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# Properties of Concrete by Part Replacement of Cement with Silica Fume, Metakaolin and GGBS

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**ABSTRACT:** Image The review discusses elective development strategies to expand existing spending plans and increase street capacity. Three options include replacing cement with Metakaolin, GGBS, and Silica Fumes, which can reduce the dependency on cement in concrete, thereby improving its strength and durability. High strength concrete, with a characteristic cube strength above 40 Mpa, is used in bridges, aqueducts, high-rise buildings, and dams. A study found that replacing cement with metakaolin, GGBS, or a combination of these materials improved compressive strength, workability, and durability. The study also examined the strength properties of M-80 grade concrete with Glenium B233. The study reveals that the strength of concrete increases with the addition of metakaolin, and the workability of concrete with GGBS is also enhanced.

**KEYWORDS:** Silica fume (SF); Ground Granulated Blast Furnace Slag; reinforced concrete; replacement of coarse aggregate, Ordinary Portland cement.

## I. INTRODUCTION

Concrete is a widely used building material in civil engineering due to its brittle nature but strength in compression and low strain capacity in tension. Cracks develop when loads exceed the tensile strength of concrete. Adding concrete to the concrete matrix improves energy absorption capacity and crack resistance of plane concrete. Recent research demonstrates that concrete made of ground granulated blast furnace slag (GGBS) can effectively prevent steel reinforcing from corroding, increasing the structure's durability. GGBS concrete reduces corrosion and produces a more durable construction without significantly raising costs by substituting a portion of the cement with industrial waste. This ground-breaking method of building with concrete is becoming more and more well-liked everywhere. The purpose of the current work is to investigate the effectiveness of metakaolin as a mineral admixture and how it affects the characteristics of concrete.

To investigate the impact of strength on concrete, metakaolin was mixed with cement in a variety of ratios. Concrete mixtures were created using ordinary Portland cement alone as the Control and with 10%, 20%, and 30% of metakaolin in place of cement. Concrete's physicochemical characteristics and compressive strength were evaluated.

## II. LITERATURE REVIEW

Strength is decreased when admixtures are used in excess or above the recommended optimal amounts. Comparative studies can be conducted with the use of various admixtures and combinations.

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Poon et al (2006) When silica fume concretes were compared to high performance MK concretes in terms of mechanical and durability attributes, it was discovered that MK's performance was superior than silica fume's in terms of strength development.

Al Amoudi et al (1995) The incorporation of supplementary cementing materials like blast furnace slag, fly ash, and silica fume as a partial replacement of ordinary cement has been found to be a beneficial technique of increasing the resistance of concrete to sulphate attack, according to research on the behavior of concrete using supplementary cementing material.

P. N. Rao et al investigated the properties of M30 concrete that had some of the cement replaced with ground granulated blast furnace slag (GGBS) and some of the sand replaced with ROBO sand (crushing dust). Both compressive and tensile tests are performed on the cubes and cylinders. By replacing some of the cement with GGBS and some of the sand with ROBO SAND, it is discovered.

Dr. P. Muthupriya, “An experimental investigation on effect of GGBS and glass fiber in high performance concrete”, International journal of civil engineering and technology (IJCIET), volume4, issue 4 in 2013.

Jun Zhao (2021) performed the experiment on “Performance of GGBS Cement Concrete under Natural Carbonation and Accelerated Carbonation Exposure” in this experiment paper investigates the effect of varying the proportions of blended Portland cement (ordinary Portland cement (OPC) and ground granulated blast-furnace slag (GGBS) on mechanical and microstructures properties of concrete exposed to two different CO<sub>2</sub> exposure conditions. Concrete cubes cast with OPC, and various percentages of GGBS (0%,30%,50%, and70%) were subjected to natural(indoor) and accelerated carbonation exposure. The aim of this paper is to present the research finding and confirm the literature results of carbonation by using GGBS cement in partial replacement of OPC. When they are comparing to concretes with different percentages of GGBS. We found that the replacement of ordinarily Portland cement (OPC) by GGBS leads to an increase in the carbonation depth of concrete under the same experimental conditions.

B. Rajalakshmi (2020) performed the experiment on “Experimental Study on Optimization of Cement by Using Ground Granulated Blast Furnace Slag (GGBS) and Sand in High Performance Concrete” in this research the OPC partially replaced with GGBS and the properties were observed using M50 concrete with various percentages of cement viz.. 40%, 45%, 50%, 55%, 60%, 65% & 70% as per Cl 18.4. of IRC 112.2011. Since River sand is becoming scarce nowadays, the use of manufactured stone (M-Sand) in concrete has become unavailable. The 7th and 28th day test results point out that the workability of concrete viz 40%, 45%, 50%, 55%, 60%, 65% & 70% substitution of cement by GGBS were excellent in High Performance Concrete (M50) and it is increased from 25 % to 68% compared to conventional concrete. It achieved maximum Compressive strength when there is partial replacement of 45% GGBS with 100% M-Sand. But the target mean strength as specified by IRC is satisfied at the partial replacement of 50% GGBS. So, the optimum percentage of replacement of GGBS is 50%.

P.K. Prasanna (2019) perform the experiment on “Compressive Strength Assessment using GGBS and Randomly Distributed Fibers in Concrete” in this experiment GGBS is used as a replacement material of cement to understand its compressive strength and long-term behavior. 100x100x100 mm size cubes were cast in six numbers and GGBS is replaced by cement by 20%,30%,40%,50%,60%,80% and cured for 3,7,28,56,90 and 180days and then compressive strength is determined. It has been found that GGBS can be efficiently replaced by cement up to 60% without compromising the strength of GGBS based concrete in comparison with OPC concrete. It was also observed that with an increase in the fiber content from 0.5% to 1.5%, there is a marginal increase in the strength of approximately 5% to 12% at 28 days to 180 days.

S.k.Sirajuddin (2019) has carried out the experiment on “Experimental Investigation on Properties of Concrete by Partial Replacement of Cement with GGBS and Fine Aggregate with Quarry Dust” in this experiment the replacement percentages of cement with GGBS are 20%, 40% and 60% by weight and fine aggregate with QD are 25%, 50% and 75% by weight to study compressive strength, split tensile strength and flexural strength tests. It was found that, an increment of 10%, 12% and 15% observed in Compressive strength, Split tensile strength and Flexural strength obtained at 40% GGBS and 50% QD replacements of cement and fine aggregate respectively.

Pratap Singh (2019) has carried out the experiment on “An Experimental Study on Effect of Concrete Performance in Addition of GGBS and Partial Replacement of Cement by Glass Fiber” in this experiment he replaces few percentage of cement with Ground granulated blast-furnace slag which varies from 0% to 25% at interval of 5% for concrete mixes of M35 and then compressive strength, split tensile strength and flexure strength is calculated for 7 and 28 days. Compressive Strength increased initially up to when addition of Ground granular blast furnace and OPC replacement by glass fiber increased up to 5% and 0.2% respectively. However, it started decreasing as additional alterations made in the same ratio and finally achieved similar values as starting. Due to partial replacement of OPC by glass fiber, tensile strength increased 32% having 3.27 N/mm<sup>2</sup>. Initially it increased slowly but as partial replacement and addition GGBS ratio increased, tensile strength increased immediately.

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### III. MATERIAL INTRODUCTION

#### Metakaolin

An SCM that complies with ASTM C618 and Class N pozzolan standards is metakaolin (Pozzofilz). A naturally occurring mineral is used to create Pozzofilz HRM, which is then created under strictly regulated settings to enhance its color, eliminate inert impurities, and customize the particle size for a considerably greater degree of purity.

Additionally, pozzolanic reactivity is attainable. This range increases several concrete qualities while lowering cement usage.



Fig: Metakaolin

#### Materials used and mix proportioning: Metakaolin

The natural clay mineral kaolin is heated to a temperature between 650°C and 800°C in order to create metakaolin. When this temperature is exceeded, metakaolin turns inert and nonreactive. Equation demonstrates that metakaolin ((Al<sub>2</sub>Si<sub>2</sub>O<sub>5</sub>) or AS<sub>2</sub>) is produced when kaolin ((Al<sub>2</sub>Si<sub>2</sub>O<sub>5</sub>(OH)<sub>4</sub>) or AS<sub>2</sub>H<sub>4</sub>) is heated. This process is known as hydroxylation. The Table displays physical attributes. 650–800 °C for Al<sub>2</sub>Si<sub>2</sub>O<sub>5</sub>(OH)<sub>4</sub>. SiO<sub>2</sub> + water + al<sub>2</sub>o<sub>3</sub> Metakaolin is an aluminosilicate substance with various percentages of alumina (40–45%) and silica (50–55%). It often comes in the form of a white powder with particles that are slightly smaller than 2 m, making it finer than Portland cement. The reaction of metakaolin with accessible calcium hydroxide or portlandite results in secondary calcium silica hydrate (C-S-H) and several other hydrates (C<sub>4</sub>AH<sub>13</sub>, C<sub>3</sub>AH<sub>6</sub>, and C<sub>2</sub>ASH<sub>8</sub> or starlight), which are known for their potential to enhance the performance of concrete. It is clear from the information at hand that the microstructure and hydration states affect the qualities of concrete that make it resistant to chloride.

#### Ground granulated blast furnace slag (GGBS)

When molten iron blast furnace slag is quickly cooled by immersion in water, GGBS is created. It is a granular substance with very little crystallinity, is highly cementative in nature, is crushed to cement fines, and hydrates similarly to Portland cement. In Chennai, Astrra Chemicals has been supplying it.



**Fig: Ground Granulated Blast Furnace Slag**

Ground granulated blast slag is a by-product of blast furnaces.

In order to produce iron, (GGBS) is frequently used (Li and Zhao, 2003; Suresh and Nagaraju, 2015). This content may be generated at temperatures of over 1500 C, and it is fed an iron combination that has been carefully regulated. Coal, limestone, and ore are examples (Suresh and Nagaraju, 2015). About 40% of the calcium in the melted slag is calcium silicon dioxide ( $\text{SiO}_2$ ), which is close to the chemical production of OPC, and calcium oxide ( $\text{CaO}$ ).

Slag is produced when iron ore is converted to iron and then floats on top of the iron (Suresh and Nagaraju, 2015). To create GGBS, this slag must be swiftly quenched in huge amounts of water after being often tapped out as a molten liquid (Sahithi and Priyanka, 2015). This quenching technique creates granules that are similar to coarse sand by using the slag's cementation characteristics. After that, the granulated slag is dried out and pulverized into a fine powder.

**Silica Fume:** Micro silica, commonly referred to as silica fume, is an amorphous (non-crystalline) form of the mineral silica. It is an ultrafine powder that was gathered as a waste product from the manufacturing of silicon and ferrosilicon alloys. With spherical particles smaller than 1 in diameter and an average diameter of roughly 0.15, silica fume is an ultrafine substance. This reduces it to a size that is around 100 times smaller than the typical cement particle. The bulk density of silica fume ranges from 130 (unknown) to 600  $\text{kg/m}^3$ , depending on the silo's level of densification. In their study of concrete using waste paper sludge ash as a partial replacement for cement, Ahmad et al. came to the conclusion that using 5% less cement and more waste paper sludge ash resulted in a 10% increase in compressive strength after seven days and a 15% increase after 28 days. Therefore, the hunt for acceptable local resources to make pozzolana cement was stepped up. In order to limit the emission of greenhouse gases, the majority of the increase in cement demand might be satisfied by the use of supplemental cementing materials (Bentur, 2002).

#### IV. PROBLEM STATEMENT

From the above literature review the following conclusions can be drawn:

1. The purpose of this study is to assess the compressive strengths of concrete made using Silica Fume, Metakaolin and GGBS as an alternative to concrete made with Ordinary Portland Cement (OPC). The particular goals will comprise:
2. Fly ash, copper slag, and silica fume are examples of substitute materials that can be used in place of Silica Fume, Metakaolin and GGBS.
3. Metakaolin, a cement substitute with lower costs than the more widely used super pozzolan, has enormous promise in concrete.

#### V. CONCLUSION

The following statements can be drawn from the results tabulated in the prior chapter.

1. The desired characteristic compressive strengths for cubes in conventional concrete, Silica Fume, Metakaolin and GGBS are obtained from the prescribed mix proportions of M30 grade of concrete.

2. When compared to cement, the strengths produced in concrete formed with a proportion of Silica Fume, Metakaolin and GGBS attained high strengths.
3. In order to achieve workability and a water-to-cement ratio, super plasticizer is utilized.
4. The 30% substitution of cement with Silica Fume, Metakaolin and GGBS during 28 days of curing produced extremely high strength.
5. It is demonstrated by the aforementioned experimental findings that Silica Fume, Metakaolin and GGBS may be utilized as a cement substitute, lowering cement consumption and building costs. Utilizing industrial waste helps the environment and protects natural resources.

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