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# A COMPARATIVE STUDY OF CONCRETE WITH DIFFERENT CEMENTITIOUS MATERIALS (GGBS & SILICA FUME)

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## ABSTRACT
Concrete is a most versatile construction material because it can be designed to withstand the hardest environment while taking on the most inspirational forms. Engineers are continually pushing the limits to improve its performance with the help of innovative mineral admixture. Nowadays, most concrete mixture contains different cementitious material which forms part of the cementitious component. The main benefits of this are their ability to replace certain amount of cement and still able to display cementitious property, thus reducing the cost of using Portland cement and increasing concrete properties. The different cementitious materials like Ground Granulated Blast Furnace Slag (GGBS), Silica Fume, are some of the cementitious materials which can be used in concrete as cement. In this project, our study is mainly confined to evaluation of changes in compressive, splitting tensile and flexural strength test in four different mixes of M25 Grade namely i) Normal Concrete, ii) Concrete made by 10% replacement of cement by GGBS and Silica Fume iii) Concrete made by 15% replacement of cement by GGBS and Silica Fume iv) Concrete made by 20% replacement of cement by GGBS and Silica Fume. Compressive test, splitting test, flexural test will be conducted on the prepared cubes, cylinders &prisms. The tests were conducted for 7days and 28days of curing.

**KEYWORDS**: Comparison, Different Cementitious Material, Concrete, Replacement, Strength Test.

## I. INTRODUCTION
Concrete is the most widely used man-made construction material in the world. The Ordinary Portland Cement (OPC) is one of the main ingredients used for the production of concrete and has no alternative in the civil construction industry. Construction Industry is an essential part of infrastructure development which gives incredible boost to our country's economy. The Indian construction industry has registered massive growth for the past 20 years. The future global challenge for construction industry is clearly to meet the world's growing needs while at the same time limiting the impact.

The production of cement involves emission of large amounts of carbon-dioxide gas into the atmosphere, a major contributor for greenhouse effect and the global warming, hence it is inevitable either to replace it by different cementitious material. The cement is the costliest and energy intensive component of concrete. The unit cost of concrete can be reduced as much as possible by partial replacement of cement with GGBS and Silica Fume. In recent studies, many researchers found that the use of additional cementitious materials like GGBS and Silica Fume in concrete is economical and reliable. Most of these researchers used GGBS and Silica Fume as a replacement of cement in concrete mix in order to investigate their effects on the physical and mechanical properties of concrete.

**COARSE AND FINE AGGREGATE**:
The coarse aggregate are granular materials obtain from rocks and crushed stones. They may be also obtained from synthetic material like slag, silica, clay, and fly ash for use in light weight concrete. The sand obtained from quarries or river beds is used as fine aggregate. The fine aggregate along with the hydrated cement paste fill the space between the coarse aggregate.

**CEMENT**:

In present day, cement is a mixture of limestone and clay heated in a kiln to 1400 – 1600 ºC. The types of cement permitted as per IS 456:2000, plain and reinforcement concrete code of practice. Ordinary Portland cement, 53 grade shall be manufactured by intimately mixing together calcareous and argillaceous and other silica, alumina or iron oxide bearing materials, burning them at a clinkering temperature and grinding the resultant clinker so as to produce a cement capable of complying with this standard. No material shall be added after burning, other than gypsum (natural or chemical), water, performance improver and not more than a total of 1.0 percent of air entraining or other agents including color agents, which have proved not to be harmful.

**WATER:**

The water should satisfy the requirement of section 5.4 of IS 456:2000. The water used for mixing and curing shall be clean and free from injuries amount of oils, acids, salts, sugar, organic materials and other substances that may be deleterious to concrete and steel.

**GGBS:**

Ground granulated blast furnace slag (GGBS) is a byproduct from the blast furnace used to make iron. Blast furnace are fed with controlled mixture of iron ore, coke and limestone, and operated at a temperature of about 1500o C. When iron ore coke and limestone melt in the blast furnace, two products are produced molten iron, molten slag. The molten slag is lighter and floats original iron ore, combined with some oxides from the limestone. The process of granulating the slag involves cooling of molten slag through high pressure water jet. This rapidly quenches the slag and granular particles generally not bigger than 5mm. the rapid cooling prevents the formation of larger crystals and the resulting granular material comprises around 95% non-crystalline calcium alumina silicates. The granulated slag is further processed by drying and then grinding in vertical roller mill or rotating ball mill to a very fine powder, which is GGBS.

**SILICA FUME:**

Silica fume is a byproduct of producing silicon metals or ferrosilicon alloys. one of the most beneficial uses for silica fume is in concrete. because of its chemical and physical properties, it is a very reactive pozzolan. Concrete containing silica fume can have a very high strength and can be very durable. Silica fume has entered into common use in a majority of industrial countries and many developing countries. Silica fume has long since been and an internationally tradable product. Today, it is estimate that 15 million $m^3$/year silica fume concrete are produced globally; the accumulated volume must be now have exceeded.

## II. SCOPE

The scope of the study is

1. To study the strength properties of concrete (Grade M25) using cementitious materials at different percentages(%) 10,15,20.
2. Use of GGBS & Silica Fume of cementitious materials to determine the performance of concrete for various proportion of addition.
3. To compare the compressive strength, splitting tensile and flexural beam strength of replacement concrete with normal concrete.
4. Study the strength properties of concrete.
5. To study the behavior of concrete under various loading conditions.

## III. LITERATURE REVIEW

*A. Oner and S. Akyuz* conducted a study in which he replaced cement partially with GGBS in various percentages from 15% - 110% by weight. Compressive strength test was conducted on test specimens cured at 7, 14, 28, 63, 119, 180 and 365 days and it was found that early age strength values of GGBS concrete mix are lower than control mixtures but as the curing period is extended the strength values increases. This is because the pozzolanic reaction is slow and depends on the calcium hydroxide availability so the strength gain takes longer time for the GGBS concrete. It was also observed that as the percentage of GGBS is increased, the strength gain increases. The optimum level of GGBS content for maximizing strength was found out about 55% – 59% byBolomey and Feret strength equation. He also found out that as the GGBS content increases, the water/binder ratio decreases for the same workability and thus, the GGBS has positive effects on the workability.

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*Grutzeck et al.* (1982) reported that the concrete containing silica fume shows significantlyreduced bleeding. This effect is caused primarily by the high surface area of the silica fume to be wetted; there is very little free water left in the mixture for bleeding. Additionally, the silica fume reduces bleeding by physically blocking the pores in the fresh concrete. Jahren (1983) reported that fresh concrete containing silica fume is more cohesive and less prone to segregation than concrete without silica fume.

*Er. Kimmi Garg, Er. Kshipra Kapoor* studied and experimented, it is proved that GGBS can be used as an alternative material for cement, reducing cement consumption and reducing the cost of construction. Use of industrial waste products saves the environment and conserves natural resources.

*Hossam et al.* (1995) reported that the optimum benefit of the addition of silica fume is attainedwhen it is used in combination with superplasticizers. This combination increases the cohesiveness of the fresh composites and reduces the water content.

*Oner and Akyuz* studied on optimum level of GGBS on compressive strength of concrete and concluded that the optimum level of GGBS content for maximizing strength is at about 55–59% of the total binder content.

*Wang Ling et al.* (2004) analyzed the performance of GGBS and the effect of GGBS on fresh concrete and hardened concrete. GGBS concrete is characterized by high strength, lower heat of hydration and resistance to chemical corrosion.

*Qian Jueshi and Shi Caijun* studied on high performance cementing materials from industrialslag and reviewed the recent progresses in the activation of latent cementitious properties of different slag. They opined that Alkali-activated slag, such as blast furnace slag, steel slag, copper slag and phosphorus slag should be a prime topic for construction materials researchers.

*Roy &Sil* (2012) Studied the Effect of Partial Replacement of Cement by Silica Fume on Hardened Concrete. From the study it has been observed that maximum compressive strength (both cube and cylinder) is noted for 10% replacement of cement with silica fume and the values are higher (by 19.6% and 16.82% respectively) than those of the normal concrete (for cube and cylinder) whereas split tensile strength and flexural strength of the SF concrete (3.61N/mm$^2$and 4.93N/mm$^2$ respectively) are increased by about 38.58% and 21.13% respectively over those (2.6 N/mm$^2$ and 4.07 N/mm$^2$ respectively) of the normal concrete when 10% of cement is replaced by SF.

*Kumar & Dhaka* (2016) write a Review paper on partial replacement of cement with silica fume and its effects on concrete properties. The main parameter investigated in this study M-35 concrete mix with partial replacement by silica fume with varying 0, 5, 9, 12 and 15% by weight of cement. The paper presents a detailed experimental study on compressive strength, flexural strength and split tensile strength for 7 days and 28 days respectively. The results of experimental investigation indicate that the use of silica fume in concrete has increased the strength and durability at all ages when compared to normal concrete.

*Jain &. Pawade* (2015) studied the Characteristics of Silica Fume Concrete. The physicalproperties of high strength silica fume concretes and their sensitivity to curing procedures were valuated and compared with reference Portland cement concretes, having either the same concrete content as the silica fume concrete or the same water to cementitious materials ratio. The experimental program comprised six levels of silica-fume contents (as partial replacement of cement by weight) at 0% (control mix), 5%, 10%, 15%, 20%, and 25%, with and without superplasticizer. It also included two mixes with15% silica fume added to cement in normal concrete. Durability of silica fume mortar was tested in chemical environments of sulphate compounds, ammonium nitrate, calcium chloride, and various kinds of acids.

*Scali et al*. (1987) reported that the water demand of concrete containing silica fume increases with increasing amount of silica fume at the stage of fresh concrete. Osborne (1989) reported the test results of slump, time and compaction factor for concrete containing zero, 40 and 70 percent GGBS and concluded that when the percentage of GGBS is increased, the workability properties is reduced.

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## V. METHODOLOGY

**MATERIALS**

The materials used in this experiment study were cement, fine aggregate, coarse aggregate, water, GGBS and Silica fume.

***COARSE AGGREGATE***

***FINE AGGREGATE***

***CEMENT***

***SILICA FUME***

***GGBS(FINE)***

***FIGURE 1***

| MATERIALS | TYPE/SOURCE | SPECIFIC GRAVITY | FINENESS ($M^2/KG$) | BULK DENSITY ($KG/M^3$) |
|---|---|---|---|---|
| OPC | 53 grade | 3.15 | 292 | 1440 |
| GGBS | Iron | 2.87 | 275 | 1100 |
| SILICA FUME | Pozzolanic materials | 2.40 | 400 | 700 |
| COARSE AGGREGATE | Quarry | 2.66 | As per IS 456 | 1442 |
| FINE AGGREGATE | River sand (Quarry) | 2.63 | As per IS 456 | 1520 |
| WATER | Construction purpose | 1.0 | NIL | 1600 |

***TABLE 1: MATERIALS DATA***

MIX DESIGN RATIO OF M25 GRADE: [1:1.28:2.26]

## VI. TYPE OF TESTS

**COMPRESSIVE STRENGTH TEST**

A compression test is a test in which a material experiences opposing forces that push inward upon the specimen from opposite sides or is otherwise compressed, “squashed”, crushed, or flattened. The test sample is generally placed in between two plates that distribute the applied load across the entire surface area of two opposite faces of the test sample and then the plates are pushed together by a universal test machine causing the sample to flatten. The test specimen shall consist of concrete cube of size 150x150x150 mm.

**FLEXURAL STRENGTH TEST**

A flexure test is more affordable than a tensile test and test results are slightly different. The material is laid horizontally over two points of contact (lower support span) and then a force is applied to the top of the material through either one or two points of contact (upper loading span) until the sample fails. The maximum recorded force is the flexural strength of that particular sample. The test specimen shall consist of concrete beam of size 100 x 100 x 500 mm.

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**SPLITTING TENSILE STRENGTH TEST**

The tensile strength of concrete is one of the basic and important properties. The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. The concrete develops cracks when subjected to tensile forces. Thus, it is necessary to determine the tensile strength of concrete to determine the load at which the concrete members may crack. The test specimen shall consist of concrete cylinder of size 150 x 300 mm.

## VII. TEST RESULTS

**COMPESSIVE STRENGTH TEST**

Cubes casted for compressive strength test of dimension 150 x150 x 150 mm. They are tested after 7 &28 days of curing. The test was carried out by using CTM (Compressive Strength Testing Machine).

**NORMAL CONCRETE:**

| NORMAL CONCRETE | 7 DAYS COMPRESSIVE STRENGTH ($N/mm^2$) | 28 DAYS COMPRESSIVE STRENGTH ($N/mm^2$) |
|---|---|---|
| | 17.6 | 25.4 |

***TABLE 2. Test Results for Compressive Strength of Normal Concrete (M25 Grade).***

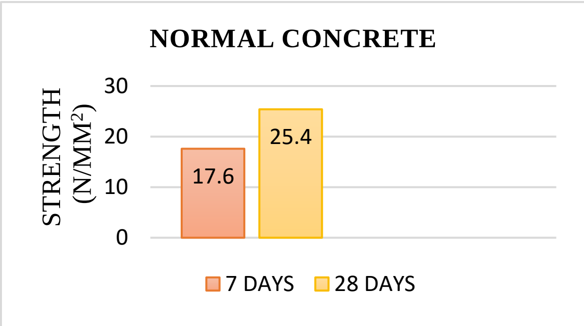


***FIGURE 2. Compressive Strength Results of Normal Concrete.***

**GROUND GRANULATED BLAST FURNACE SLAG(GGBS):**

| GGBS (%) | 7 DAYS COMPRESSIVE STRENGTH ($N/mm^2$) | 28 DAYS COMPRESSIVE STRENGTH ($N/mm^2$) |
|---|---|---|
| 10% | 21.4 | 32.5 |
| 15% | 21.7 | 32.9 |
| 20% | 22.1 | 33.3 |

***TABLE 3. Test Results for Compressive Strength of GGBS Concrete (M25 Grade).***

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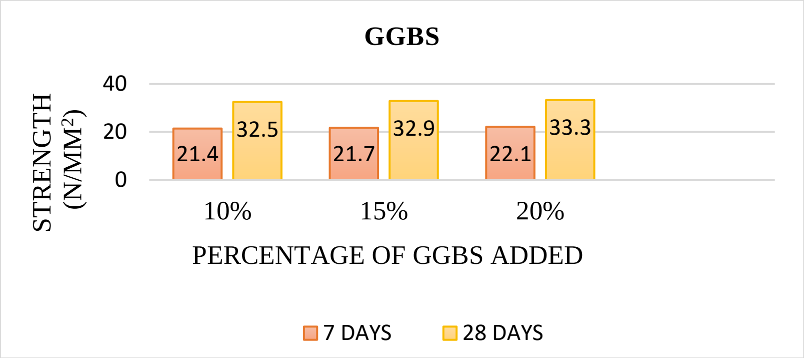


*FIGURE 3. Compressive Strength Results of GGBS.*

**SILICA FUME:**

| SILICA FUME (%) | 7 DAYS COMPRESSIVE STRENGTH ($N/mm^2$) | 28 DAYS COMPRESSIVE STRENGTH ($N/mm^2$) |
|---|---|---|
| 10% | 22.21 | 31.6 |
| 15% | 23.19 | 32.22 |
| 20% | 22.91 | 30.7 |

*TABLE 4. Test Results for Compressive Strength of Silica Fume Concrete (M25 Grade).*

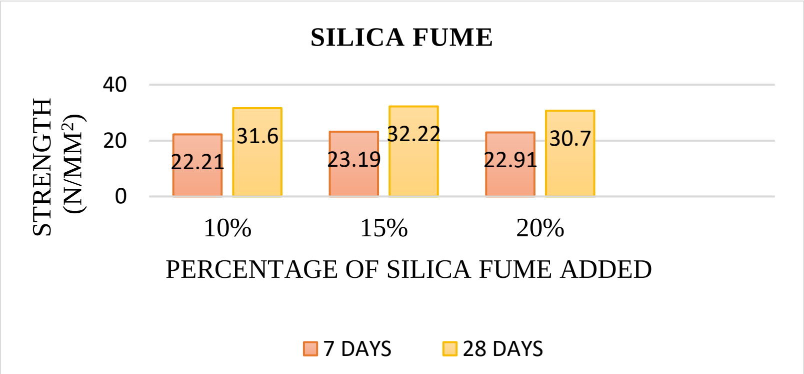


*FIGURE 4. Compressive Strength Results of Silica Fume.*

**FLEXURAL STRENGTH TEST**

The beam specimen of size 500 x 100 x 100 mm, after 7&28 days of curing was subjected to flexural strength test using UTM (Universal testing machine).

**NORMAL CONCRETE:**

| NORMAL CONCRETE | 7 DAYS FLEXURAL STRENGTH ($N/mm^2$) | 28 DAYS FLEXURAL STRENGTH ($N/mm^2$) |
|---|---|---|
| | 4.1 | 5.72 |

*TABLE 5. Test Results for Flexural Strength of Normal Concrete (M25 Grade).*

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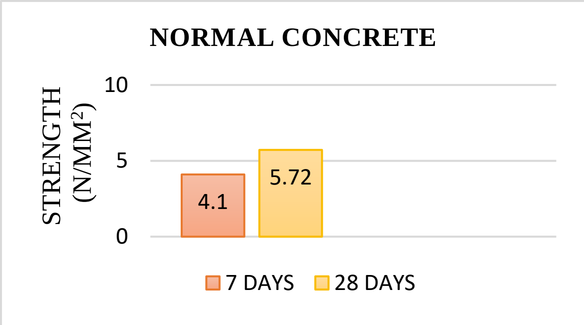


*FIGURE 5. Flexural Strength Results of Normal Concrete.*

**GROUND GRANULATED BLAST FURNACE SLAG(GGBS):**

| GGBS (%) | 7 DAYS FLEXURE STRENGTH ($N/mm^2$) | 28 DAYS FLEXURE STRENGTH ($N/mm^2$) |
|---|---|---|
| 10% | 4.14 | 4.97 |
| 15% | 4.54 | 5.56 |
| 20% | 5.13 | 5.99 |

*TABLE 6. Test Results for Flexural Strength of GGBS Concrete (M25 Grade).*

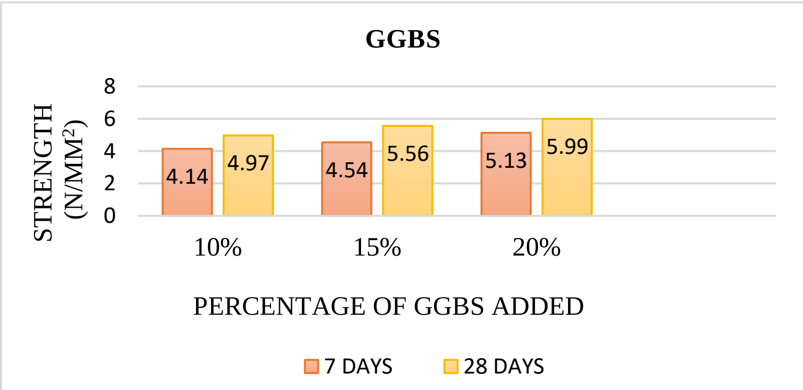


*FIGURE 6. Flexural Strength Results of GGBS.*

**SILICA FUME:**

| SILICA FUME (%) | 7 DAYS FLEXURE STRENGTH ($N/mm^2$) | 28 DAYS FLEXURE STRENGTH ($N/mm^2$) |
|---|---|---|
| 10% | 5.02 | 5.72 |
| 15% | 4.55 | 5.22 |
| 20% | 4.11 | 4.51 |

*TABLE 7. Test Results for Flexural Strength of Silica Fume Concrete (M25 Grade).*

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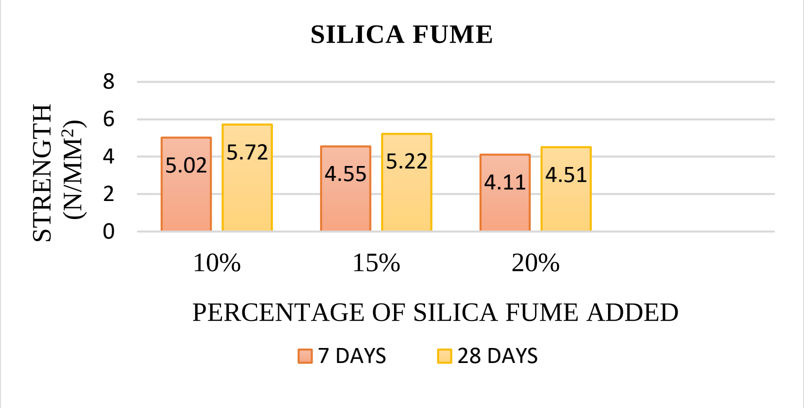


***FIGURE 7. Flexural Strength Results of Silica Fume.***

**SPLITTING TENSILE STRENGTH TEST**

Cylinder casted for splitting tensile strength test of dimension 150 x 300 mm. They are tested after 7&28 days of curing. The test was carried out by using CTM (Compressive Strength Testing Machine).

**NORMAL CONCRETE:**

| NORMAL CONCRETE | 7 DAYS (N/mm$^2$) | 28 DAYS (N/mm$^2$) |
|---|---|---|
| SPLITTING TENSILE STRENGTH | 2.41 | 3.31 |

***TABLE 9. Test Results for Splitting Tensile Strength of Normal Concrete (M25 Grade).***

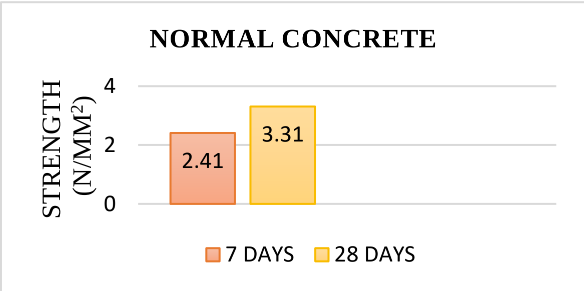


***FIGURE 8. Splitting Tensile Strength Results of Normal Concrete.***

**GROUND GRANULATED BLAST FURNACE SLAG(GGBS):**

| GGBS (%) | 7 DAYS FLEXURE STRENGTH (N/mm$^2$) | 28 DAYS FLEXURE STRENGTH (N/mm$^2$) |
|---|---|---|
| 10% | 2.30 | 3.49 |
| 15% | 2.36 | 3.52 |
| 20% | 2.41 | 3.57 |

***TABLE 9. Test Results for Splitting Tensile Strength of GGBS Concrete (M25 Grade).***

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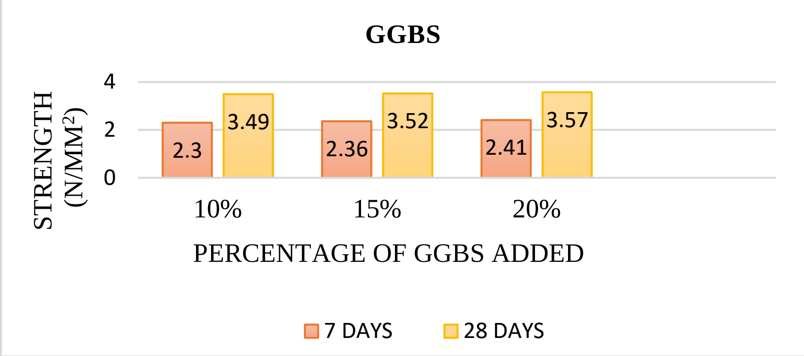


***FIGURE 9. Splitting Tensile Strength Results of GGBS Concrete.***

**SILICA FUME:**

| SILICA FUME (%) | 7 DAYS SPLITTING TENSILE STRENGTH (N/mm$^2$) | 28 DAYS SPLITTING TENSILE STRENGTH (N/mm$^2$) |
|---|---|---|
| 10% | 2.34 | 3.46 |
| 15% | 2.23 | 3.31 |
| 20% | 2.2 | 3.13 |

***TABLE 10. Test Results for Splitting Tensile Strength of Silica Fume Concrete (M25 Grade).***

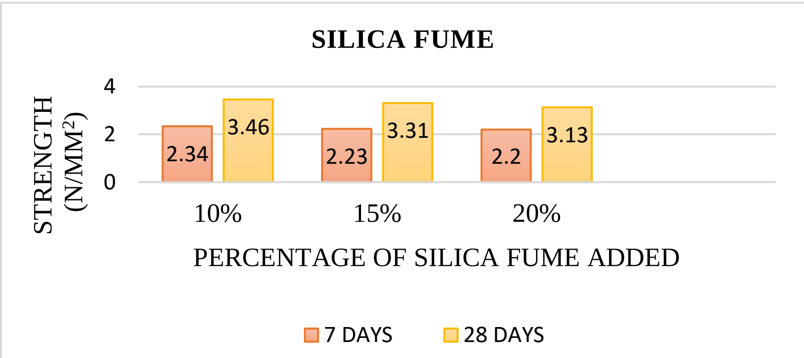


***FIGURE 10. Splitting Tensile Strength Results of Silica Fume.***

## VIII. CONCLUSION

•The study was carried out using M25 grade concrete.
•Test results indicate that both GGBS & Silica Fume are suitable for improving the properties of concrete.
•GGBS & Silica Fume in concrete mix proved to be very useful to solve environmental problems and up to some extent one can minimize the requirement of cement in large quantity.
•The compressive, flexural, splitting strength for the 49 concrete samples was obtained at the curing age of 7 days.
•The highest & the maximum compressive, flexural, splitting strength for the 49 concrete samples was obtained at the longest curing age of 28 days.
•The compressive strength, flexural strength & splitting tensile strength of GGBS and Silica Fume concrete is found to be more than that of normal concrete for a mix of

1)90% cement and 10% of GGBS & Silica Fume.
2)85% cement and 15% of GGBS & Silica Fume.
3)80% cement and 20% of GGBS & Silica fume.

•As the replacement of cement with different percentages with GGBS & Silica fume increases consistency.
•Along with GGBS, Silica Fume is also blended with cement to make the triple blend mix so as to surpass the

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compressive strength of OPC.

•It also acts as green building material and reduces the cost in GGBS compared to OPC.

•When the percentage of the Silica Fume is increased, the workability of the mix becomes very poor as compared to the normal concrete and the cost is high. Hence, silica fume is not applicable.

•As we have seen GGBS is a good replacement to cement in some cases and serves effectively but it cannot replace cement completely. But even though it replaces partially it gives very good results and a greener approach in construction and sustainable development which we are engineers are keen about today.

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