Experimental Study on Strength Characteristics of Concrete by Replacement of Cement and Fine Aggregate by GGBS and M Sand

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Abstract- *Cement is the major component in making the concrete. Due to urbanization and industrialization, the production of concrete is increasing day by day. Based on researches, it is well known fact, that the production of cement emits carbon dioxide. A recent survey shows that for production of every ton of structural concrete, around 400 kg/m3 of carbon dioxide is liberated. So in present scenario it has become a matter of prime importance, to keep the cement production same and increase the production of substitute materials to the save the environment. Experiments are taking place for replacement of cement with mineral admixtures possessing same characteristics as that of the cement. Another scarce material is river sand which is due to the growing communities, as that of cement the replacement of river sand is also very important. Therefore in the present study M30 grade of concrete is considered to replace cement, by Ground Granulated Blast furnace Slag (GGBS) and natural sand by Manufactured Sand. The cement is replaced by GGBS as 10%, 20%, 30%, 40% and 50% with M – sand. Experiments are conducted to determine the compressive strength, flexural strength, split tensile strength and water absorption test.*

Keywords- Ground granulated blast furnace slag, manufactured sand, compression strength, flexural strength, split tensile strength, water absorption.

I. INTRODUCTION

For any type of construction, concrete is the basic need, whose ingredients are cement, fine aggregates, coarse aggregates and water. As the world's population is growing day by day, the forests are converting into concrete jungles. Due to which the production of cement is increasing annually by huge proportion. Every ton of cement emits certain amount of carbon dioxide, because large amount of thermal energy is needed to burn the ingredients to make the cement. Based on recent study cement production was around 2.8 billion metric ton in the year 2009 emitting more than 2 gigatons of carbon dioxide. Also, the study forecasted that by the year 2020 the cement production is expected to reach 5.5 billion ton emitting more than 4 gigatons of carbon dioxide. In addition the study forecasted that China itself will be producing about 3 billion tons of cement in the year 2020. The study clearly proves that the cement production is escalating in turn increasing carbon dioxide content and harming the environment. So it becomes a matter of prime importance to reduce the amount of cement production either by using any substitute material in place of cement in the construction industry or one has to limit the growing population. The easier part is to use the substitute material. The cement replacing materials are known as mineral admixtures like fly ash, ground granulated blast furnace slag (GGBS), silica fume, metakaolin and many more. These materials are waste products either from thermal power plants or left overs in production of iron. The disposal of such matter is becoming a huge environmental problem.Therefore the industry is utilizing the substitutes as a partial replacement of cement, as they are possessing similar properties as that of the cement

Another important ingredient is river sand. The faster growth of construction industry has resulted in the demand for river sand as well as that of the cement, as a result of which the river sand, is becoming a rare material. So in present investigation the river sand is replaced by manufactured sand either partially or completely. Manufactured sand is produced by crushing granite stone. Such sand will be of cubical shape and graded as per the requirement of construction industry. It can be made available nearby to construction site thereby reducing the transportation cost. As the manufactured sand is produced using modern techniques, it will be completely dry without silt, clay and other impurities. Hence bonding is increased which enhances the strength of concrete. The manufactured sand has optimum setting time, minimizing bleeding, segregation and capillary action in concrete. To get the river sand, one has to dredge the rivers causing depletion of ground water and affecting the bridges and dams. Therefore manufactured sand is one of the economical replacement for natural river sand.

Ground granulated blast furnace slag abbreviated as GGBS. It's very fine in texture compared to ordinary Portland cement and whitish in color. It is a by-product obtained during the manufacture of iron. GGBS is made by crushing the molten slag from the blast furnace either in water or steam, to get a glassy appearance later on dried and ground to make it a crushed powder. The main ingredients of GGBS are Cao, Sio_2, Al_2o_3 and Mgo, whose mixture varies, depending upon raw materials used in manufacture of iron. The glassy nature of GGBS is responsible for blending with ordinary Portland cement. GGBS will be directly mixed during batching as replacement of cement up to 80% but in most instances are up to 50%. Addition of GGBS to concrete makes it dense and improves the strength. It is widely used in Asia and Europe because of its fine nature and enhancing durability of structures i.e., doubling the life span of a structure. The concrete made with GGBS, when compared with one made with ordinary portland cement, GGBS concrete gains slower strength depending on the GGBS content. Increase in concrete strength is observed with longer periods. The slow strength gain of GGBS concrete reduces heat of hydration and micro cracks in concrete. Such concrete shows high resistance to chlorides and sulphates. Therefore, it is best suitable for piers of bridges and the structures across sea shore. Concrete finishes, made with GGBS concrete, show fair appearance than made with ordinary portland cement.

II. LITERATURE REVIEW

Christina Mary V and Kishore CH (2015) studied strength and durability characteristics of high performance concrete replacing cement by GGBS and natural sand by M sand. In which cement has been replaced by GGBS with 10%, 20%, 30%, 40% and 50% with 50% river sand and 50% manufactured sand. Concrete grade was taken as M40 with water cement ratio of 0.45 with superplasticizerconplast-SP430, whose dosage is maintained at 0.7%. The study included compressive strength test, flexural strength test and split tensile strength test. Secondly durability tests namely RCPT, sorpitivity and acid attack for a period of 30 days were also focused. Results showed that maximum compressive strength was for 10% GGBS and 50% M sand, as compared to control mix. Also, the split tensile strength was maximum for 10% GGBS and 50% M sand. Where as flexural strength test indicated highest value for 30% GGBS and 50% M sand. RCPT test indicated maximum chloride penetration for 10% GGBS and 50% M sand, rest all combinations were with low chloride ion penetration. Sorpitivity was low for mixes with 40% and 50% GGBS compared with other combinations. Lastly results of acid attack showed slight decrease in compressive strength for all combinations.

ReshmaRughooputh and JayalinaRana (2014) did experiment on Partial Replacement of cement by ground granulated blast furnace slag. The experiment is carried out by replacing cement with GGBS by 30% and 50%. Grade of concrete considered as M30. The results showed thatCompression strength, flexural strength and split tensile strength were maximum for mix with 50% GGBS and 50% ordinary Portland cement (OPC). Secondly the results also indicate that increase in GGBS content increases workability as well as strength properties. The drying shrinkage results were 3% and 4% for 30% and 50% GGBS respectively. Drying shrinkage increases with increase in GGBS content. The modulus of elasticity for 30% and 50% GGBS test specimens increases by 5% and 13% with respect to control mix. This proves that the addition of GGBS to concrete, makes it a denser mix by lowering the porosity. The initial surface absorption was observed for 10min, 30min and 60min. The observation clearly defines that, as the GGBS content increases the concrete becomes impermeable and the surface absorption decreases significantly.

A. AndriyaAnnal and Priya Rachel (2016) did study on high performance concrete using GGBS and M sand, for which concrete grade of M20 was considered with water cement ratio of 0.38. The GGBS has been varied into three proportions 30%, 40% and 50% with 100% of river sand replaced by M sand. The concrete cubes were casted and compressive strength at the age of 14 days was observed. The outcome showed that compressive strength increases with increase in GGBS content, also for variation with 50% GGBS and 100% M sand, there was increase in compressive strength to the extent of 92.65% almost double compared to control mix. Thus, it defines that manufactured sand meets the design requirements and can be used in place of river sand.

M. D. Narendra and G. Gangha (2015) performed experiment on high performance concrete with GGBS and robosand. Grade of concrete was M35 with water cement ratio of 0.35 withsuperplasticizerconplast SP-300 whose dosage is varied from 0.5% to 0.8% to get the desired workability. In this study, GGBS has been replaced by cement in 40%, 50% and 60% together with natural sand replaced by robo sand in 25%, 50%, 75% and 100%. The results indicated that increase in robo sand content makes the mix harsh without considering cement replacement.Robo sand acts as good replacement material for river sand as it gives desired results. The optimum replacement of GGBS with cement was 50% to get the maximum compressive strength. The split tensile strength and flexural strength increases with increase in GGBS as well as robo sand content. The end percentage rise in compressive strength was 17.22% with respect to control mix. Also, percentage increase of 26.6% and 12% were observed for split tensile strength and flexural strength respectively.

Mr.Bhaveshkumar, Mr.Sandip (2014) did investigation on concrete properties by partially replacing river sand by manufactured sand. The manufactured sand is from chikhli region of Gujarat. Natural sand has been replaced by manufactured sand in 0%, 25%, 50%, 75% and 100%. The grade of concrete considered for experiment is M25 with water cement proportion of 0.5. Slump test was performed to measure the workability of the mix, also concrete cubes were cast to ascertain the concrete compressive strength and compare it with the reference mix. The outcome showed that the workability decreases as the percentage of manufactured sand increases. In other words, the mix becomes harsh with the increase in percentage of manufactured sand. Also, there was enhancement of compressive strength with increase in replacement level. The maximum compressive strength was observed for mix containing 100% of manufactured sand. Hence manufactured sand gives satisfactory results and can be used as partially or completely in making the concrete.

2.1 Objectives

1. As the cement production is increasing day by day, destroying the environment with the emission of carbon dioxide per ton of cement, it is necessary to increase the production of substitute materials. In the present study effort has been made to determine the optimum replacement of cement with GGBS without affecting the concrete strength.
2. Due to the raid growth of construction industry, natural river sand is becoming rare and will no longer be available in future. So the present study also focuses on substitution of natural river sand by M- sand and observing replaced effects.
3. To determine the compressive strength, split tensile strength and flexural strength of concrete at the age of 28 days using GGBS and M sand and compare it with conventional concrete.
4. To determine the permeability with respect to percentage of water absorption after each day.

III. MATERIALS AND METHODOLOGY

3.1 Cement

Cement acts as a binding material in concrete. OPC of 43 Grade with respect to IS 8112 was considered for present study. The features of OPC are as shown below.

Table 1 Parameters of Cement

Sl.no	Parameters	Obtained value
1	Fineness test	2.96%
2	Normal consistency	34%
3	a) Initial setting time b) Final setting time	90 minutes 600 minutes
4	Specific Gravity	3.08

3.2 Ground Granulated Blast Furnace Slag

GGBS is by-product obtained during iron manufacture. The parameters are tabulated below.

Table 2 Parameters of GGBS

Sl.no	Chemical compound	Percentage
1	Specific Surface (m^2/kg)	380
2	SiO_2	33.8%
3	Al_2O_3	22.1%
4	Fe_2O_3	2.0%
5	CaO	34.5%
6	SO_3	0.13%
7	MgO	6.3%
8	IR	1.57%

3.3 Fine Aggregate

Fine aggregate acts as a filler material for concrete. Sieve analysis was carried out as per IS: 383-1970 and confirming to zone I. The characteristics of fine aggregates are as shown below.

Table 3 Parameters of Fine Aggregates

Sl. No	Parameters	Values
1	Specific. Gravity	2.66
2	Sieve analysis	2.46
3	Water absorption	0.5%

3.4 Coarse Aggregate

The coarse aggregates were crushed angular aggregates of maximum nominal size of 20mm, taken for the study. The parameters of coarse aggregates are as shown below.

Table 4 Parameters of Coarse Aggregates

Sl. No	Parameters	Values
1	Specific. gravity	2.59
2	Sieve analysis	3.39
3	Water absorption	1%

3.5 Water

In this study normal water was utilized for both casting and curing of specimens. For curing of specimens the water was periodically changed after every 15 days for healthy environment.

3.6 Super Plasticizer

MasterGlenium Sky 8233 (Formerly Glenium B233) of BASF Company (polycarboxylic ether based) has been used as superplasticizer. It is chloride free and has low alkali content suitable for all types of cement. Its dosage is maintained as 0.6% throughout the experiment. It is recommended to use in conventional concrete as well as concrete containing substitutes. The product has been mainly used in achieving workability, high performance and high durability characteristics.

Table 5 Test Data

Aspect	Light brown liquid
Relative density	1.08 ± 0.01 at 25 ° C
pH	≥ 6
Chloride ion content	< 0.2%
Specific gravity	1.08

3.7 Methodology

The methodology is carried out as shown below.

- Journals are collected and reviewed for more clarity of research work.
- The materials were procured as per the quantities in the design and tests were performed to evaluate the properties of materials.
- Conventional concrete was prepared and kept as a reference mix.
- Further, cement is substituted by GGBS in 10%, 20%, 30%, 40% and 50% along with complete replacement of river sand by M sand.
- Concrete cubes, beams and cylinders were casted and cured for a period of 28 days.
- The water level was maintained in such a way that to keep the specimens completely immersed. The water was changed periodically after every 15days to keep healthy environment.
- After 28days the specimens were removed and allowed to dry at room temperature. Compressive strength test, flexural strength test, split tensile strength test and water absorption test were performed.
- For strength tests CTM has been used. Lastly the results were tabulated and compared with respect to conventional concrete and conclusions remarked.

3.8 Mix Design

Table 6 Mix Design for M30 Grade

Sl.no	Material	Quantity Kg/m³
1	Cement	420
2	Fine aggregate	715
3	Coarse aggregate	1167
4	Water	168
5	Water – cement proportion	0.40

IV. RESULTS AND DISCUSSIONS

4.1 Compressive Strength

Compressive strength of M30 grade concrete with varying percentages of Ground Granulated Blast Furnace Slag as substitute for cement and using manufactured sand. Compressive Testing Machine (CTM) has been used for testing of concrete cubes. For every variation, three cubes of cross section 150 X 150mm were cast, average compressive strength was determined. To evaluate the compressive strength of concrete following formula has been used.

Compression Strength = (Failure Load / Area) in N/mm^2

Table 7 Compressive Strength of Cube

Sl. No	Mixture Identities	% of GGBS	Comp.Strength N/mm²
1	CM	0%	39.85
2	GM-A	10%	34.52
3	GM-B	20%	35.26
4	GM-C	30%	36
5	GM-D	40%	41.33
6	GM-E	50%	38.07

(Note: CM – Control Mix, GM – GGBS Mix)

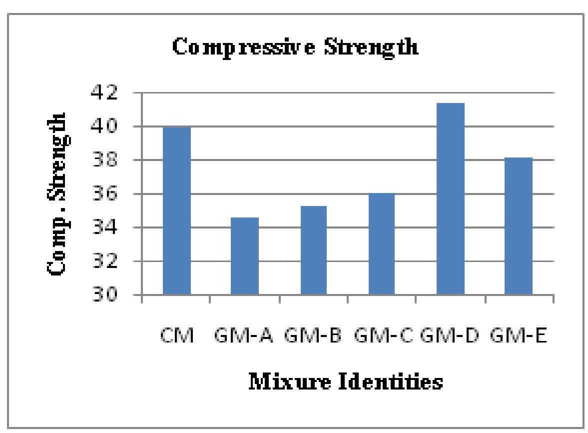

Figure.1 Graphical Representation of Compressive Strength of Cube

4.2 Split Tensile Strength

It defines the strength of concrete in tension. Due to the brittle nature of concrete, it is very weak in tension and takes less tensile load. Whenever tensile force is applied it develops cracks and leading to failure. To calculate the tensile strength, cylinder of 150mm dia and 300mm in length were cast and tested at the age of 28 days. For each variation, average of three specimen readings was determined. The compression load is applied uniformlyin the diametrical form, till the failure of the specimen.The SPT strength is evaluated in the following way.

Split tensile strength is

$$\frac{(2*\text{failure load})}{(\Pi*\text{dia of specimen}*\text{length of specimen})}$$

Table 8 SPT Strength of Cylinder

Sl. No	Mixture Identities	% of GGBS	SPT Strength N/mm²
1	CM	0%	3.04
2	GM-A	10%	3.23
3	GM-B	20%	3.49
4	GM-C	30%	3.87
5	GM-D	40%	4.01
6	GM-E	50%	3.21

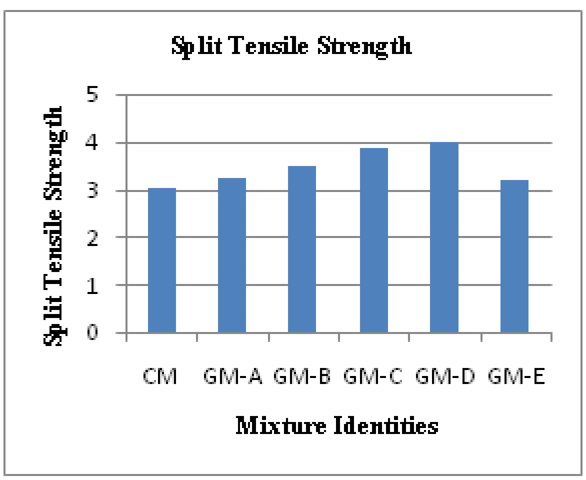

Figure.2 Graphical Representation of Split Tensile Strength of Cylinder

4.3 Flexural Strength

Flexural concrete strength is the ability of unreinforced (Plain) concrete specimen (beam) to withstand the deflecting action. Flexural concrete strength is also known as modulus of rupture and it is the property of material. Flexural test gives the value of highest stress just before the material yields. Also, defined as maximum tensile stress resisted before the specimen fails.For each variation, three beams of 150 x 150 x 750mm were castand cured for a period of 28 days. Average of three specimen readings was determined. Compression Testing Machine (CTM) has been used for testing of specimens. Bending strength is calculated using the following expression.

Flexural concrete Strength=

$$\frac{(\text{Failure load}*\text{length of specimen})}{(\text{Breadth of specimen}*\text{Sq. of depth of specimen})}$$

Table 9 Flexural Strength of Beam

Sl. No	Mixture Identities	% of GGBS	Flexural Strength N/mm²
1	CM	0%	5.9
2	GM-A	10%	6.1
3	GM-B	20%	6.3
4	GM-C	30%	6.7
5	GM-D	40%	7.2
6	GM-E	50%	6.1

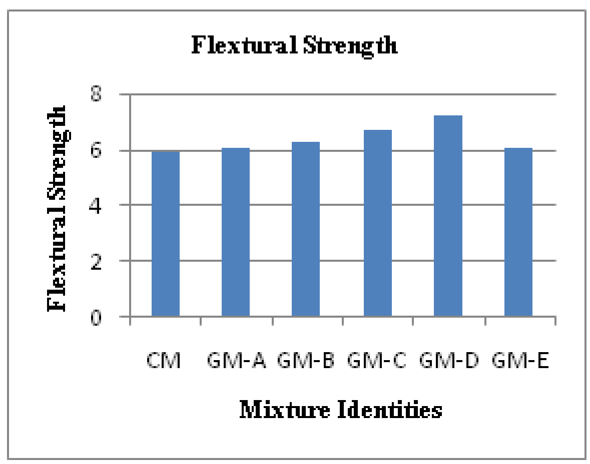

Figure.3 Graphical Representation of Flexural Strength of Beam

4.4 Water Absorption Test

It is one of the durability tests performed on concrete cubes.Lesser the percentage of water absorption, suitable for construction activities. To evaluate the percentage water absorption, dry weights of concrete cubes were recorded and kept immersed in water. Water absorption test was conducted for a period of 6 days and it was found that there was no further absorption of water. For each variation, three cubes were cast and average percentage water absorption was determined. It is calculated using the following formula.

Percentage of water absorption =

$$\frac{(\text{Wet weight} - \text{Dry weight})}{(\text{Dry weight})}$$

The final readings are tabulated as shown below

4.4.1 Water absorption after each day

Table 10 Water Absorption Test

Sl. no	Mixture Identities	% of GGBS	Initial weight, kg	Final weight, kg	% Water absorption (7 th day)
1	CM	0%	**8.479**	**8.504**	0.3
2	GM-A	10%	**8.625**	**8.653**	0.32
3	GM-B	20%	**8.753**	**8.784**	0.35
4	GM-C	30%	**8.511**	**8.545**	0.4
5	GM-D	40%	**8.506**	**8.55**	0.52
6	GM-E	50%	**8.513**	**8.71**	0.68

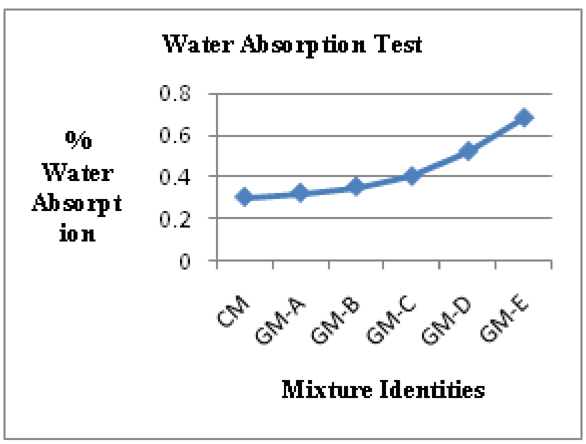

Figure. 4 Water Absorption Test

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VI. CONCLUSION AND SCOPE FOR FURTHER STUDIES

6.1 Conclusion

1. As the percentage of GGBS increases, so the compressive strength of concrete also increases. Maximum compressive strength was observed for mix containing 40% GGBS and 100% M sand. Further GGBS increase, decreases the strength of concrete. Therefore the optimum replacement for cement with GGBS was 40%. The percentage rise in compressive strength was 3.71% when compared with conventional concrete.
2. Results of split tensile strength show the same trend as in case of compressive strength, increase in GGBS content increases split tensile strength. Maximum split tensile strength was observed for mix containing 40% GGBS and 100% M sand. There was 31.91% of increase in split tensile strength when compared with conventional concrete.
3. Results of flexural strength showed that, increase in GGBS content increases flexural strength. The maximum flexural strength was observed for mix with 40% GGBS and 100% M sand. There was 22.03% of increase in flexural strength compared with respect to control mix.
4. Water absorption test indicated that addition of GGBS to concrete increases the water absorption.

6.2 Scope for Further Studies

- Study the effects of concrete specimens subjected to sulphate attack, chloride attack for a period of 30, 60 and 90 days as durability test and observe the variations.
- Study the effects of concrete specimens subjected to elevated temperature and evaluate the mechanical properties and compare it with the conventional concrete.

REFERENCES

[1] VinayakAwasare, Prof. M. V. Nagendra .“Analysis of strength charecteristics of GGBS concrete”.International journal of advanced engineering technology.E-ISSN 0976-3945.

[2] Christina Mary V, Kishore CH. “Experimental investigation on strength and durability characteristics of high performance concrete using GGBS and M sand”. ARPN journal engineering and applied sciences. Vol. 10, no. 11, June 2015.

[3] A. AndriyaAnnal, Priya Rachel."Experimental study on behavior of high performance concrete using GGBS and M sand".International journal engineering research and technology. Vol. 5, issue 02, February 2016.

[4] Indumati. B, V. Gnanadevi. "An experimental investigation on properties of hybrid fiber reinforced concrete with GGBS and fly ash". International journal of emerging technology in computer science and electronics. ISSN: 0976-1353, Vol. 13, issue 4, March 2015.

[5] M.D. Narendra, G. Gangha. "An experimental study on high performance concrete partially replacing cement and fine aggregate with GGBS and ROBO sand".International journal of engineering sciences and emerging technologies. Vol. 7, issue 5, pp: 737-742, March 2015.

[6] ReshmaRughooputh, JayalinaRana. "Partial replacement of cement by ground granulated blast furnace slag in concrete". Journal of emerging trends in engineering and applied sciences. ISSN: 2141-7016. 2014.

[7] Mr. Bhaveshkumar M. Kataria, Mr. Sandip U. Shah. "An experimental study of using manufactured sand in concrete". International journal of advanced research in engineering, science and management. ISSN: 2394-1766

[8] IS 10262: 2009. "Concrete mix proportioning – guidelines". Bureau of Indian Standards, New Delhi.

[9] IS 456: 2000. "Plain and reinforced concrete – code of practice". Bureau of Indian Standards, New Delhi.