International Journal of Multidisciplinary Approach and Studies ISSN NO:: 2348 – 537X

Experimental Studies on High Performance Concrete Using Blast Furnace Slag as a Cement Replacement Material

Ashish J. Bharnuke* & Dr. H.S. Chore**

**P.G. Student, Department of Civil Engineering, Datta Meghe College of Engineering, Airoli, Navi Mumbai*

***Professor and Head, Department of Civil Engineering, Datta Meghe College of Engineering, Airoli, Navi Mumbai*

ABSTRACT:

The paper presents the experimental investigation on the performance evaluation of the high performance concrete. The ground granulated blast furnace slag was used to replace the cement partially. The study was aimed at finding out the optimum contents of the GGBFS as the partial replacement of cement without affecting the properties of concrete. The study was further aimed at evaluating the effect of crushed sand on the performance of concrete in place of river sand. The equal amounts of these materials were used in eight trial mixes with varying amount of cement. The water cement ratio was also varied. The chemical admixture was also added to improve the workability of concrete. The engineering properties such as compressive strengths of cubes and cylinders for 7 and 28 days' curing in respect of the concrete made using GGBFS are evaluated.is the most widely used material of construction.

Keywords— *Concrete; strength; Pozzolanic materials; ground granulated blast furnace slag (GGBFS); river sand; crushed sand.*

INTRODUCTION

The concrete is a versatile construction material owing to the benefits it provides in terms of strength, durability, availability, adoptability and economy. It is a heterogeneous mix of cement, water and the aggregates. Great efforts have been made to improve the quality of concrete by various means in order to raise and maximize its level of performance. Using same ingredients with little adjustments in the micro- structure (and probably adding specific materials), it is possible to obtain some of the special types of concrete such as high performance concrete (HPC), self-compacting concrete (SCC) and roller compacted concrete, high volume fly ash concrete (HVFAC).

High Performance Concrete is an engineered concrete possessing the most desirable properties during fresh as well as hardened concrete. The performance and quality of each ingredient is critical for HPC in order to exploit the full potential of the composite. HPC is developed by using super plasticizer, micro fillers and different types of fibers. As it exhibits higher workability, greater mechanical properties and better durability, HPC has been increasingly applied in the constructions such as tall building, bridges and off-shore structures. The proportions in which fundamental components are mixed, and the admixtures that are used, constitute the main difference between conventional concrete and HPC. A high-range water-reducing admixture may provide a required low water/cement ratio. The development of these concretes has brought forth the need for admixtures, both- mineral and chemical, to improve the performance of concrete.

By-products from various industries cause a major environmental problem around the world. In order to encourage waste recycling and prevent waste dumping, a landfill tax has also been imposed in the developed countries. However, the waste dumping is still a serious environmental issue throughout the world. Amongst various by-products generated by the industries, Fly Ash (FA) and Ground Granulated Blast-Furnace Slag (GGBFS) have attracted much attention by concrete researchers. The admixtures may be added in concrete in order to enhance some of its properties desired specially.

BRIEF REVIEW OF THE LITERATURE :

There have been several studies reporting the utilization of Pozzolanic waste materials such as Ground granulated blast furnace slag. Meusel and Rose (1983) worked for production of granulated blast furnace slag at sparrows point and studied the workability and strength potential of concrete incorporating the slag. Dubovoy and Gebler (1986) performed tests for three manufacturers of ground granulated blast furnace slag to determine the performance of their products with Portland cement and concluded that use of slag can be beneficial without resulting in significant technical problems or adverse construction problems. Frigione (1986) showed that 'the resistance to sulfates and to alkali aggregate reaction remains very strong if the slag percentage in the cement is high'. Wimpenny and Ellis (1989) presented the findings from low temperature curing conditions. Olorunsogo and Folarin (1998) studied the influence of particle-size distribution (PSD) of ground granulated blast-furnace slag (GGBFS) on the compressive strength of slag mortar. Osborne (1999) reported the performance and long-term durability of concrete where ground glassy blast -furnace slag (granulated and pelletized) was used as a cementitious material. Hooton (2000) reported the use of GGBFS as a supplementary cementing material for enhanced performance of concrete.

Corrosion of reinforcement embedded in concrete causes most of the failures in concrete structures. Pal and Mukherjee (2002) worked along the similar lines and reported in detail the study on the behaviour of concrete made from GGBFS, obtained from some premier steel manufacturing plants in India, on the rate and amount of corrosion in reinforcement. The study revealed that an increase in the proportion of slag decreases the corrosion of reinforcement.

Wang and Trettin (2005) presented the influence of fineness and particle size distribution of granulated blast-furnace slag (GGBFS) on its hydraulic reactivity in cement systems. Wang and Miao (2010) reported the influence of high temperature curing at early ages on the hydration characteristics of a complex binder containing ground granulated blast furnace slag (GGBFS).

Durai et al. (2013) worked on the performance of concrete mix for higher grade with different combination of GGBFS and glass fibers and concluded that the GGBS can be used as alternative material for the cement. The addition of super plasticizer was also found to reduce the strength of concrete remarkably due to the chemical action between the super plasticizer and GGBS. Palaniappan et al. (2013) carried out the experimental investigation on conventional concrete and concrete made using GGBFS for the high performance concrete. The use of GGBFS in concrete shows increases in the compressive, split tensile and flexural strength by 14%, 18% and 30%, respectively as compared to that in conventional concrete. Patil et al. (2013) reported that the utilization of GGBFS up to 20% as a cement replacing material seems to be optimum.

Gadpaliwar et al. (2014) reported an experimental study on replacement of cement with GGBFS and rice husk ash (RHS) with different percentage of river and quarry sand. Malagavelli and Rao (2010) reported that that the crushed sand can be used as alternative material for river sand since the increase in compressive and tensile strength of concrete was found to increase with 50 % replacement of the cement with GGBFS.

Tamilarasan and Perumal (2012) studied the workability of concrete with GGBFS as a cement replacement material with and without the addition of super-plasticizer. Zhi Ge and Wang (2009) studied the behavior of concrete made from both- fly ash and ground granulated blast furnace slag combined. Muzaffer Khan and Usman Ghani (2004) observed that with increase in the replacement of ordinary Portland cement with GGBS the W/C ratio can be reduced with constant Slump with increase in Comp. Strength

Based on the afore-mentioned review of literature, an effort has been made in this investigation to study the effect of pozzolanic waste materials such as ground granulated blast furnace slag (GGBFS) when used as a cement replacing materials with ordinary Portland cement on the strengths of concrete. The chemical admixture was also added in the concrete mix to ensure the effect of workability.

EXPERIMENTAL PROGRAMME

The particulars of the materials used in the present investigation along with the methodology of investigation are described in this section.

A. Materials

The materials used in the study include cement, river sand, crushed sand, aggregates, water, admixtures and cement replacing materials such as ground granulated blast furnace slag (GGBFS). The properties of GGBFS are summarized in Table 1. The cement used in the said investigation comprised of Ordinary Portland Cement (ACC: 53 Grade). While the sand brought from Mahad River (Maharashtra) was used in the study, the coarse aggregates (Metal I and II) procured from the local quarry at Ulwe in Navi Mumbai were used. The GGBFS (JSW) was procured from, Pen (India). The potable water was added for obtaining concrete mix. The physical properties of the constituents of concrete obtained through various laboratory tests are summarized in Table 2.

TABLE I: PROPERTIES OF GGBFS

Particulars	Requirement as per BS:6699	Test Results
Physical Properties		
Loss of ignition (Max) %	3.00	0.18
Moisture content (Max) %	1.00	0.015
Chemical Composition		
CaO + MgO + SiO2 (Min) %	66.66	77.78
Magnesium Oxide MgO (Max) %	14	7.00
Sulphur Tri Oxide SO3 (Max) %	2.5	0.39
Total Chlorides (Max)%	0. 1	0.001

The chemical admixture (plasticizer) Glenium® was also used in the present study. Glenium® is a pure polymer based super-plasticizer which when added to concrete/mortar/plaster modifies the properties of concrete such as workability, strength, permeability, cohesion etc. The technical specifications of Glenium® are given in Table 3. The admixture is added to concrete by weight of cement mix after stirring in little water and then the solution is added after adding other ingredients in the mixer. Glenium®, when added in fresh concrete /mortar/plaster disperse cement uniformly in the mix. Due to deflocculating action on cement agglomerates the entrapped water is released and would be available for workability

TABLE 2: PROPERTIES OF CEMENT AND AGGREGATES.

Properties	Value
Cement	
Fineness (IS: 4031 Part II)	320 (Minimum 225 cm2/gm)
Consistency	31.7 %
Specific Gravity	3.2
Setting Time	
Initial Setting Time	180 Min (Minimum 30 Min)
Final Setting Time	265 Min (Maximum 600 Min)

Compressive strength	
3 Days' curing	29 MPa
7 Days' curing	36 MPa
28 Days' curing	56 MPa
Specific Gravity of Aggregates	
Fine Aggregate	2.70
Coarse Aggregates (20 mm)	2.80
Coarse Aggregates (10 mm)	2.75

TABLE 3: SPECIFICATIONS OF GLENIUM® 143.

Dosage	0.5% upto 2% as pre Workability requirements
Drt material content % by mass	37.63
Relative Density at 25 deg. C	1.110
pH	6.8
Stability	12 months in closes container
Chloride % by mass	0.003

EXPERIMENTAL PROGRAMME

The experimental programme involved the combination of Ordinary Portland Cement (OPC) and mineral admixtures such as ground granulated blast furnace slag (GGBFS). For this combination the various parameters such as water cement ratio, percentage of cement, GGBFS, fine and coarse aggregates; and chemical admixture (Glenium) were kept in varying proportions. On the backdrop of the literature review, the percentage variation in cement replacing materials and cement was decided. The concrete mix was designed as per IS 10262 – 1982 with the conventional concrete and different % of GGBS (0%, 20%, 30%, 35%, 40%, 50% and 60%) with river sand as well as crushed sand for M-30 and M-60 grade.

In all, twenty eight trial mixes were prepared. In each trial mix, 9 cubes and 9 cylinders were cast. Cement, sand, coarse aggregate and cement replacing materials were thoroughly mixed in dry state by machine so as to obtain the uniform color. The required percentages of admixture were added to the water and then, the required water as per the designated water cement ratio was added to the dry mix in order to obtain uniform mixture. The compaction factor test and slump test were carried out on fresh concrete and the respective values were recorded for all the trial mixes. The moulds with standard dimensions, i.e., 150×150×150 mm were filled with concrete in 3 layers. Along similar lines, the cylinders of size 150 mm diameter and 300 mm length and 150 mm diameter and 150 mm length were also cast. The samples (cubes and cylinders) were air dried for a period of 24 hours and then, they were weighed to find out their weight prior curing. Thereafter, they were immersed in water. The cubes were allowed for 7, 28 and 56 days' curing while the cylinders were allowed for 28 days' curing. The samples were tested for their respective strengths.

V. RESULTS AND DISCUSSION

The effect of cement replacing materials such as GGBFS when used in varying proportions in conjunction with OPC for different water cement ratio with River sand and Crushed sand are studied on the engineering properties of the of concrete. The results are discussed in the subsequent section.

i. Compressive Strength of Cubes

The particulars of different trial mixes with varying proportions of cement and cement replacing materials and varying water cement ratio are given in Table 4 to 7. The values of the compressive strengths for different curing periods are also indicated in Table 4 - 7.

Table 4: Compressive strength (N/mm^2) of the cubes for M-30 (River sand)

Sr. No.	Trial No.	w/c Ratio	Cement (%)	GGBFS (%)	7 Days	28 Days
1	R30/1	0.49	100	0	25.60	33.20
2	R30/2	0.47	80	20	26.10	32.19
3	R30/3	0.45	70	30	26.30	34.88
4	R30/4	0.44	65	35	22.19	35.50
5	R30/5	0.43	60	40	21.87	36.60
6	R30/6	0.42	50	50	19.30	34.10
7	R30/7	0.40	40	60	17.30	30.40

Table 5: Compressive strength (N/mm^2) of the cubes for M-30 (Crushed sand)

Sr. No.	Trial	w/c Ratio	Cement (%)	GGBFS (%)	7 Days	28 Days
1	C30/1	0.49	100	0	28.80	36.20
2	C30/2	0.47	80	20	28.00	35.19
3	C30/3	0.45	70	30	26.20	39.30
4	C30/4	0.44	65	35	25.15	40.10
5	C30/5	0.43	60	40	23.90	42.30
6	C30/6	0.42	50	50	21.70	38.50
7	C30/7	0.40	40	60	20.03	32.15

Table 6: Compressive strength (N/mm^2) of the cubes for M-60 (River sand)

Sr. No.	Trial	w/c Ratio	Cement (%)	GGBFS (%)	7 Days	28 Days
1	R60/1	0.295	100	0	49.50	61.90
2	R60/2	0.295	80	20	46.89	65.27
3	R60/3	0.295	70	30	45.41	76.59
4	R60/4	0.290	65	35	43.50	82.60
5	R60/5	0.290	60	40	43.80	72.12
6	R60/6	0.285	50	50	40.50	70.50
7	R60/7	0.285	40	60	38.30	65.41

Table 7: Compressive strength (N/mm^2) of the cubes for M-60 (Crushed sand)

Sr. No.	Trial	w/c Ratio	Cement (%)	GGBFS (%)	7 Days	28 Days
1	C60/1	0.295	100	0	52.50	73.78
2	C60/2	0.295	80	20	51.13	82.50
3	C60/3	0.295	70	30	50.50	97.90
4	C60/4	0.290	65	35	49.30	101.35
5	C60/5	0.290	60	40	49.20	103.83
6	C60/6	0.285	50	50	45.15	78.10
7	C60/7	0.285	40	60	42.15	68.30

It is seen from the afore-mentioned Tables that the w/c ratio can be lowered by increasing percentage of GGBFS keeping the slump constant or under workable condition in respect of either grades of concrete with river as well as crushed sand for a constant dosage of admixture.

The performance of the various mixes with respect to cement contents, water cement ratio, curing periods and that of cement replacing materials is discussed below. The Fig. 1 shows the compressive strength of the concrete of M-30 grade corresponding to 28 days curing for different percentage of blast furnace slag.

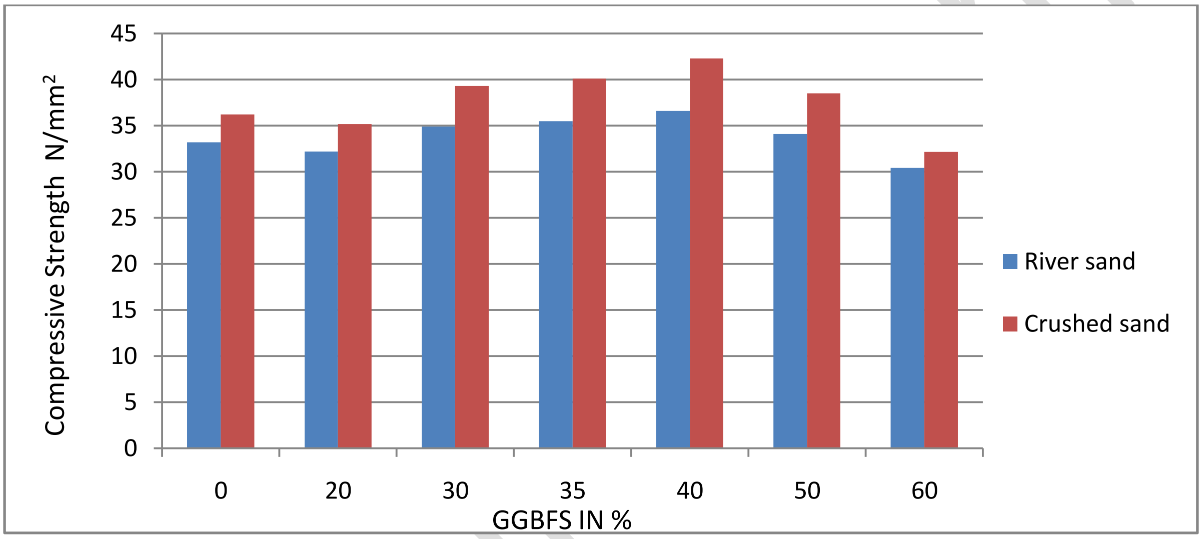

Fig.1: Variation of strength (N/mm^2) of M-30 concrete for different contents of GGBFS (28 days' curing)

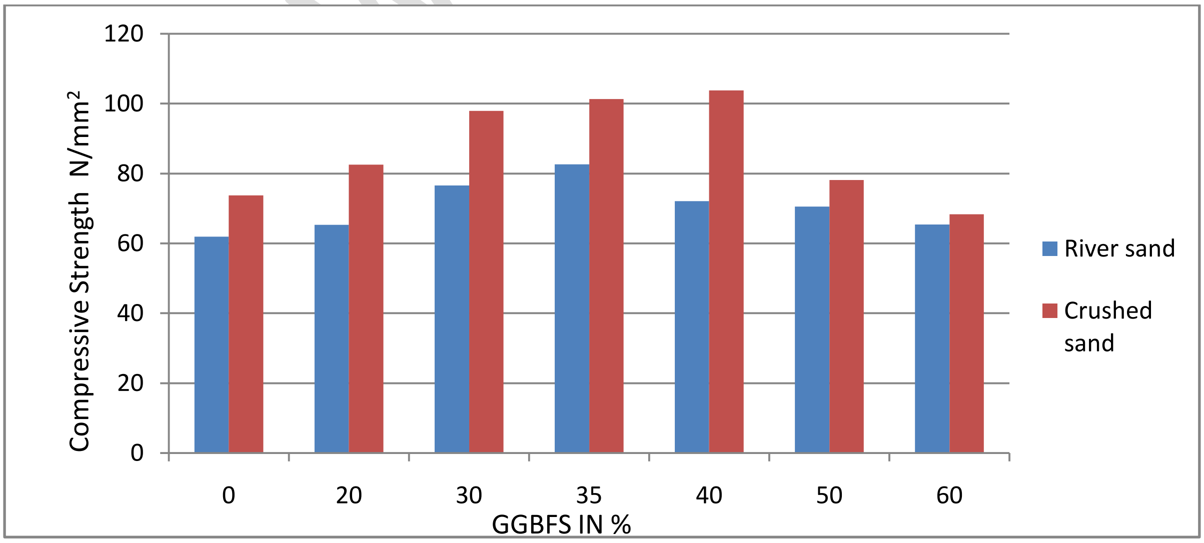

Fig.2:Variation of strength (N/mm^2) of M-60 concrete for different contents of GGBFS (28 days' curing)

From Fig. 1 it is observed that there is an increase in the compressive strength of the concrete when crushed sand is used as compared to that in case of river sand. The average increase in the strength is around 10.18% greater than the average strength obtained in case of river sand. The strength of the concrete made with river sand as well as crushed sand is found to be maximum corresponding to use of 40% GGBFS. The increase in strength at this content of GGBFS as compared with the conventional concrete is observed to be 10.24% and 16.85%, respectively in case of river sand and crushed sand.

From Fig. 2 it is observed that there is an increase in the compressive strength of the concrete when crushed sand is used as compared to that in case of river sand. The average increase in the strength is around 22.58% greater than the average strength obtained in case of river sand. The strength of the concrete made with river sand and crushed sand is found to be maximum corresponding to use of 35% and 40% GGBFS, respectively. The increase in strength corresponding to these contents of GGBFS as compared with the conventional concrete is observed to be 33.44% and 40.73 %, respectively in case of river sand and crushed sand.

ii. Compressive Strength of Cylinder

The compressive strength of the cylinders corresponding to 28 days' curing in respect of M-30 and M-60 grade of concrete for river as well as crushed sand is indicated in table 8 and table 9.

TABLE 8: 28 DAYS COMPRESSIVE STRENGTH (N/MM^2) OF THE CYLINDERS FOR M-30

Sr. No.	Trial	w/c Ratio	Cement %)	GGBFS %)	River sand	Crushed sand
1	R-C 30/1	0.49	100	0	32.40	31.80
2	R-C 30/2	0.47	80	20	31.80	32.40
3	R-C 30/3	0.45	70	30	33.00	34.00
4	R-C 30/4	0.44	65	35	33.48	35.20
5	R-C 30/5	0.43	60	40	35.69	33.49
6	R-C 30/6	0.42	50	50	30.10	32.10
7	R-C 30/7	0.40	40	60	30.50	30.55

Table 8: 28 Days compressive strength (N/mm²) of the cylinders for M-60

Sr. No.	Trial	w/c Ratio	Cement (%)	GGBFS (%)	River sand	Crushed sand
1	R-C 60/1	0.295	100	0	52.30	64.10
2	R-C 60/2	0.295	80	20	55.18	73.86
3	R-C 60/3	0.295	70	30	59.35	78.21
4	R-C 60/4	0.290	65	35	64.80	85.74
5	R-C 60/5	0.290	60	40	63.70	88.20
6	R-C 60/6	0.285	50	50	54.80	66.48
7	R-C 60/7	0.285	40	60	51.80	62.58

The graphical representation of the variation of GGBFS % with Compressive strength is shown in Figure 3 and Figure 4.

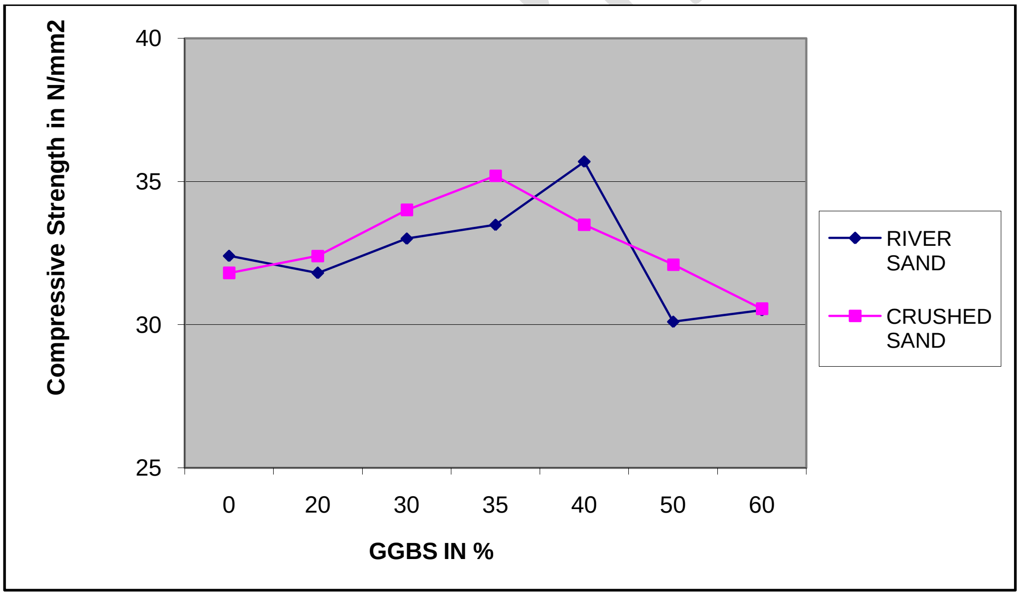

Fig. 3: Effect of contents of GGBFS on the compressive strength of cylinder (M- 30 Grade)

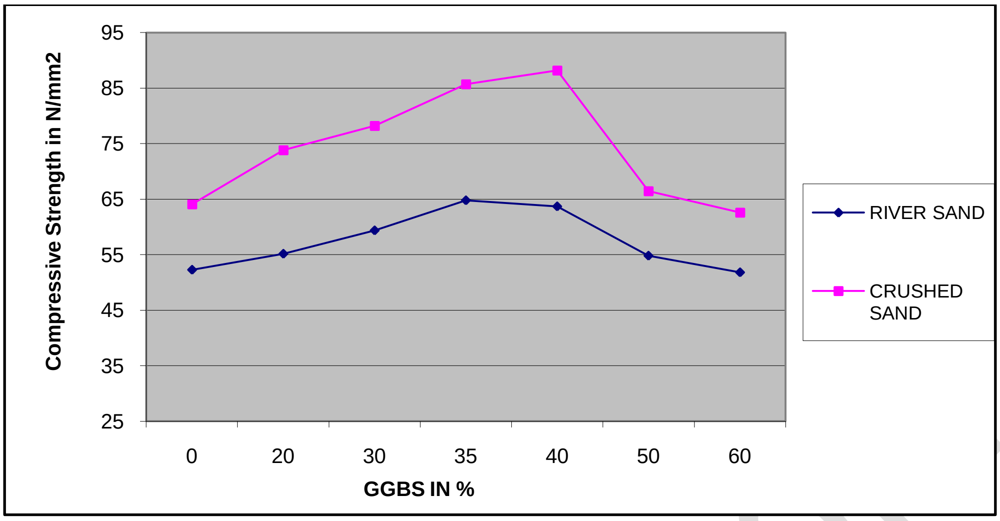

Fig. 4 : Effect of contents of GGBFS on the compressive strength of cylinder (M- 60 Grade)

From Fig.3, for M30 grade it is seen that there is an increase in the compressive strength of the concrete when crushed sand is used as compared to that in case of river sand. The average increase in the strength is around 1.12% greater than the average strength obtained in case of river sand. The strength of the concrete made with river sand and crushed sand is found to be maximum corresponding to use of 35% and 40% GGBFS, respectively. The increase in strength at these contents of GGBFS as compared with the conventional concrete is observed to be 10.15% and 10.69 %, respectively in case of river sand and crushed sand.

From Fig.4, for m60 grade it is observed that there is an increase in the compressive strength of the concrete when crushed sand is used as compared to that in case of river sand. The average increase in the strength is around 22.58% greater than the average strength obtained in case of river sand. The strength of the concrete made with river sand and crushed sand is found to be maximum corresponding to use of 35% and 40% GGBFS, respectively. The increase in strength at these contents of GGBFS as compared with the conventional concrete is observed to be 23.90% and 37.59 %, respectively in case of river sand and crushed sand.

From the results, there is reduction in cylindrical comp. strength with respect to cubical compressive strength in both the river sand as well as crushed Sand.

V. CONCLUSIONS

The present experimental investigation was aimed at evaluating the suitability of the industrial waste containing pozzolanic materials such as ground granulated blast furnace slag as the cement replacing materials in the concrete as a sustainable construction materials, as well replacement of River sand with Crushed sand. Some of the broad conclusions deduced from the present study are as follows.

i. From the Experimental study the GGBS can be used as cement replacement material.
ii. As there was an appreciable increase in the workability of concrete with increase percentage replacement of cement with GGBS, therefore W/c ratio can be reduced keeping the Slump constant.
iii. From this experiment study it is observed that for M30 grade and M 60 grade the OPC can be replaced with GGBS at a range of 35% to 40% for the River sand and crushed sand.
iv. From this experiment study it is observed that for Crushed sand can be replaced with River sand as Cubical Compressive strength is higher.
v. From the results, there is reduction in cylindrical comp. strength with respect to cubical compressive strength in both the River sand as well as Crushed Sand.

In view of the afore-mentioned results some of the findings emerged from the present investigation, it can be concluded that the pozzolanic waste materials such as GGBFS when used as a cement replacing materials in conjunction with OPC can render the sustainable concrete.

REFERENCES

i. J.W. Meusel and J.H. Rose (1983): "Production of granulated blast furnace slag at sparrows point and the workability; and strength potential of concrete incorporating the slag", American Concrete Institute, **SP-79**, 867–90.
ii. V.S. Dubovoy, S. H. Gebler and P. Klieger (1986): "Effects of ground granulated blast furnace slag on some properties of pastes, mortars and concretes", American Society for Testing and Materials (Blended cement), **ASTM STP- 897**, (Editor: G. Frohnsdorff), Philadelphia, 29-48.

iii. G. Frigione (1986): "Manufacture and characteristics of Portland blast furnace slag cements", American Society for Testing and Materials (Blended cement), **ASTM STP- 897**, Philadelphia, 15-28.

iv. D.E.Wimpenny, C. Ellis and C.M. Reeves (1989): "Development of strength and elastic properties in slag cement concretes under low temperature curing conditions", *Proc. 3rd International Conference on Fly Ash, Silica Fume, Slag and Natural Pozzolanas in Concrete, Trondheim, Norway.*

v. T. Folarin, Olorunsogo and J.W. Peter (1998): "Effect of GGBFS particle-size distribution on mortar compressive strength", *Journal of Materials in Civil Engineering (ASCE)*, **10(3)**, 180-187.

vi. G.J. Osborne (1999): "Durability of Portland blast furnace slag cement concrete", *Cement and Concrete Composites*, **21**(1), 11-21

vii. R.D.Hooton (2000): "Canadian use of Ground Granulated Blast Furnace Slag (GGBFS) as a supplementary cementing material for enhanced performance of concrete", *Canadian Journal of Civil Engineering*, **27**, 754-760.

viii. S.C.Pal, J. Mukherjee and S.R. Pathak (2002), "Corrosion behavior of reinforcement in slag concrete", *ACI Materials Journal*, **99** (6), 521-527.

ix. P.Z.Wang and R. Trettin.(2005), "Effect of fineness and particle size distribution of granulated blast-furnace slag on the hydraulic reactivity in cement systems", *Advances in Cement Research*, **17**(4), 161 –167.

x. Q.Wang and M. Miao. (2012), "The influence of high-temperature curing on the hydration characteristics of a cement–GGBS binder", *Advances in Cement Research*, 24 (1), 33 –40.

xi. Durai S. Remya M., Dr. P.Muthupriya, Dr.R.Venkatasubramani. (2013), "Experiment investigation on high performance concrete using GGBS as admixture", IJETED, **2** (3), 388-394.

xii. Ke.A.Palanippm, S.Vasantha, S.Siva Prakasen, Mr.S.Prabhu (2013): "GGBS as alternative to OPC in Concrete as an environmental pollution Reduction Approach", *International Journal of Engineering Research and Technology*, **2**, 190-195.

xiii. Yogendra Patil, P.N.Patil and Arun Kumar Dwivedi (2013), “GGBS as partial replacement of OPC in Cement Concrete”, *International Journal of Scientific Research*, 189-191.

xiv. Sonali K. Gadpalliwar, R.S. Deotale. Abhijeet R. Narde (2014): “Study the partial replacement of element by GGBS, RHA and natural sand by quarry sand in concrete”, *IOSR-JMCE*, **11**(2), 69-77

xv. Venu Malagavelli and P.N. Rao (2010): “High Performance Concrete with GGBS and Robo sand”, *International Journal of Engineering Science and Technology*, **2**(10), 5107-5113.

xvi. V.S. Tamilarasan and P. Perumal (2012): “Workability studies on concrete with GGBFS as a replacement material for cement with and without super-plasticizers”, *International Journal of Advanced Research in Engineering and Technology (IJARET)*, **3**(2), 11-21.

xvii. G.Zhi and K. Wang. (2009): “Modified heat of hydration and strength models for concrete containing fly ash and slag”, *Computers and Concrete*, **6**(1), 19-40.

xviii. Kommran Muzaffer Khan and Usman Ghani (2004): “Effect of blending of Portland cement with GGBS on the Properties of Concrete”, Cipermier PTE LTD, Singapore, 100029040, 329-334.