^2 with 3.8% increase over that of control mix i.e 3.87 N/mm^2 and later for the continuous replacement of GGBFS beyond 20%, the flexural strength results decrease continuously. But even at 60% replacement of natural fine aggregate it is observed that the strength is marginally decreased.

4. In-plane Shear Strength:

To proceed with this type of experimental program DCN specimens are cast with various percentage replacements of sand by GGBFS. Each time 12 no of DCN specimens are cast. The notch depths provided are 45, 60, 75 and 90mm running throughout the width of the specimen. Thus the values of a/w ratio are 0.3, 0.4, 0.5, and 0.6 where 'a' is the notch depth and 'w' is the specimen. The load is applied within the notches. The punching test on the DCN cubes is conducted on 3000KN digital compression testing machine, the size of specimen being 150mmx150mmx150mm. The rate of loading applied is 0.5 KN/sec. The IN-PLANE SHEAR STRESS at Ultimate load is presented in table 8. Super-imposed variations of ultimate shear load and ultimate in-plane shear stress with a/w ratios (i.e., 0.3, 0.4, 0.5, 0.6) versus percentage of GGBFS replacing fine aggregate is presented in figure 5&6. From the figure it can be observed that due to the increase in percentage of slag replacement the ultimate shear load and ultimate in-plane shear stress gets increased upto 20% replacement and later for the continuous replacement of GGBFS beyond 20%, the strength results decrease continuously. But even at 60% replacement of natural fine aggregate it is observed that the strength is marginally decreased.

5. X-Ray diffraction test and analyzed X' Pert High Score software

The sample preparation consists of grinding the dried concrete samples and testing them in XRD machine in mass percentages of 0%, 20%, 40%. From the data generated by X-Ray diffractometer the chemical analysis is determined by using X' Pert High Score software sample results are tabulated in table no 9. The mineral properties of 20% replacement of fine aggregate shown in fig 7.In this experimental test the Polynomial type of "Cubic" is observed. The XRD pattern of GGBFS mainly representing the crystalline Quartz, due to the presence of Quartz the diffraction lines appears more intensely because of sand particles are shown in graph.

ss

TABLE 5: Cube and cylinder compressive strength results

S.No	Designation of the mix	Percentage volume of replacement of fine aggregate		Cube compressive strength (N/mm^2)	Percentage of increase or decrease in cube compressive strength	Cylinder compressive strength (N/mm^2)	Percentage of increase or decrease in cylinder compressive
		Conventional fine Aggregate	GGBFS				
1	G-0	100	0	35.45	0.00	21.22	0.00
2	G-20	80	20	37.71	6.4	21.70	2.3
3	G-40	60	40	34.19	-3.5	20.14	-5.0
4	G-60	40	60	29.15	-18.0	19.44	-8.3
5	G-80	20	80	25.86	-27.0	18.44	-13.0
6	G- 100	0	100	23.42	-34.0	17.56	`-17.2

TABLE 6: Split tensile strength results

S.No	Name of the mix	Percentage volume of replacement of fine aggregate		Split tensile strength (N/mm^2)	Percentage increase or decrease in Split tensile strength w.r.t G-0
		Conventional fine Aggregate	GGBFS		
1	G-0	100	0	2.83	0.00
2	G-20	80	20	3.00	6.0
3	G-40	60	40	2.66	-6.0

4	G-60	40	60	2.44	-14.0
5	G-80	20	80	2.15	-24.0
6	G- 100	0	100	1.92	-32.0

TABLE 7: Flexural strength results

S.No	Name of the mix	Percentage volume of replacement of fine aggregate		Flexural strength (N/mm^2)	Percentage increase or decrease in Flexural strength of concrete w.r.t G-0
		Conventional fine Aggregate	GGBFS		
1	G-0	100	0	3.87	0.00
2	G-20	80	20	4.02	3.8
3	G-40	60	40	3.61	-7.0
4	G-60	40	60	3.30	-15.0
5	G-80	20	80	3.09	-20.0
6	G- 100	0	100	2.58	-33.0

TABLE 8: IN-PLANE SHEAR STRESS at Ultimate Load for DCN specimens with a/w ratios = 0.30, 0.40, 0.50, 0.60:

S. No	Name of the mix	Percentage volume of replacement of fine aggregate		a/w=0.3		a/w=0.4		a/w=0.5		a/w=0.6	
		Conventional fine Aggregate	GGBFS	Ultimate load (KN)	In-plane shear stress in N/mm^2	Ultimate load (KN)	In-plane shear stress in N/mm^2	Ultimate load (KN)	In-plane shear stress in N/mm^2	Ultimate load (KN)	In-plane shear stress in N/mm^2
1	G-0	100	0	154.0	4.96	128.3	4.75	105.0	4.66	80.0	4.44
2	G-20	80	20	158.0	5.01	130.0	4.81	106.0	4.71	83.66	4.64
3	G-40	60	40	148.0	4.69	124.0	4.59	100.6	4.47	71.0	3.94
4	G-60	40	60	112.5	3.57	95.0	3.51	93.0	4.13	68.0	3.77
5	G-80	20	80	111.0	3.52	91.0	3.37	75.0	3.33	59.0	3.27
6	G- 100	0	100	106.0	3.36	89.0	3.29	73.0	3.24	57.82	3.21

TABLE 9: Using X' Pert High Score software from mineral group matched data Pattern list identified for 20% replacement of GGBFS concrete results at 28 days curing period (G-20)

Pos. [°2Th.]	Height [cts]	FWHM [°2Th.]	d-spacing [Å]	Rel. Int. [%]	Compound Name
20.7573	43.30	0.3542	4.27935	36.31	Quartz, Berlinite, Cebaite, Frondelite

21.9187	13.89	0.3542	4.05516	11.65	Albite high, Cebaite, Albite, calcian low
26.6276	119.24	0.4723	3.34777	100.00	Quartz, Berlinite, Cebaite, Frondelite, Albite calcian low
27.7055	24.87	0.4723	3.21992	20.85	Albite high, Cebaite, Frondelite, Albite calcian low
29.2726	23.26	0.3542	3.05101	19.51	Cebaite, Frondelite, Nitratine, Albite calcian low
32.4352	5.88	0.7085	2.76038	4.93	Berlinite Albite high Cebaite Frondelite
36.4986	13.55	0.3542	2.46186	11.36	Quartz, Berlinite, Albite high, Cebaite, Frondelite, Albite calcian low
39.3743	34.39	0.3542	2.28843	28.84	Quartz, Berlinite, Albite high, Cebaite, Frondelite, Nitratine, Albite calcian low
40.1460	7.83	0.3542	2.24621	6.57	Quartz, Berlinite, Cebaite, Frondelite, Albite calcian low
42.3831	19.82	0.3542	2.13268	16.62	Quartz, Berlinite, Albite high, Cebaite, Frondelite, Nitratine, Albite calcian low
45.7512	7.48	0.3542	1.98321	6.28	Quartz, Berlinite, Cebaite, Frondelite, Albite calcian low
47.1046	9.67	0.3542	1.92934	8.11	Berlinite, Albite high, Cebaite Frondelite, Nitratine, Albite calcian low
50.0255	19.80	0.3542	1.82332	16.60	Quartz, Berlinite, Albite high, Cebaite, Frondelite, Albite calcian low
59.9163	28.18	0.3542	1.54383	23.63	Quartz, Berlinite, Albite high, Cebaite, Frondelite, Nitratine, Albite calcian low
63.9881	4.52	0.3542	1.45506	3.79	Quartz, Berlinite, Albite high, Cebaite, Nitratine, Albite calcian low
68.1587	19.84	0.3542	1.37584	16.63	Quartz, Berlinite, Albite high, Nitratine

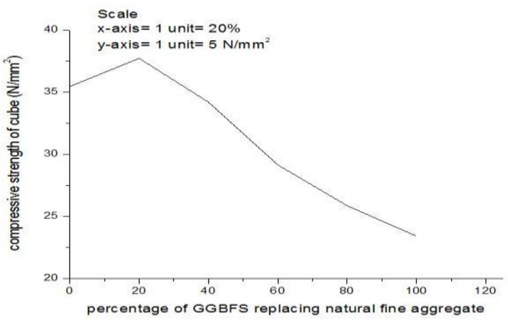

Figure 1: Variation between cube compressive Strength and percentage of GGBFS replacing natural fine aggregate

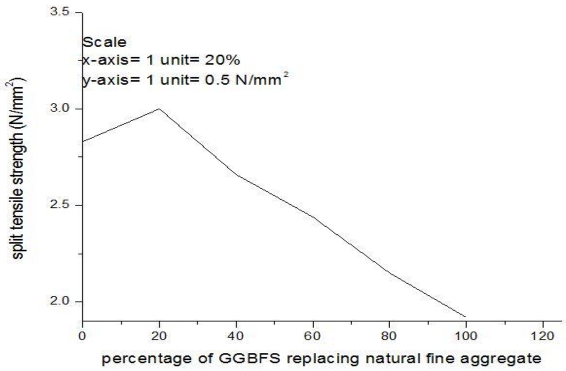

Figure 3: Variation between split tensile strength and percentage of GGBFS replacing natural fine aggregate

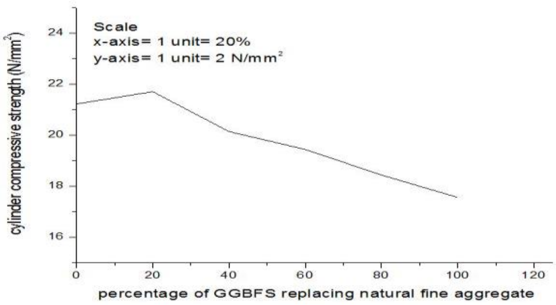

Figure 2: Variation between cylinder compressive Strength and percentage of GGBFS replacing natural fine aggregate

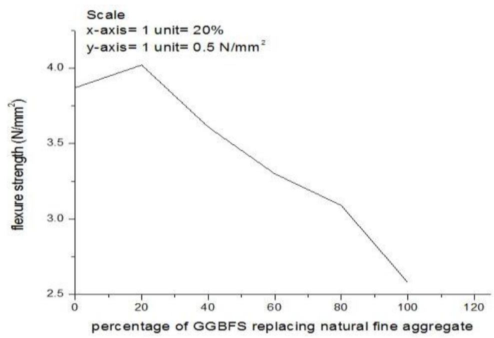

Figure 4: Variation between flexural strength and percentage of GGBFS replacing natural fine aggregate

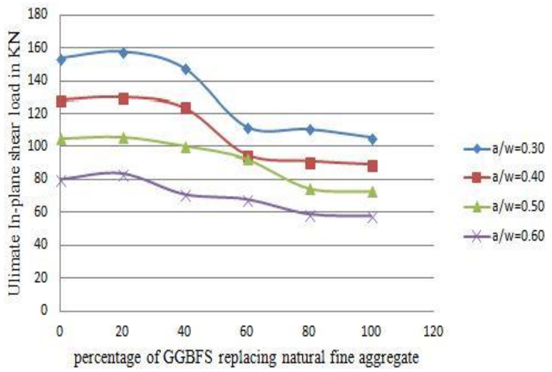

Figure 5: superimposed Variation between ultimate in-plane shear load and percentage of GGBFS replacing natural fine aggregate

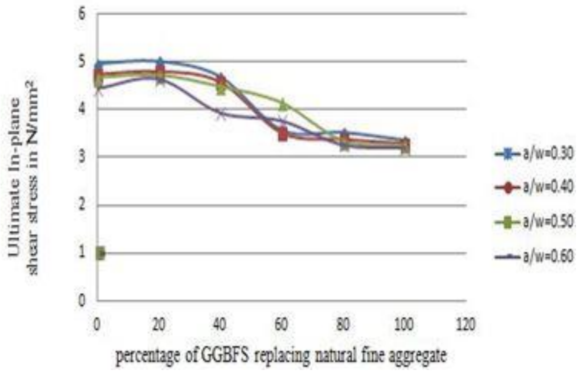

Figure 6: superimposed Variation between ultimate in-plane shear stress and percentage of GGBFS replacing natural fine aggregate

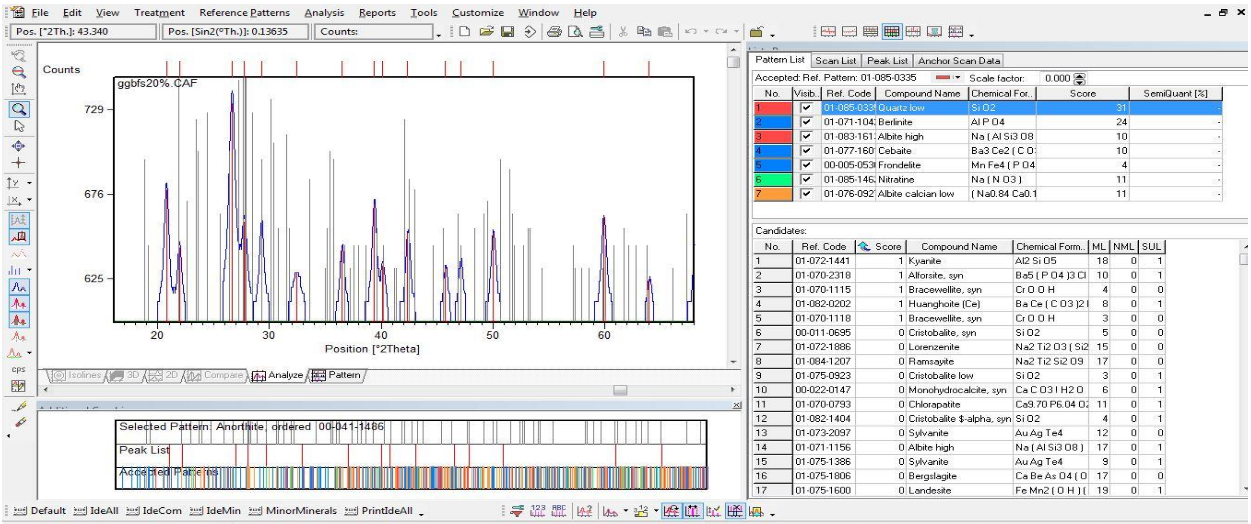

Figure 7: Using X' Pert High Score software from mineral group matched data Pattern list identified for 20% replacement of GGBFS concrete results at 28 days curing period (G-20)

Plate 1: View of cracks at ultimate load of testing specimens

IV. CONCLUSION

From the limited experimental investigation carried out the fallowing conclusions can be drawn:

1. With the increase in addition of GGBFS replacing the fine aggregate in different percentages, it adversely affects the workability properties of the concrete due to the more absorption of water by GGBFS. Hence addition of super plasticizers is

recommended specially after mixing 60% of GGBFS for the more workability

2. With the increase in percentage of GGBFS content replacing the sand, it is observed that the compressive strength is increased upto 20% replacement (37.71 N/mm^2) and afterwards it is decreased.
3. With the increase in percentage of GGBFS content replacing the sand, it is observed that the split tensile strength is increased upto 20% replacement (3 N/mm^2) and afterwards it is decreased.
4. All the beams have failed in the flexural zone and evidently all the beams are failed as such. The flexural crack has propagated from the bottom side to top with crushing of concrete at the top surface with no horizontal cracks at the level of the reinforcement, indicating no bonding failure. With the increase in percentage of GGBFS content replacing the sand, it is observed that the flexure tensile strength is increased upto 20% replacement (4.01 N/mm^2) and afterwards it is decreased.
5. Ultimate loads in Mode-II fracture are found to increase upto 20% and afterwards they are found to decrease continuously with the percentage increase in the GGBFS content beyond 20% for an $\frac{a}{w}$ ratios.
6. The addition GGBFS content significantly enhanced the in-plane shear strength. During the test it is clearly observed that the crack is developed more or less along the notches. Further the in-plane shear strength increases with upto 20% GGBFS addition. As in other cases the strength decreases with increasing the replacement of sand by GGBFS beyond 20%.
7. From the X-Ray diffraction test using X' Pert High Score software, for 20% replacement of sand by GGBFS maximum percentage of Quartz with the score 31 is identified from the pattern list and in peak list the chemical compounds of Quartz low, Berlinite, Albite high, Cebaite, Frondelite, Nitratine, Albite calcian are observed.
8. Based on the experimental investigations, it could be recommended that GGBFS could be effectively utilized as fine aggregates in all the concrete constructions.
9. Keeping all the strength considerations as a via media the GGBFS can be effectively utilised uto 50% replacement as there is not much strength decrease. However some durability long term tests are necessary before going for official utilization.
10. The substitution of natural fine aggregate with GGBFS has positive impact on the strength properties. From this experimental study it may be construed that GGBFS can be effectively used in various civil engineering works.

V. REFERENCES

[1] Mohammed Nadeem, Arun D. Pofale: “Experimental investigation of using slag as an alternative to normal aggregates (coarse and fine) in concrete”, International Journal Of Civil and Structural Engineering, Volume 3, No 1, 2012.

[2] K.G. Hiraskar and Chetan Patil: “Use of Blast Furnace Slag Aggregate in Concrete”, International Journal Of Scientific & Engineering Research, Volume 4, Issue 5, May 2013 ISSN 2229¬5518.

[3] V.Bhaskar Desai, K.Balaji Rao, Jagan Mohan , " some studies on Mode-II fracture of heavy weight metallic aggregate cement concrete ", An International Research of Engineering sciences and technologies , Vol.1,No,2, october2008,pp.41-47.

[4] V.Bhaskar Desai, D.Jagan Mohan , V.Vijay Kumar, "some studies on strength properties of Metallic aggregates", proceedings of the International Conference on advance in concrete composites and structures, January 2005, pp.235-246.

[5] Neetu Singh, Sameer Vyas, R.P.Pathak, Pankaj Sharma, N.V.Mahure, S.L. Gupta, “Effect of Aggressive Chemical Environment on Durability of Green Geopolymer Concrete”, International Journal of Engineering and Innovative Technology (IJEIT) ISSN: 2277-3754, Volume 3, Issue 4, October 2013.

[6] Patnaikuni Chandan Kumar, Nutulapati V. S. Venugopal “X-Ray Diffraction Studies of Rice Husk Ash—An Ecofriendly Concrete at Different Temperatures”, published in American Journal of Analytical Chemistry, 2013, 4, 368-372.