# EFFECT OF ADDITION OF SILICA FUME AND GGBS ON CEMENT CONCRETE IN FRESH AND HARDENED STATE

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***Abstract :*** Concrete is the most used construction material in the civil engineering. Concrete is the world's most consumable product next to water. The silica fume and GGBS has been used as partial replacement of cement in the concrete. The silica fume is obtained from electric arc furnace by burning the coal, coke, and wood-chips and collected by mechanical dust collector or electro static precipitator. The GGBS is by-product of iron and steel making industry, obtained by quenching of molten iron slag from a blast furnace in water or steam to produce a glassy granular product that is then dried and ground into a fine powder. By utilizing these two products as partial replacement of cement in concrete, the concrete can be made more eco-friendly by reducing the use of cement.

In the present work, an attempt has been made to use a silica fume and GGBS as a partial replacement of cement. The main aim of this work is to study the fresh and hardened properties of M-30 grade control concrete and concrete made with partial replacement of silica fume and GGBS with various percentages. To study the fresh properties slump test, compaction factor test are conducted. To study hardened properties of concrete, compressive and split tensile strength tests are conducted and comparative study is carried out.

*Index Terms* – **Silica Fume, Ground Granulated Blast Furnace Slag (GGBS), Compressive strength, Split tensile strength.**

## I. INTRODUCTION

Concrete is a composite product produced by mixing cement, aggregates and water and sometimes admixture if needed, undergoes a number of operations such as handling, placing and curing. Inspection and control at all stages of procurement of raw materials to the development of finish product contributes to the uniformity of concrete. Concrete consists of four ingredients which can be classified in to two groups. Active group and inactive group. The active group consists of water and cement. And the inactive group consists of fine and coarse aggregates. Silica Fume is a by-product of the smelting process in the production of silicon metal and ferrosilicon alloys. It has also been called silica fume, microsilica, amorphous silica and other similar names. However, the silica fume used in concrete are those from the production process of silicon metal or ferrosilicon alloy containing more than 75% silicon. Ground granulated blast-furnace slag (GGBS) is a by-product in the manufacture of pig iron and the amounts of iron and slag obtained of the same order. The slag is a mixture of lime, silica and alumina, the same oxides that make up Portland cement, but not in the same proportion. The composition of blast-furnace slag is determined by that of the ores, fluxing stone and impurities in the coke charged in to the blast furnace. Typically, silica, calcium, aluminium, magnesium and oxygen constitute 95% or more of the blast- furnace slag. To maximize hydraulic (cementitious) properties, the molten slag must be chilled rapidly as it leaves the blast furnace. Rapid quenching or chilling minimizes crystallization and converts the molten slag into fine-aggregate-size particles generally smaller than a 4.75 mm sieve, composed predominantly of glass. This product is referred to as granulated iron blast-furnace slag (GGBS) is obtained by finely grinding of this material.

## II. LITERATURE REVIEW

F. Ghassemzadeh et.al., [1] showed that concrete containing GGBS is highly influenced by the type of curing regime used at early ages. Curing for more than 3 days is necessary for the strength development of the GGBS concrete. In fact, extending the curing time in concrete containing GGBS has a positive effect on increasing of compressive strength in later ages. Using SF and GGBS simultaneously in the concrete, have a positive synergistic effect on increasing compressive strength in the both early and later ages. During the curing time, concretes containing GGBS expanded about 4 to 5 times more than plain and SF concretes. This swelling initially induced compressive pre stressing force and de-layed the onset of tensile restraining force. This phenomenon is effective for the assessment and preventation of early age cracking in concrete. The shrinkage strain of GGBS concrete in short-term and long-term is considerably less (40%) than the shrinkage strain of plain and SF concretes. Similar effect was observed for long-term when combination of SF and GGBS was used to make blended concrete. Anusha Suvarna et.al., [2] showed that replacement of cement with silica fume & GGBS, the properties of concrete are studied. Use of GGBS as cement replacement increases consistency. Cement replaced with 50% GGBS with 0.3 % fiber shows higher compressive strength. Using 50% GGBS with 0.3% fiber percentage the 28 days compressive strength increases 7% more than concrete with 0.3% fiber only. So it is inculcated that 0.3% Recron fibre and replacement of 50 % GGBS with cement is required to achieve desired needs. As the replacement of cement with different percentages with Silica fume increases the consistency increases. The compressive strength of the M30 mix at 7 and 28 days age, with replacement of cement by silica fume with 0.3% fiber content was increased gradually up to an optimum replacement level of 10% and then decreased. As the replacement level of cement by silica fume increases there is an increase in split tensile strength & flexural strength for M30 grade of concrete up to 10% replacement level, and beyond that level there is a decrease in split tensile and flexural strength. S. Vijaya Bhaskar Reddy and P. Srinivasa Raon [3] drawn from the observations and discussions of this investigation. The workability of fresh concrete increases with increase in GGBS content up to 30% replacement and density of fresh mix increases with Micro Silica and GGBS. Workability of concrete is getting reduced with increasing the mineral admixtures at higher percentages. These needs super plasticizers to maintain work abilities. The combinations of Micro Silica and GGBS is complementary, Micro Silica improves the early age performance of concrete with GGBS by refining the properties of hardened concrete continuously as it matures. As the curing period is extended the SCM mixtures with replacement of GGBS (50%), have higher strength than the base mix. Even in the early age (7 days) compressive strength development of the ternary concrete is slightly more than that of ordinary concrete. This trend is due to the presence of Micro Silica. The combination (MS 10%+GGBS 30%) gives more workable and highest compressive strength for all curing days when compared to ordinary concrete. Based on the above studies and test results, in case of ternary blended concrete. It is advisable to replace the cement by mineral admixtures at an optimum percentage of Micro Silica (10%) and GGBS (30%). At which we can get better results in workability and compressive strength comparatively with reference to ordinary concrete.

## III. OBJECTIVES OF THE EXPERIMENTAL WORK

### 3.1 OBJECTIVES

The following are the objectives of the present experimental work:

- To evaluate the fresh properties of control concrete of M-30 grade and concrete made with partial replacement of cement by silica fume and ground granulated blast furnace slag for fresh properties, slump cone test, compaction factor test are conducted.
- To find out the compressive strength of control concrete of M-30 grade and concrete made with silica fume and ground granulated blast furnace slag as a partial replacement of cement at 28 days cube compression test is conducted.
- To find out the split tensile strength of control concrete of M-30 grade and concrete made with silica fume and ground granulated blast furnace slag as a partial replacement of cement at 28 days cylinder tensile tests is conducted.

### 3.2 MIX DESIGNATION

1. *M0:* Where M0 refers to control concrete without addition of silica fume and GGBS.
2. *M1:* Where M1 refers to addition of 80% cement with 10% silica fume and 10% GGBS.
3. *M2:* Where M2 refers to addition of 70% cement with 10% silica fume and 20% GGBS.
4. *M3:* Where M3 refers to addition of 60% cement with 10% silica fume and 30% GGBS.
5. *M4:* Where M4 refers to addition of 50% cement with 10% silica fume and 40% GGBS.
6. *M5:* Where M5 refers to addition of 40% cement with 10% silica fume and 50% GGBS.

## IV. MATERIALS AND METHODOLOGY

### 4.1 MATERIALS

The following materials are used in the present work:

*Cement:* 43 grade ordinary Portland cement (OPC) was used in this experimentation program with specific gravity 3.15 and conforming to IS: 8112-2013.

*Fine aggregate:* Locally available river sand was used in this experimentation program with specific gravity 2.60 and belongs to zone II of IS: 383-2016.

*Coarse Aggregate:* Crushed angular aggregates of specific gravity 2.71 was used. The water absorption was 0.2%.

*Water:* Potable tap water is used for the preparation of specimens and for curing specimens.

*Silica fume:* Silica fume was obtained from Sai Durga Enterprises, Bengaluru.

*Ground granulated blast furnace slag (GGBS):* GGBS is obtained from JSW, Toranagallu, Hospet.

### 4.2 METHODOLOGY

Cement, sand and coarse aggregate were taken in the proportion 1:1.60:2.87 corresponding to M-30 grade concrete the mix design is done as per IS 10262 : 2019. The concrete was produced by mixing all the ingredients homogeneously. To this dry mix, required quantity of water was added (w/c=0.44) and the entire mass was again homogeneously mixed. This wet concrete was poured into the moulds which were compacted through hand compaction in three layers; the specimens were given smooth finish. After 24 hours the specimens were de-moulded and transferred to curing tanks where they were allowed to cure for required number of days. For evaluating compressive strength, specimens of dimensions 150×150×150 mm were prepared. They were tested on 3000 kN capacity compressive strength testing machine as per IS: 516-1959. The compressive strength is calculated by using the following equation,

$F=P/A$

Where, F=compressive strength of specimen (in MPa)

P= maximum load applied to the specimen (in N)

A= cross sectional area of the specimen (in mm2)

For evaluating the split tensile strength, cylindrical specimen of diameter 150 mm and length 300mm were prepared. Split tensile strength test was carried out on 3000 kN capacity compression testing machine as per IS: 5816-1999. The split tensile strength is calculated by using the following equation,

$F=2P/(\pi DL)$

Where, F=split tensile strength of specimen (in MPa)

P= load at failure (in N)

L=length of cylindrical specimen (in mm)

D=diameter of the cylindrical specimen (in mm).

## V. TESTS ON CONCRETE

### 5.1 TESTS ON FRESH CONCRETE

### 5.1.1 SLUMP TEST

The concrete slump test measures the consistency of fresh concrete before it sets. It is performed to check the workability of freshly made concrete, and therefore the ease with which concrete flows. It can also be used as an indicator of an improperly mixed batch. Slump cone test basically comprises of a steel mould in sort of frustum of a cone having the interior top dia 10cm, base dia 20cm and 30cm as shown in Fig. 5.1

### 5.1.2 COMPACTION FACTOR TEST

Compaction factor test can also be utilized to examine the workability of fresh concrete. Compacting factor experiment is gives a more accurate workability occurs in fresh concrete than slump cone test. Compaction factor test is also known as “drop test”. Compaction factor test is the ratio of the load partly compacted concrete to the burden of fully compacted concrete.

### 5.2 TESTS ON HARDENED CONCRETE

### 5.2.1 COMPRESSIVE STRENGTH TEST

Compressive strength is the capacity of a material or constitution withstand axial masses tend to reduce the scale. It is measured using of compression testing machine [CTM]. Concrete can be made excessive compressive strength. Both silica fume and GGBS with cement in concrete specimen were tested at varying percentage of cement and GGBS keeping silica fume at 10% constant. Compression testing machine as shown in Fig. 5.1. Compressive force for evaluating, mould dimension (150x150x150) mm. compression testing machine is capacity 3000 kN as per Indian standard 516-1959.

### 5.2.2 SPLIT TENSILE STRENGTH TEST

For conducting the split tensile strength, cylinder specimen of dia 150mm and height 300mm were cast. The spilt tensile test was carried out in 3000 kN capacity compression testing machine (Fig. 5.1) as per Indian Standard 5816-1999.

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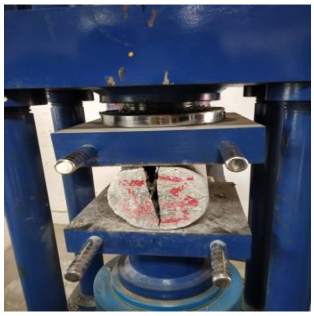
|  |  |  |  |
| Slump Test | Compaction Factor Test | Compressive Strength Test | Split Tensile Strength Test |

**Fig 5.1: Tests on Concrete**

## VI. EXPERIMENTAL RESULTS

### 6.1 SLUMP AND COMPACTION FACTOR TEST

The slump and compaction factor test results are presented in the Table 6.1.

**TABLE 6.1: SLUMP AND COMPACTION FACTOR VALUES**

| Sl. No | Mix designation | Slump in mm | Compaction Factor |
|---|---|---|---|
| 1 | M0 | 80 | 0.91 |
| 2 | M1 | 90 | 0.92 |
| 3 | M2 | 95 | 0.92 |
| 4 | M3 | 95 | 0.94 |
| 5 | M4 | 100 | 0.95 |
| 6 | M5 | 110 | 0.96 |

### 6.2 COMPRESSIVE STRENGTH TEST

The compressive test is conducted on cubes of dimensions 150 mm the values of compressive strength for different mixes for 28 days curing is represented in the Table 6.2 and Fig.6.2.

TABLE 6.2: COMPRESSIVE STRENGTH OF CONCRETE FOR 28 DAYS

| Sl. No | Mix designation | Compressive strength (MPa) |
|---|---|---|
| 1 | M0 | 37.92 |
| 2 | M1 | 38.22 |
| 3 | M2 | 39.25 |
| 4 | M3 | 44.14 |
| 5 | M4 | 34.36 |
| 6 | M5 | 30.95 |

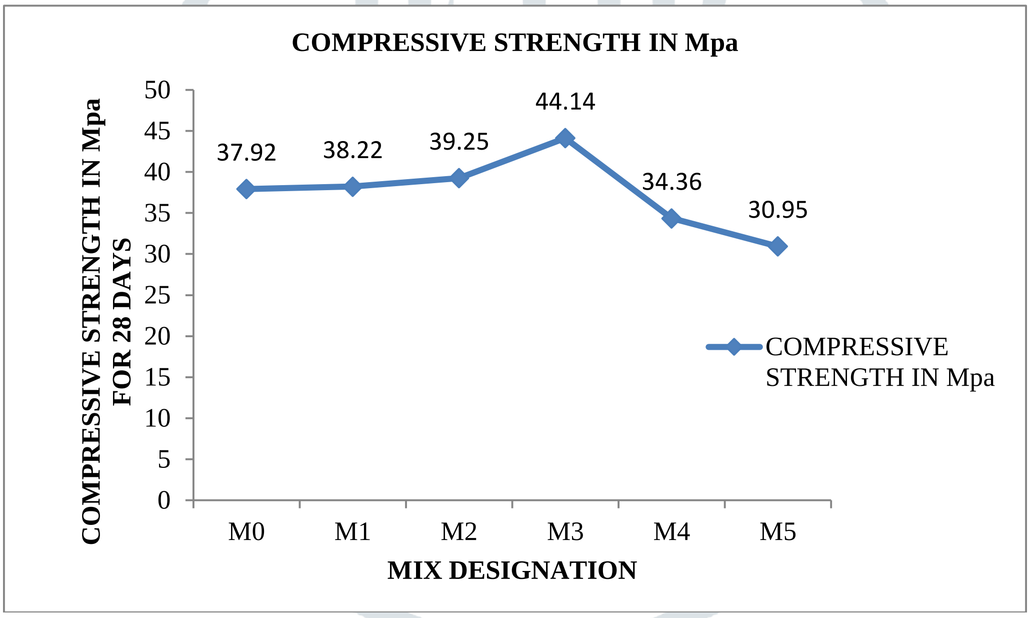



FIG. 6.2: COMPRESSIVE STRENGTH OF CONCRETE FOR 28 DAYS

### 6.3 SPLIT TENSILE STRENGTH TEST

The split tensile test is conducted on cylinders of dimensions 150mm dia and 300mm height. The values of split tensile strength for different mixes for 28 days curing is represented in the Table 6.3 and Fig 6.3.

TABLE 6.3: SPLIT TENSILE STRENGTH OF CONCRETE FOR 28 DAYS

| Sl. No | Mix designation | Split tensile strength (MPa) |
|---|---|---|
| 1 | M0 | 2.12 |
| 2 | M1 | 2.26 |
| 3 | M2 | 2.44 |
| 4 | M3 | 2.99 |
| 5 | M4 | 2.21 |
| 6 | M5 | 2.19 |

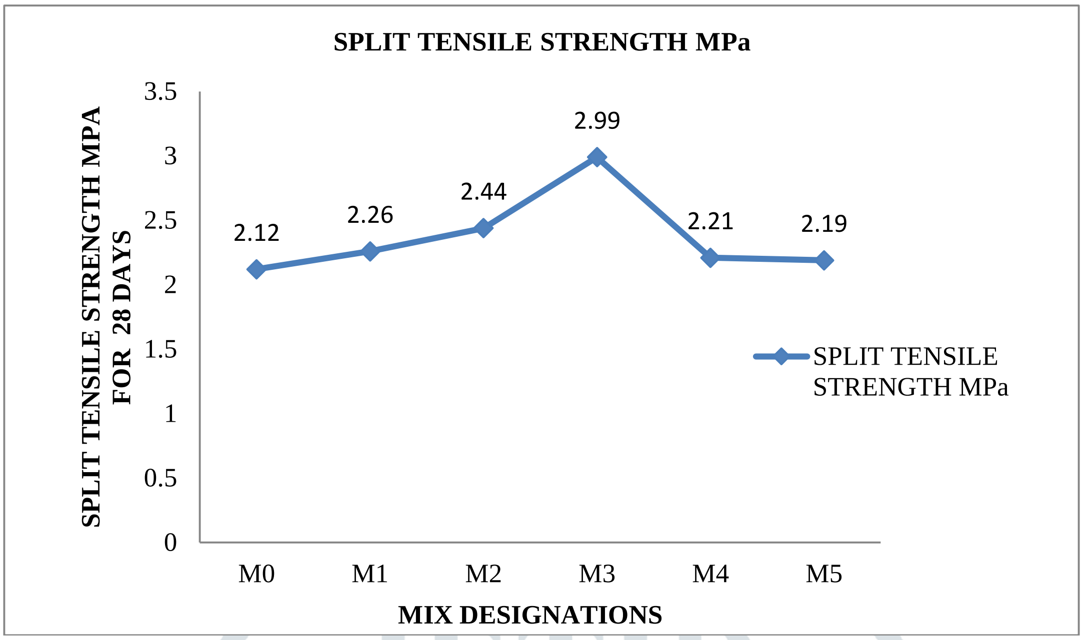



**FIG. 6.3: SPLIT TENSILE STRENGTH OF CONCRETE FOR 28 DAYS**

## VII. OBSERVATIONS AND DISCUSSIONS

In the present work, the effect of silica fume and GGBS on cement concrete in the fresh and hardened state is investigated and the following observation were made from the experiments conducted. The test results show that the workability increased with addition of silica fume and GGBS. Use of right quality GGBS results in reduction of water demand for desired slump. The concrete made by the combination of silica fume and GGBS had shown increase in workability compared to the control concrete and workability kept on increasing with the addition of GGBS content in concrete. At 28 days curing period, the compressive strength increased as the replacement level of GGBS increased. The silica fume in all mixes was kept constant. The compressive strength of mix M1, M2, M3, M4 & M5 is having higher compressive strength by 0.79%, 3.50%, 16.40% (9.38% & 18.38% in –ve) respectively compared to control concrete. Mix M3 was showing highest compressive strength compared to all the mixes.

At 28 days of curing period. The split tensile strength of mix M1, M2, M3, M4 & M5 is having higher split tensile strength by 6.60%, 15.09%, 41.03%, 4.24% & 3.30% respectively compared to control concrete. Mix M3 was showing the highest split tensile strength compared to all the mixes. From the experimental results of compressive strength and split tensile strength of control concrete and concrete made with silica fume and GGBS is performing better than control concrete. In all the combinations the strength was more compared to control concrete. But as the replacement level increases the strength was also increasing, this clearly shows that the GGBS can be used in any combination .Since all the mixes were giving better results than the control concrete. But the mix M3 where the cement is partially replaced by GGBS shows the best results. So this observation clearly indicates that GGBS can be used as a partially substituted for cement on the basis of limited study done. But also checked for durability characteristics of concrete made with GGBS.

## VIII. CONCLUSIONS

Based on the fresh concrete properties and limited strength tests, the following conclusion can be drawn.

1. Addition of silica fume and GGBS in combination to the concrete improves workability.
2. As the percentage of GGBS increases workability also increases.
3. Compressive strength results shows that until M3 mixes, they are having higher results compared to control concrete. But the mix M3 is showing best results.
4. Split tensile strength results shows that all the mixes are having higher results compared to control concrete. But the mix M3 is showing best results.
5. The percentage of silica fume and GGBS can be partially replaced into of cement. These two materials will give best results compared to control concrete.

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