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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 constantly looking for supplementary cementitious material with the objective of reducing the solid waste disposal problem. Ground granulated blast furnace slag (GGBS) and Quarry sand (QS) are among the solid wastes generated by industry. The global consumption of natural sand is too high due to its extensive use in concrete. The demand for natural sand is quite high in developing countries owing to rapid infrastructural growth which results supply scarcity. This paper describes the feasibility of using waste in concrete production as a partial replacement of 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 The cement has been replaced by GGBS in the range of 30%, 40% and 50% by weight of cement, quarry sand in the range of 40%, 50% and 60% by weight of cement for M40 grade mix. Slump test was carried on fresh concrete while compressive strength, split tensile strength and flexural strength were carried on hardened concrete. The cube, beams and cylinders are tested for compressive, Flexural and tensile strengths. 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. These tests are carried out to determine the mechanical properties of concrete up to 7, 28, 56, 90 days for compressive strength, 28 days for split tensile strength and flexural strength*
***Keywords:** Ground Granulated Blast Furnance Slag (ggbs), Quarry Sand (QS), Compressive Strength, Split Tensile Strength, Flexural Strength.*

I. INTRODUCTION

Concrete is the first choice for construction in many countries today. This has led to the fast vanishing of natural resources. The emission of CO_2 into the atmosphere from the production of cement, deterioration, poor performance, and inadequate resistance to hostile environment of many concrete structures has led to the continuous research on concrete. On the other hand, cost of concrete is attributed to the cost of its ingredients which are becoming increasingly scarce and expensive. This has led to recycling of industrial wastes and By-products that help reduce the cost of waste treatment prior to disposal and eventually in preserving the natural resources and energy. This requirement has drawn the attention of researchers to explore and experiment with various alternative materials as ingredients for concrete which are sustainable. Blast furnance slag is a solid waste discharged in large quantities by the iron and steel industry in India. 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 constituent of slag is soluble in water and exhibits an alkalinity like that of cement or concrete. Ground Granulated Blast furnace slag (GGBS) is a by-product for manufacture of pig iron and obtained through rapid cooling by water or quenching molten slag. Here the molten slag is produced which is instantaneously tapped and quenched by water. This rapid quenching of molten slag facilitates formation of "Granulated slag". Ground Granulated Blast furnace Slag (GGBS) is processed from Granulated slag. If slag is properly processed then it develops hydraulic property and it can effectively be used as a pozzolanic material. However, if slag is slowly air cooled then it is hydraulically inert and such crystallized slag cannot be used as pozzolanic material.

The global consumption of natural sand is too high due to its extensive use in concrete. The demand for natural sand is quite high in developing countries owing to rapid infrastructural growth which results supply scarcity. To overcome from this crisis, partial replacement of natural sand with quarry sand is economic alternative. The concrete industry is constantly looking for supplementary cementitious material with the objective of reducing the solid waste disposal problem. Ground granulated blast furnace slag (GGBS) and Quarry sand (QS) are among the solid wastes generated by industry. Substantial energy and cost savings can result when industrial by-products are used as partial replacements for the energy- intensive Portland cement. This investigation attempts to study the feasibility of using locally available GGBS, and QS as partial replacements for cement and sand in concrete.

II. OBJECTIVE

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

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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 and Mixing 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)	FA (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
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

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J. Casting of Specimens

Concrete mixer was used for the mixing of concrete. 100*100*100mm cube, 3 cylinder of 100mm dia and 200mm in height and 3 beams of 100*100*500mm are casted for each mixes to measure the compressive strength, split tensile strength and Flexural strength of concrete. 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 mx to measure workability of concrete. Totally 144 cubes, 36 cylinder and 36 beams are casted. After mixing of concrete done, the concrete is filled into moulds and compacted on vibration table. Demoulding was done after 24 hours of casting. Specimens are cured in a curing tank. Water immersion method of curing is adopted. Cubes are cured for 7, 28, 56, 90 days and remaining specimens are cured for 28 days. Figure 1 show the concrete placed in moulds.

Fig 1: 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

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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 and 28 days as presented in graph

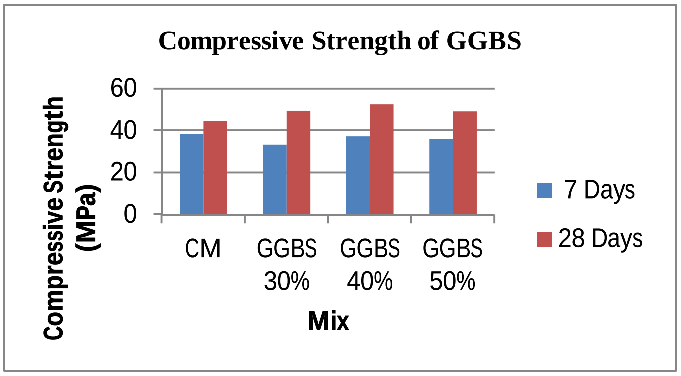

Fig 5: 7 and 28 Days Compressive Strength of GGBS

From the above graph 5 represents the comparison of 7 and 28 days compressive strength of concrete with partial replacement of cement by GGBS. It was found to be compressive strength of concrete has greater strength when cement replaced by 40% GGBS.

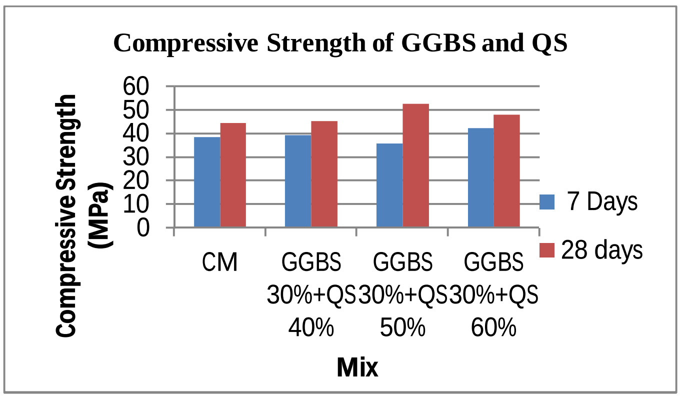

Fig 6: 7 and 28 Days Compressive Strength of GGBS with the variation of QS

The graph 6 represents the comparison of 7 and 28 days compressive strength of partial replacement of GGBS with the variation of QS. When cement replaced by GGBS and sand replaced by QS concrete there is a gradual increase in strength compared to control concrete.

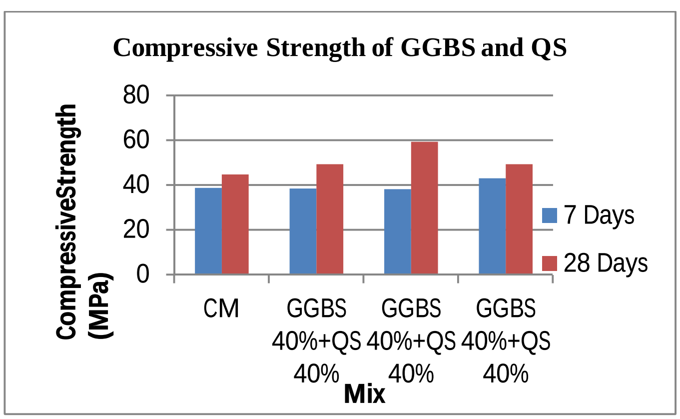

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Fig 7: 7 and 28 Days Compressive Strength of GGBS with the variation of QS

The graph 6 represents the comparison of 7 and 28 days compressive strength of concrete with partial replacement of GGBS with the variation of QS. Addition of QS to the concrete increases the compressive Strength of concrete. When cement replaced by 40% GGBS and sand replaced by 50% QS in concrete has greater strength than that of control concrete.

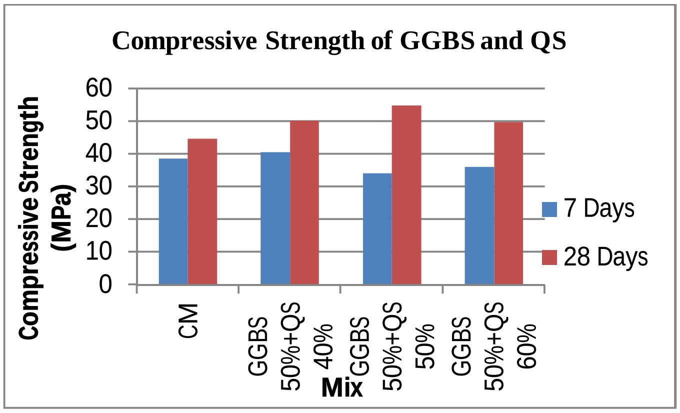

Fig 8: 7 and 28 Days Compressive Strength of GGBS with the variation of QS

The figure 8 represents the 7 and 28 days compressive strength of GGBS with the variation of QS. From the graph it was found that there is a decrease in compressive strength of concrete when replaced by cement by GGBS and sand by QS.

B. Split Tensile Strength

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

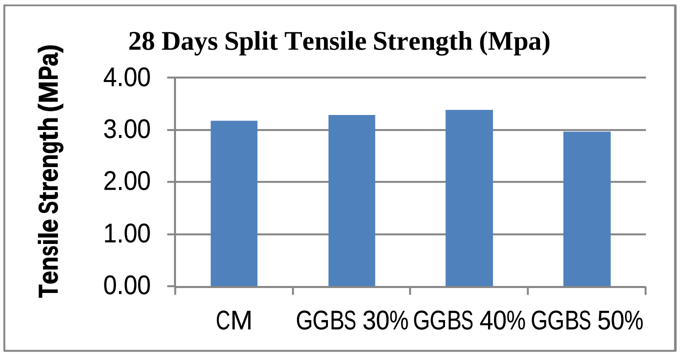

Fig 9: 28 Days Flexural Strength of GGBS variation

The figure 9 represents the 28 days flexural strength of concrete with partial replacement of cement by GGBS. Split tensile strength of GGBS concrete was similar to the control mix concrete. The 28 days tensile strength was found at 40% replacement of cement by GGBS.

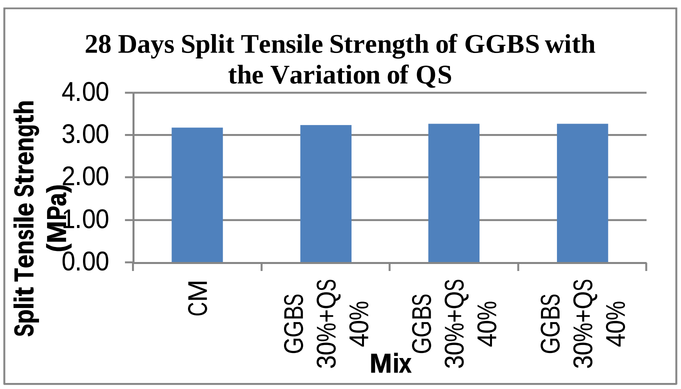

Fig 10: 28 Days Tensile Strength of GGBS and QS Variation

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The figure 10 represents the 28 days split tensile strength of concrete with partial replacement of cement by GGBS and natural sand by QS. It was found to be tensile strength was almost similar to the controlled mix concrete when cement replaced by GGBS and sand replaced by QS.

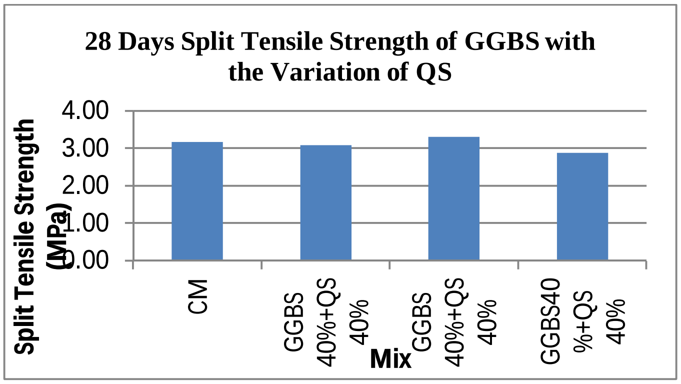

Fig 11: 28 Days Tensile Strength of GGBS and QS Variation

The figure 11 represents the 28 days split tensile strength of concrete with partial replacement of cement by GGBS and natural sand by QS. It was found to be when cement replaced by 40% GGBS and sand replaced by 50% QS has a higher split tensile strength compared to the controlled mix concrete.

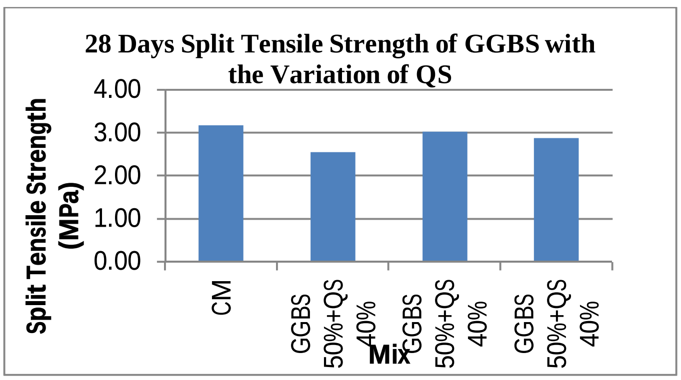

Fig 12: 28 Days Tensile Strength of GGBS and QS Variation

The figure 12 represents the 28 days split tensile strength of concrete with partial replacement of cement by GGBS and natural sand by QS. It was found to be there is a decrease in strength of concrete when cement replaced by GGBS and sand replaced by QS.

C. Flexural Strength

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

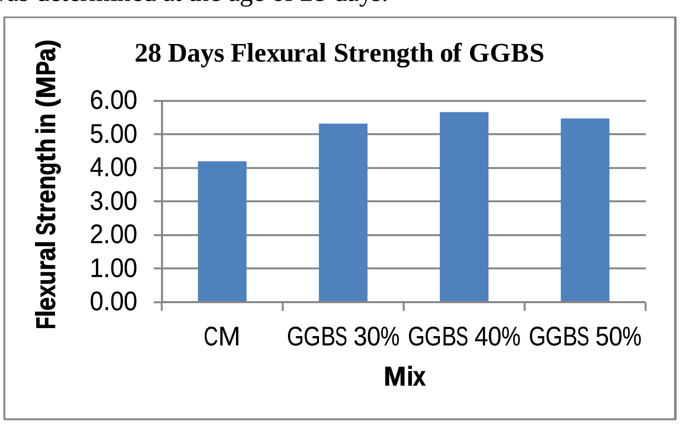

Fig 13: 28 Days Flexural Strength of GGBS

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The figure 13 represents the 28 days flexural strength of concrete with partial replacement of cement by GGBS. Split tensile strength of GGBS concrete was similar to the control mix concrete. The 28 days tensile strength was found at 40% replacement of cement by GGBS

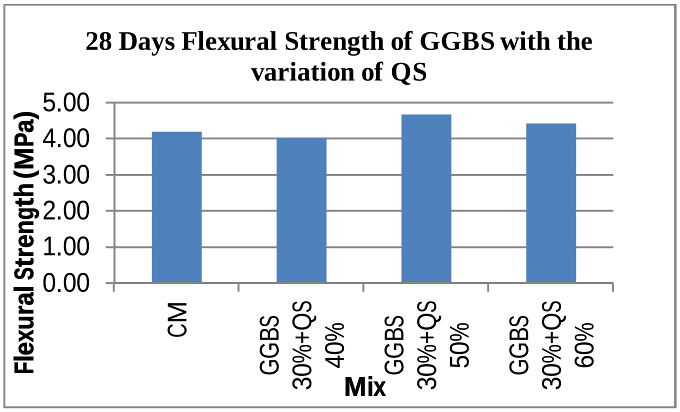


Fig 14: 28 Days Flexural Strength of GGBS and QS Variation

The figure 14 represents the 28 days flexural strength of concrete with partial replacement of cement by GGBS. Flexural strength of GGBS concrete has lower strength compared to the control mix concrete.

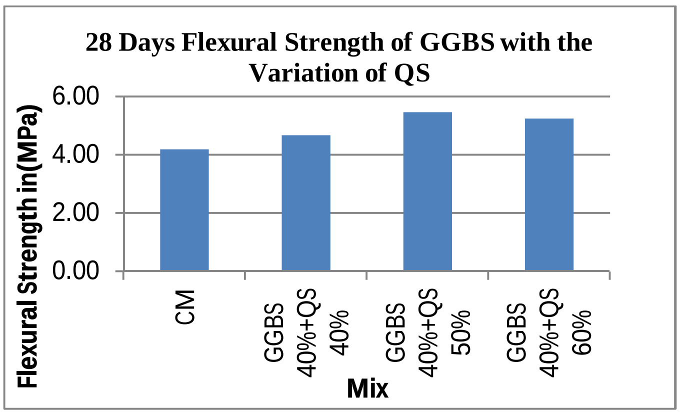


Fig 15: 28 Days Flexural Strength of GGBS and QS Variation

The figure 15 represents the 28 days flexural strength of concrete with partial replacement of cement by GGBS. Split tensile strength of GGBS concrete was similar to the control mix concrete. The 28 days tensile strength was found at 40% replacement of cement by GGBS and 50% replacement of sand by QS.

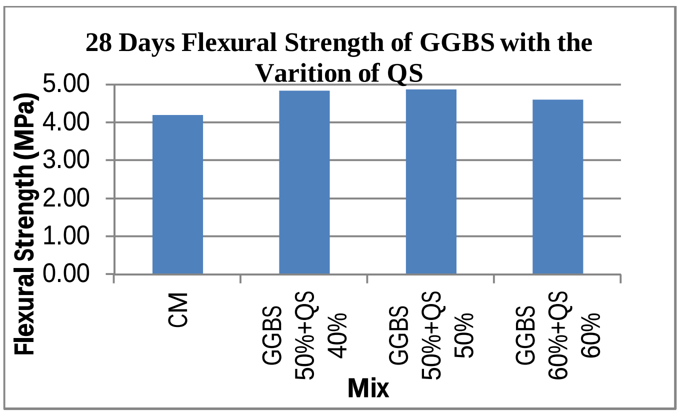


Fig 16: 28 Days Flexural Strength of GGBS and QS Variation

The figure 16 represents the 28 days flexural strength of concrete with partial replacement of cement by GGBS. There is a decrease in strength of concrete.

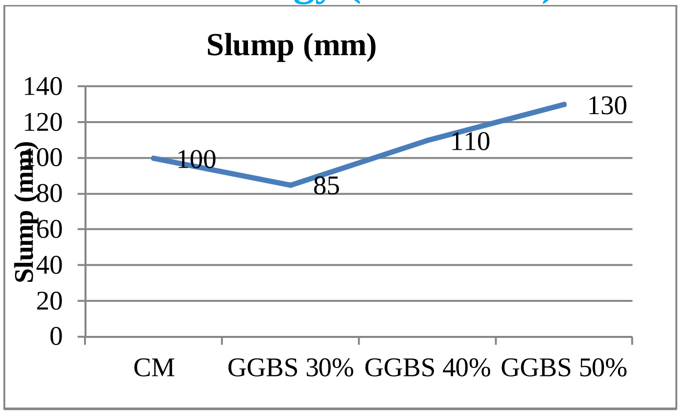
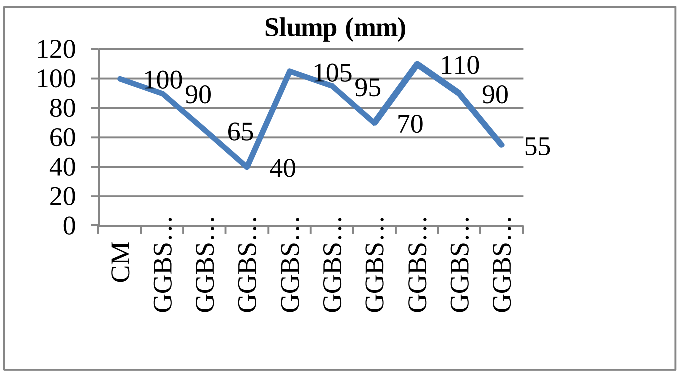


Fig 17: Workability of GGBS Concrete Mix

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



Figv18: Workability of GGBS variation with the Variation of QS

The above graph 18 represents the workability of GGBS variation with the variation of QS. From the graph 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.

V. CONCLUSION

Based on the experimental investigation the following conclusion are drawn

A. It is observed that GGBS based concretes have achieved an increase in strength for 40% replacement of cement at the age of 28 days.

B. The replacement of cement by GGBS and QS not only increases the compressive strength but also reduced the usage of cement content and sand content.

C. 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.

D. The optimum split tensile strength of concrete was found to be at 40% replacement of cement by GGBS and 50% replacement of sand by QS.

E. As the percentage of QS increased, the Compressive strength also increases.

F. Flexural strength of GGBS + Cement, GGBS+ QS was increased with increase in percentage of replacement and it was greater than control concrete mix.

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