# EXPERIMENTAL INVESTIGTION ON HIGH STRENGTH CONCRETE IN WHICH CEMENT IS PARTIALLY REPLACED WITH GGBS AND SILICA FUME

**A.Jayseeli abitha, S.Divya priya, R. Muthu kumar, P.Abarna**

## ABSTRACT:

***In this paper is an effort is to be carried out to investigate the strength properties of concrete in which cement is partially replaced with GGBS (Ground granulated blast furnace slag) and silica fume. A experimental study is to be carried out to investigate the possibility of utilizing a broad range of materials as partial replacement materials for cement in the production of concrete. Also the mechanical behaviour like compression strength, split tensile strength, flexure strength, water absorption is to be studied. For this the cement content is replaced at various percentage of GGBS and silica fume say 0%, 10%, 20%, 30% respectively. Totally mix is to be designed. At the end the optimum percentage of GGBS and silica fume replacement is to found out.***

***keywords: Compressive strength, Split tensile strength, flexure strength, water absorption, Ground granulated blast furnace slag, silica fume***

- **INTRODUCTION:**

Concrete is a mixture of naturally, cheaply and easily available ingredients as cement, sand, aggregate and water. Cement is occupied second place as most used material in the world after water. The rapid production of cement creates big problems to environment. First environment problem is emission of $CO_2$ during the production process of the cement. The $CO_2$ emission is very harmful which creates big changes in environment. According to the estimation, 1 tonne of carbon dioxide is released to the atmosphere when 1 tonne of ordinary Portland is manufactured.

As there is no alternative building material which totally replace the cement. The search for any such material, which can be used as an alternative or as a supplementary for cement should lead to global sustainable development and lowest possible environmental impact. Substantial energy and cost savings can result when industrial by products are used as a partial replacement of cement. Fly ash, Ground Granulated Blast furnace Slag, Rice husk ash, High Reactive Meta kaolin, silica fume are some of the pozzolanic materials which can be used in concrete as partial replacement of cement.

Concrete, as a material, has significantly been benefited from the usage of silica fumes, and GGBS. Silica fume has a very high reactivity with calcium hydroxide, and this reactivity permits silica fume as a replacement for a small proportion of Portland cement. Silica Fumes are more commonly used as mineral admixtures in the development of high performance concrete mixes. It was first used in 1969 in Norway but systematically employed in North America and Europe in the early 1980s. The small particles of silica fume can enter the space between the particles of cement and improve the bonding. Most of the researchers agree that the C-S-H formed by the reaction of micro silica and Ca (OH) 2. This gel has been appeared as dense and amorphous. Ground Granulated Blast Furnace Slag is one of the important mineral admixtures. It is recyclable material created when the molten slag is chilled rapidly by quenching from melted iron ore and then ground into a powder. This is materials has cementitious properties. It can be used in concrete as a replacement for cement. When GGBS is added to mixture, it also reacts with water and produces C-S-H from its available supply of calcium oxide and silica. The pozzolanic reaction also takes place which uses the excess SiO2 from the slag source and produces Ca (OH) 2 during heat of hydration.

- **PRODUCTION OF CEMENT, GGBS AND SILICA FUME IN INDIA:**

- **CEMENT:**

"With nearly 390 million tonnes (MT) of cement production capacity, India is the second largest cement producer in the world and accounts for 6.7 percent of worlds cement output. The cement production is estimated to touch **550 MT** by FY20." Of the total capacity, 98 percent lies with the private sector lies with the public sector. The top 20 companies account for around 70 percent of the total production.

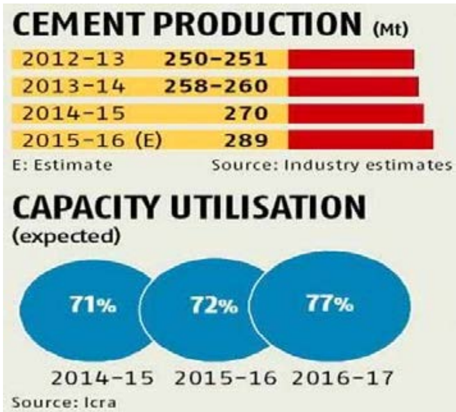




**Fig.1: Cement production in India** **Fig.2: Cement**

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

(GGBS or GGBFS) is obtained by quenching molten iron slag (a by-product of iron and steel making)from a **blast furnace** in water or steam ,to produce a **glassy,** granular product that is then dried and ground into a fine powder. GGBS cement can be added to concrete manufactures batching plant, along with Portland cement , aggregates and water. The use of GGBS in addition to Portland cement in Europe is covered in the concrete standard EN 206:2013.this standard establishes two categories of additions to concrete along with ordinary Portland cement : nearly din the latter category. As GGBS cement is slightly less expensive than Portland cement , concrete made with GGBS cement will be similarly priced to that made with ordinary Portland cement.

**Fig.3: GGBS**

- **SILICA FUME:**

Silica fume is a byproduct of producing silicon metal 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 pozzoloan. Concrete containing silica fume can have very high strength and can be very durable.

Exact data on the annual output of silica fume in Canada and United states are not available but estimtes are that in 1981 a total of about 22,000 tons was available in Canada. The corresponding estimates figure for the United States was on the order of 200,000 to 500,000 tons.

Norway is one of the worlds largest producers of silica fume with an estimated production of about 200,000 tons and this is expected too double over the next several years. Total worldwide production is estimated at about 1.1 million tons.



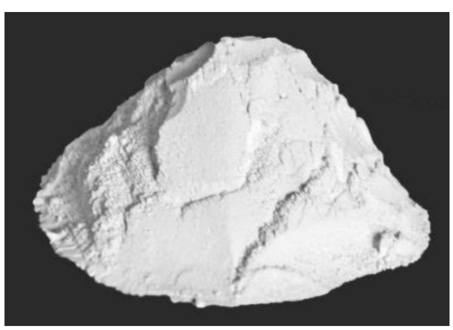


**Fig.4; Silica fume** **Fig.5:Different colours of Silica fume**

- **MATERIALS USED:**
- **Cement***:* Ordinary Portland cement of 43 grade of conforming to IS 8112-1989 was used.

Physical Properties of Cement:

Specific gravity = 3.1

Standard consistency = 31%

Initial setting time = 38min

Final setting time = 480min

Fineness = 5.3%

- **Fine Aggregate***:* Natural river sand of size below 4.75mm conforming to zone II of IS 383-1970 was used as fine aggregate.

Physical Properties of Fine Aggregates:

Specific gravity = 2.62

Water absorption = 1.45%

- **Coarse Aggregate:** Natural crushed stone with 20mm down size was used as coarse aggregate.

Physical Properties of Coarse Aggregates

Specific gravity = 2.65

Water absorption = 0.39%

- **Silica Fume:** CORNICHE SF was used in the present investigation, conforming to IS 15388-2003.

Physical Properties of Silica Fume:

Specific gravity 2.23

- **Ground Granulated Blast Furnace Slag:** GGBS conforming to IS 12089-1981 was used in the investigation.

Physical Properties of GGBS

Specific gravity 2.86

Water absorption 0.14%

- **Water:** Potable water was used in this investigation of both for mixing and curing.

- **EXPERIMENTAL INVESTIGATION:**

**3.1 General:**

In the present study we are partially replacing the cement by Ground Granulated Blast Furnace Slag /(GGBS) and Silica fume (SF) for M40 Grade concrete in different percentages 0%, 10%, 20%, 30% and casted 12 no. of cubes of 150mm×150mm×150mm,3 no. of cubes 70mm×70mm×70mm, 12 no. of cylinder of diameter =150mm and height =300mm, 12 no. of prism of length = 490mm , breadth = 120mm, height = 100mm. To achieve the objectives of the investigation the experimental program was planned. And the cubes were tested under compression testing machine to study the compression strength of the cubes and the split tensile strength of cylinder, the prism were tested under Universal Testing Machine (UTM) to study the flexure strength of the prism, the details of the experimental program for cubes, cylinders, prisms are mentioned in the table below.



**3.2. MIX PROPORTION:**

The concrete mixture proportions for M40 Grade concrete are 1:1.65:2.92 and water cement ratio 0.4, the cubes , prism , cylinders were casted using varying OPC-GGBS-SF Ratio. The Cement is replaced by GGBS and SF in different ratio.

| % | OPC | GGBS | SF |
|---|---|---|---|
| 0% | 100 | 0 | 0 |
| 10% + 10% | 80 | 10 | 10 |
| 20% + 20% | 60 | 20 | 20 |
| 30% + 30% | 40 | 30 | 30 |

**Table 1. Mix Proportion**

ISSN 2229-5518

**Fig.6: Concrete placed in moulds**

- **TEST & RESULTS:**
- **COMPRESSION TEST:**

Compressive strength or compression strength is a capacity of a material or structure to withstand loads tending to elongate. The ultimate compressive strength of the material is that the value of uniaxial compressive stress reached when the materials failed completely. The apparatus used for this experiment is the same as that used in the tensile strength.



**Fig.7:Compressive strength of concrete with GGBS and Silica Fume**

**SPLIT TENSILE STRENGTH TEST:**

The tensile strength of concrete is one of the basic and important properties. Splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete. The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension.

**Fig .8: Split tensile strength**

**Fig.9: Split tensile strength of concrete with GGBS and Silica Fume**

- **FLEXURE STRENGTH TEST:**

Flexural test are generally used to determine the flexure modulus or flexure strength of a material. The flexure test is more affordable than a tensile test and the test results are slightly different. The material is laid horizontally over two points of contact and then the force is applied to the top of the material through either one or two points of contact until the sample fails. The maximum recorded force is the flexural strength of particular sample.

**Fig.10: Flexure strength** **Fig.11: Failure of prism**

**Fig.12: : Flexure strength of concrete with GGBS and Silica fume**

- **WATER ABSORPTION TEST:**

Water absorption gives an idea of strength of aggregate. Aggregates having more water absorption are more porous in nature and are generally considered unsuitable unless they are found to be acceptable based on strength impact and hardness tests. The specific gravity of an aggregate is considered to be a measure of strength or quality of a material.

| **NO. OF DAYS** | **WATER ABSORPTION IN %** |
|---|---|
| 7 DAYS | 10.51% |
| 14 DAYS | 9.27% |
| 28 DAYS | 7.68% |

**Table 2: Water absorption in %**



**Fig.13: Water absorption in % for control mix**

| **% REPLACEMENT** | **CURING** | **COMPRESSIVE STRENGTH (N/mm2)** | **FLEXURE STRENGTH (N/mm2)** | **SPLIT TENSILE STRENGTH (N/mm2)** |
|---|---|---|---|---|
| 0% | 7 DAYS | 40.21 | 3.25 | 3.183 |
| 0% | 14 DAYS | 42.25 | 3.31 | 3.216 |
| 0% | 28 DAYS | 45.34 | 3.45 | 3.278 |
| 10% | 7 DAYS | 41.33 | 3.50 | 3.295 |
| 10% | 14 DAYS | 45.39 | 3.58 | 3.307 |

| | | | | |
|---|---|---|---|---|
| 10% | 28 DAYS | 47.43 | 3.63 | 3.319 |
| 20% | 7 DAYS | 43.21 | 3.75 | 3.327 |
| 20% | 14 DAYS | 48.21 | 3.97 | 3.333 |
| 20% | 28 DAYS | 50.21 | 4.02 | 3.347 |
| 30% | 7 DAYS | 45.31 | 4.05 | 3.358 |
| 30% | 14 DAYS | 50.12 | 4.10 | 3.360 |
| 30% | 28 DAYS | 53.41 | 4.18 | 3.375 |

**Table 3: Compressive, tensile and flexure strength of concrete**

## CONCLUSION:

Based on the experimental investigation the following conclusions are drawn

- The compressive strength, split tensile strength, flexure strength decreases with increase in percentage replacement of OPC with Ground Granulated Blast furnace Slag and Silica Fume.
- Compressive strength of Silica Fume and Ground Granulated Blast furnace Slag was achieved more strength than the control mix.
- The optimal 28 days strength for OPC-GGBS-SF mix is recorded at 30% replacement (53.41 $N/mm^2$) , tensile strength is 3.375 $N/mm^2$ and flexure strength is 4.18 $N/mm^2$.

## REFERENCES:

[1] Chinnaraju K., Subramanian K and Senthil Kumar S.R.R., "Role of Silica Fume and GGBS on Strength Characteristics of High Strength Concrete",
International Journal of Earth Science and Engineering. ISSN 0974-5904., Vol.2. No.5. October 2009, pp 450-457.
[2] Sowmya.S.M., Premanand Kumbar., and Amar R., " An Experimental Investigation on Stregth Properties of concrete by Replacing Cement with GGBS and
Silica Fume", International Journal of Research., Vol.1., Issue-8., September 2014.

[3] Murali G., Meenalakshmi D ., Nithya S .,, "Enhancing Compressive Strength of Concrete by Using Silica Fume", International Journal of Emerging trends in Engineering and Development.,Issue 2, Volume 4, May 2012.

[4] Bhikshama V., Nitturkar K and Venkateshan Y, "Investigation on Mechanical Properties of High Strength Silica Fume Concrete", Asian Journal of Civil Engineering (Building and Housing) Volume 10, No.3(2009), Pages 335-346.

[5] Ajay Verma., Dr. Rajeev Chandak, R.K Yadav., "A Review For Characterization Of Silica Fume And its Effect on Concrete with Pozzolanic Portland Cement", International Journal of Scientific & Engineering Research Volume 4, Issue 1, January 2013.

[6] Vinayagam P., (2012), "Experimental investigation on High performancr concrete using Silica Fume and Superplasticizer", International Journal of Computer and Communication Engineering, Volume 1, No.2, July 2012.

[7] Neville, “Properties of concrete”, 4th and final edition, person education Asia Pvt.Ltd, England, 2000.