International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 05, May-2015

An Experimental Study on Partial Replacement of Cement by Ggbs and Natural Sand by Quarry Sand in Concrete

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Abstract: **Concrete is the most widely used construction material in civil engineering industry because of its high structural strength and stability. The concrete industry is looking for supplementary cementitious material or industrial by product with the objective of reducing the carbon dioxide emission which is harmful to environment. Ground granulated blast furnace slag (GGBS) is the solid wastes generated by industry are used as a replacement material for cement. Quarry sand is produced from quarry industry which is thrown on land fill; to reduce the sand consumption quarry sand is used as an alternative material for sand replacement.**

This paper deals with the effective utilization of waste material in concrete production as a partial replacement for Cement and sand. The cement has been replaced by GGBS in the range of 30%, 40% and 50% by weight of cement, quarry sand in the range of 40%, 50% and 60% by weight of cement for M40 grade mix. Workability test was carried out on fresh properties of concrete while compressive strength, split tensile strength and flexural strength were carried on hardened concrete. It is found that by the partial replacement of cement with GGBS and sand with Quarry sand helped in improving the strength of the concrete substantially compared to normal mix concrete. Compressive strength test was carried out for 7, 28 and 56 days while flexural and split tensile strength test was carried out at 28 days curing period.

Keywords: Ground Granulated Blast Furnace Slag (GGBS), Quarry Sand (QS), Compressive Strength, Split Tensile Strength, Flexural Strength, Workability.

I. INTRODUCTION

Concrete has been the major instrument for providing stable and reliable infrastructure since the days of Greek and roman civilization. Concrete is the most world widely used construction material. The increase in demand of concrete more the new method and materials are being developed for production of concrete. Concrete is a mixture of cement, water, and aggregates with or without chemical admixtures. The most important part of concrete is the cement. Use of cement alone as a binder material produces large heat of hydration. Since the production of this raw material produces lot of CO_2 emission. The carbon dioxide emission from the cement raw material is very harmful to the environmental changes. Nowadays many researchers have been carried out to reduce the CO_2. The effective way of reducing CO_2 emission from the cement industry is to use the industrial by products or use of supplementary cementing material such as Ground Granulated Blast Furnace Slag (GGBS), Fly Ash (FA), Silica Fume (SF) and Metakaolin (MK). In this present experimental work an attempt is made to replace cement by GGBS to overcome these problems.

River sand has been used as a major building material component. Its well- graded and that all sizes grains are well distributed in a given sample. River sand is mainly used for all kinds of civil engineering construction. River sand has been the most important choice for the fine aggregate component of concrete in the early periods. Overuse of the material have been led to environmental concerns, the depleting of securable river sand due to this the material cost also increases. Nowadays the natural river sand becomes scarce and very costly. To overcome from this crisis, partial replacement of natural sand with quarry sand is economic alternative. Use of QS in concrete increases the strength characteristics.

A) GROUND GRANULATED BLAST FURNACE SLAG (GGBS)

Ground Granulated Blast Furnace is a by product from the Blast furnace slag is a solid waste discharged in large quantities by the iron and steel industry in India. These operate at a temperature of about 1500 degree centigrade and are fed with a carefully controlled mixture of iron – ore, coke and limestone. The iron ore is reduced to iron and remaining materials from slag that floats on top of the iron. This slag is periodically tapped off as a molten liquid and if it is to be used for the manufacture of GGBS it has been rapidly quenched in large volumes of water. The quenching optimizes the cementitious properties and produces granules similar to coarse sand. This granulated slag is then dried and ground to a fine powder.

The re-cycling of these slag's will become an important measure for the environmental protection. Iron and steel are basic materials that underpin modern civilization, and due to many years of research the slag that is generated as a by-product in iron and steel production is now in use as a material in its own right in various sectors. The primary constituents of slag are lime (CaO) and silica (SiO_2). Portland cement also contains these constituents. The primary

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constituent of slag is soluble in water and exhibits an alkalinity like that of cement or concrete. Meanwhile, with the development of steel industry, the disposal of such a material as a waste is definitely a problem and it may cause severe environmental hazards.

B) QUARRY SAND

The fine aggregates or sand used is usually obtained from natural sources specially river beds or river banks. Now-a-days due to constant sand mining the natural sand is depleting at an alarming rate. Sand dragging from river beds has led to several environmental issues. Due to various environmental issues Government has banned the dragging of sand from rivers. This has led to a scarcity and significant increase in the cost of natural sand. There is an urgent need to find an alternative to river sand. The only long term replacement for sand is Quarry sand.

C) OBJECTIVE

- To determine the most optimized mix of GGBS- based concrete.
- To optimize strength characteristics of concrete by partially replacement of cement by GGBS and sand by Quarry sand
- To determine the variation of workability of concrete by partially replacing the cement by GGBS sand by Quarry sand
- To study the fresh properties of concrete
- To understand the mechanical properties of concrete

III. MATERIALS AND METHODS

A) cement

Ordinary Portland cement of 43 grade (Ramco) conforming to IS 8112-1989 is used. Table 1 shows the test results of basic properties of cement.

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%

B) Fine aggregate

Natural river sand of size below 4.75mm conforming to zone II of IS 383-1970 is used as fine aggregate. Table 2 shows the test results of basic properties of fine aggregates.

TABLE 2: BASIC PROPERTIES OF FINE AGGREGATES

Properties	Fine Aggregate
Specific gravity	2.62
Water Absorption	1.45%

C) Coarse Aggregate

Natural crushed stone with 20mm down size is used as coarse aggregate. Table 3 shows the test results of basic properties of coarse aggregates.

TABLE 3: BASIC PROPERTIES OF COARSE AGGREGATES

Properties	Coarse Aggregate
Specific gravity	2.65
Water absorption	0.39%

D) Ground Granulated Blast Furnace Slag

GGBS was collected from JSW cement limited, vidyanagar Bellary. Table 3 shows the test results of basic properties of GGBS.

TABLE 4: BASIC PROPERTIES OF GGBS

Properties	GGBS
Specific gravity	2.86
Water absorption	0.14%

E) Quarry Sand

Quarry Sand was collected from Gonikoppa from kodagu dist. It confirms to zone II. The following propertiesof QS show in below table 5.

TABLE 5: BASIC PROPERTIES OF QS

Properties	QS
Specific gravity	2.61

F) Water

Ordinary portable water is used in this investigation both for mixing and curing.

G) Super plasticizer (SP)

CONPLASTT SP430 is used as a superplasticizer. It is a chloride free, super plasticizing admixture. It was used to enhance the workability of concrete.

H) Concrete Mix Design

Mix proportion used in this study is 1:1.61:2.65 (M40) with water-cement ratio of 0.4 and superplasticizer of 0.75%.

I) Batching of Materials

Weight batching and machine mixing are adopted in this study for concrete production. The percentage replacement of ordinary cement by GGBS and QS and their material weight are shown in Table 6

TABLE 6: MIX PROPORTION PER CUBIC METER

Mixes Name	GGBS (Kg)	Cement (Kg)	F A (Kg)	QS (Kg)	CA (Kg)	Water (w/c 0.4) (liters)	0.75 % SP (liters)
M	-	425	684.25	-	1126.25	170	3.187
M1	127.5	297.5	684.25	-	1126.25	170	3.187

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M2	170	255	684.25	-	1126.25	170	3.187
M3	212.5	212.5	684.25	-	1126.25	170	3.187
M4	127.5	297.5	410.55	273.7	1126.25	170	3.187
M5	127.5	255	342.12	342.12	1126.25	170	3.187
M6	127.5	212.5	273.7	410.55	1126.25	170	3.187
M7	170	297.5	410.55	273.7	1126.25	170	3.187
M8	170	255	342.12	342.12	1126.25	170	3.187
M9	170	212.5	273.7	410.55	1126.25	170	3.187
M10	212.5	297.5	410.55	273.7	1126.25	170	3.187
M11	212.5	255	342.12	342.12	1126.25	170	3.187
M12	212.5	212.5	273.7	410.55	1126.25	170	3.187

J) Mixing of Material

Machine mixing was used for the mixing of material. First aggregate was added to the mixer, followed by 25% of total water and superplasticizer to prevent cement sticking to blades or at the bottom of the drum. Superplasticizer will be added to water measured and stirred well. Then sand is added with 25% of water and superplasticizer again. After through mixing of aggregates, cement with admixtures if any is added and remaining 50% of water and superplasticizer is introduced. Slump test is conducted for each mix to measure workability of concrete. Three cubes of 100*100*100mm, 3 cylinder of 100mm dia and 200mm in height and 3 beams of 100*100*500mm casted for each mixes to measure the compressive strength, split tensile strength and Flexural strength of concrete. Cylinder of 150mm dia and 300 mm height are casted for each mixes to measure the modulus of elasticity of concrete. Totally 144 cubes, 36 cylinder and 36 beams and 26 big cylinders are casted. The cast specimens were kept in ambient temperature for 24 hours. After 24 hours they were demoulded and placed in water for curing.

Fig 1: Mixing of concrete and concrete placed in moulds

K) Testing of Specimen

All cube and cylinder specimens are tested for compression strength and tensile in Compression Testing Machine (CTM) and all the beams specimens are tested for flexural strength in universal testing machine (UTM) shown in figure

Fig 2: Compressive Strength Test

Fig 3: Tensile Strength Test

Fig 4: Flexural Strength Test

IV. RESULTS AND DISCUSSIONS

Figures below represent the test results

A) Compressive Strength

The compressive strength of concrete was determined at the age of 7, 28 and 56 days as presented in graph

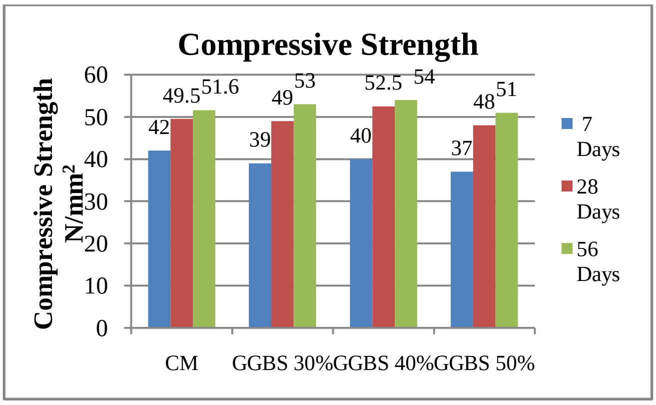

Fig 5:7, 28, 56 Compressive Strength of GGBS mixes

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Fig 5 represents the compressive strength of concrete with partial replacement of cement by GGBS 0%, 30%, 40%, 50%. It is observed that decrease in compressive strength at 7 curing periods. Increases in compressive strength observed for cement replacement at 28 and 56 curing periods. Maximum strength was achieved for 40% replacement and further it decreases.

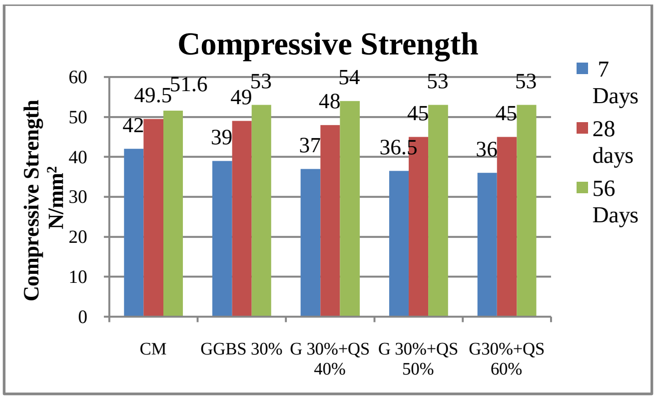

Fig 6: 7, 28, 56 Days Compressive Strength of GGBS with the variation of QS

Fig 6 shows the compressive strength results for 30% cement replacement by GGBS and sand replacement by QS 0%, 40%, 50%, 60%. It is observed that decreases in 7 and 28 days compressive strength which is lower than 30% GGBS replacement. Increase in strength is observed for 56 days curing periods and maximum strength obtained for 30% GGBS and 40% QS comparatively higher than control mix and lower than 30% GGBS.

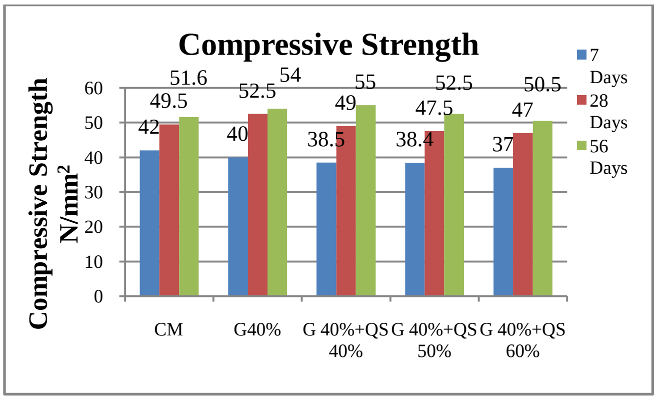

Fig 7: 7, 28, 56 Days Compressive Strength of GGBS with the variation of QS

Fig 7 shows the compressive strength results for 40% cement replacement by GGBS and sand replacement by QS 0%, 40%, 50%, 60%. It is observed that decreases in 7 and 28 days compressive strength which is higher than 40% GGBS replacement. Increase in strength is observed for 56 days curing periods and maximum strength obtained for 40% GGBS and 40% QS comparatively higher than control mix and 40% GGBS.

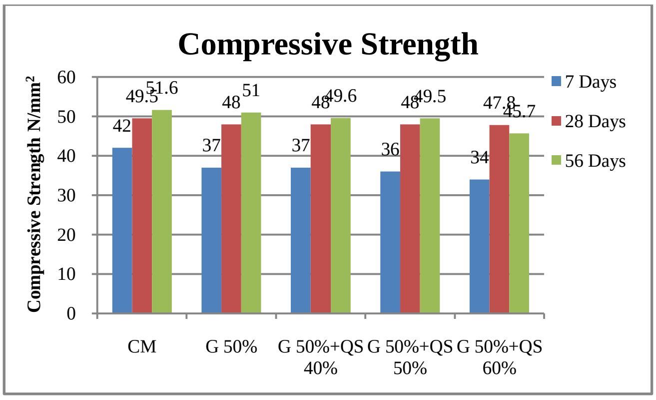

Fig 8: 7, 28, 56 Days Compressive Strength of GGBS with the variation of QS

Fig 8 shows the compressive strength results for 50% cement replacement by GGBS and sand replacement by QS 0%, 40%, 50%, 60%. It is observed that there is an increase in 7 and 28 days compressive strength which is almost similar to the 50% GGBS replacement. Decrease in strength is observed at 56 days curing periods and maximum strength obtained for 50% GGBS and 50% QS comparatively higher than control mix and 50% GGBS.

B) Split Tensile Strength

The tensile strength of concrete was determined at the age of 28 days as presented in graph.

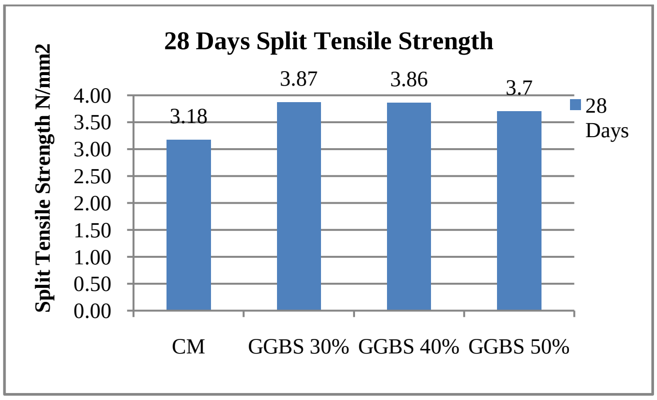

Fig 9: 28 Days split tensile strength of GGBS variation

Fig 9 represents flexural strength of concrete with partial replacement of cement by GGBS 0%, 30%, 40%, 50% and 0% QS. There is a increase in split tensile strength for replacement of GGBS. Maximum strength was obtained for 30% GGBS replacement with cement.

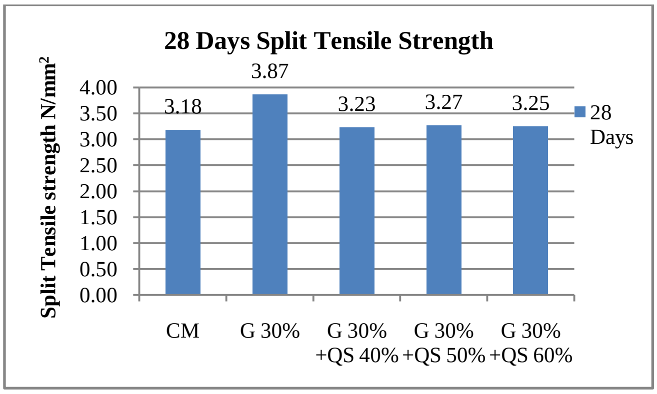

Fig 10: 28 Days Split tensile strength of GGBS with the variation of QS

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Fig 10 represents the 28 days split tensile strength of concrete with partial replacement of cement by 30% GGBS and sand by QS 0%, 40%, 50%, 60%. Increase in of split tensile strength when compared with control mix but which is lower than 30% GGBS. Maximum strength is observed for GGBS 30% and 50% QS.

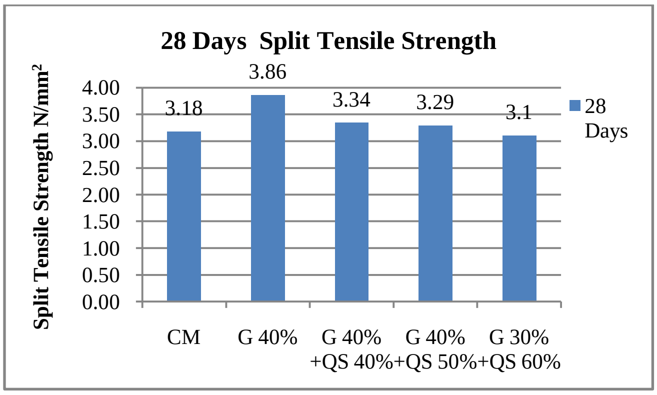

Fig 11: 28 Days Split tensile strength of GGBS with the variation of QS

Fig 11 represents the 28 days split tensile strength of concrete with partial replacement of cement by 40% GGBS and sand by QS 0%, 40%, 50%, 60%. Increase in split tensile strength with the variation of QS when compared with control mix but which is lower than 40% GGBS. Maximum strength is observed for GGBS 40% and 40% QS and further decrease in tensile strength.

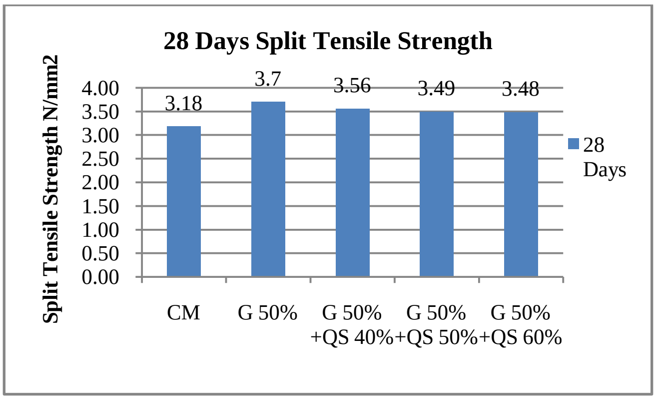

Fig 12: 28 Days Split tensile strength of GGBS with the variation of QS

Fig 12 represents the 28 days split tensile strength of concrete with partial replacement of cement by 50% GGBS and sand by QS 0%, 40%, 50%, 60%. Increase in split tensile strength with the variation of QS when compared with control mix but which is lower than 50% GGBS. Maximum strength is observed for GGBS 50% and 40% QS and further decrease in tensile strength.

C) *Flexural Strength*

The flexural strength of concrete was determined at the age of 28 days.

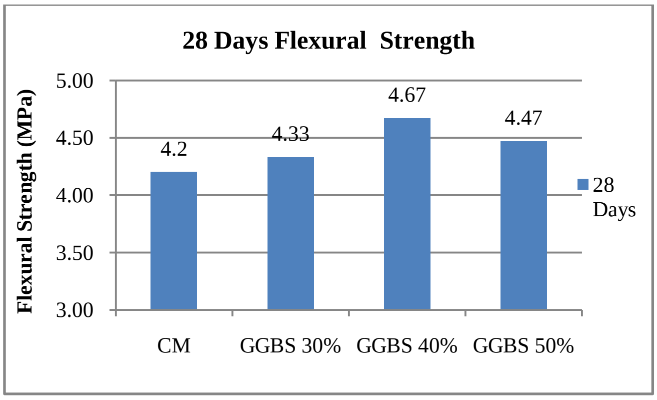

Fig 13: 28 Days Flexural Strength of GGBS

Fig 13 represents the 28 days flexural strength of concrete for replacement of cement by GGBS 0%, 30%, 40%, 50% and sand by 0%.. Increase in flexural strength with the increase of GGBS replacement. Maximum strength is obtained at 40% replacement of GGBS with cement.

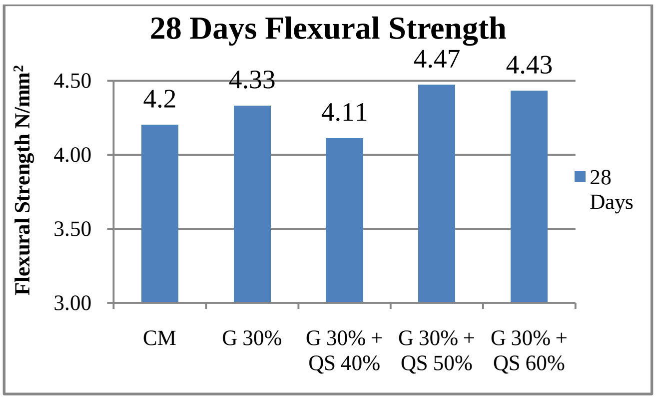

Fig 14: 28 Days Flexural Strength of GGBS and QS Variation

Fig 14 represents the 28 days flexural strength of concrete with partial replacement of cement by 30% GGBS with the variation of QS. Flexural strength of GGBS based concrete is increased which is higher than 30% GGBS. Maximum strength is observed for 30% GGBS and 50% QS.

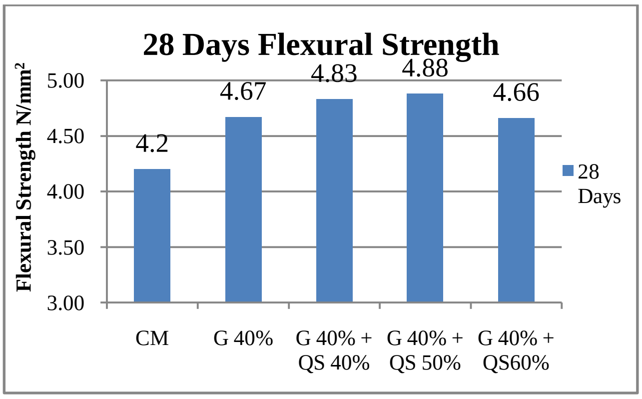

Fig 15: 28 Days Flexural Strength of GGBS with the QS variation

Fig 15 represents the 28 days flexural strength of concrete with partial replacement of cement by 40% GGBS with the variation of QS. It can be seen that flexural strength is increased with the variation of QS, which is higher than 40% GGBS. Maximum strength is observed for 40%GGBS and 50% QS.

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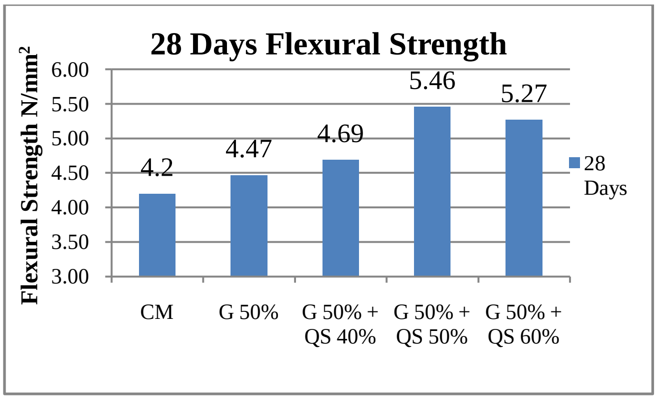

Fig 16: 28 Days Flexural Strength of GGBS and QS Variation

Fig 16 represents the 28 days flexural strength of concrete with partial replacement of cement by 50% GGBS with the variation of QS. There is an increase in flexural strength with the variation of QS which is higher than 50% GGBS. After maximum percentage the strength goes on decreases. Maximum strength was observed for 50% GGBS and 50% QS

C) Slump Test

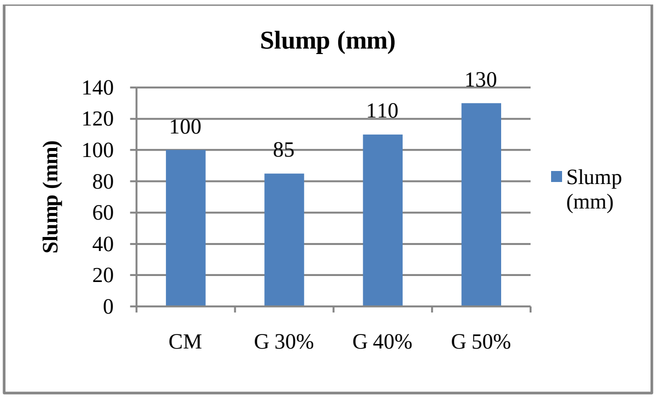

Fig 17: Workability of GGBS Concrete Mix

Fig 17 represents the workability of GGBS concrete mix. From this fig it can be seen that as the percentage of GGBS increases the workability also increases.

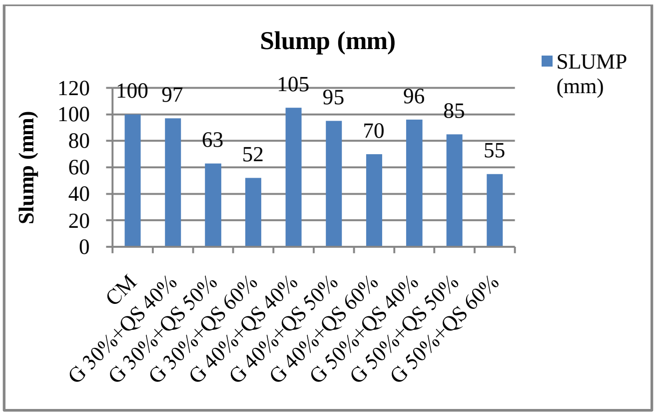

Fig 18: Workability of GGBS variation with the Variation of QS

Fig 18 represents the workability of GGBS variation with the variation of QS. It it can be seen that the as the percentage of GGBS increases the workability increases but as the percentage of QS increases workability of concrete decreases, because QS has more water absorption property.

VI. CONCLUSION

Based on the experimental investigation the following conclusion are drawn

- The workability of concrete was found to be increases with the increase in GGBS in concrete. It further decreases as the percentage of Quarry Sand increases.
- Maximum compressive and flexural strength has been obtained for replacement of cement by 40% GGBS.
- Maximum compressive strength obtained for replacement of cement by 40% GGBS and sand by 40% QS.
- Maximum flexural strength achieved for cement replacement by 50% GGBS and sand by 50% QS.
- Maximum split tensile strength is achieved for cement replacement by 50% GGBS and sand by 40% QS.
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