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# Sustainable Consideration of Concrete using GGBFS and Fly Ash

Ruchika Patil[1], Anand Mahajan[2], Gaurav Poyam[3], Tejaswini Ankar[4], Shreyash Dhanjode[5]
[1, 2, 3, 4, 5]*VIII Semester, BE, Civil Engineering Dept., KDKCE, Nagpur*

***Abstract: The economy of the nation is significantly influenced by the construction industries. The most common material used in construction is concrete. The fundamental components of concrete are cement, sand, aggregate, and water. Cement is the primary binder in concrete. 10% to 15% of the total volume of concrete is made up of cement. Large amounts of CO2 gas are released during cement production, which is very harmful to the environment. According to several studies conducted, waste products or by-products such as Fly Ash, GGBFS, silica fume, metakaolin, etc., can be employed as a cement substitute. In this study, the experimental evaluation of the compressive strength of concrete for M25 grade concrete using partial cement replacement with 10%, 15%, 20%, and 25% of GGBFS and Fly Ash is presented. For all blends, a W/C ratio of 0.5 is used. When the concrete has been cast and given a 7 and 28 day curing period, testing has been conducted. The possibility of using waste material in structural cones is the main topic of this study. Reduced cement use will result in less CO2 being produced, which will help to preserve the environment and be cost-effective. The use of industrial waste has evolved as aggressive construction material, thus feature as Sustainable construction.***
***Keywords: GGBFS, Fly Ash, Compressive Strength, Green Concrete***

## I. INTRODUCTION

Concrete is now an important material in the construction industry due to its considerable contribution to faster civilization. However, as industry and modernization progress, most developed regions face serious environmental issues such as natural resource depletion and sustainable waste management [2]. More than six billion tonnes of concrete are produced globally each year, which is equivalent to one tonne per capita on the planet [4]. Emissions of a variety of greenhouse gases from industrial processes, as well as their negative influence on climate, have shifted people's mindsets away from the mass-production, mass-consumption, and mass-waste cultures of the past and towards a zero-emission society focused on the utilization of industrial wastes [5]. As a result, green concrete plays an important role in reducing the environmental impact. We can reduce CO2 emissions from concrete as well as the environmental impact on the earth by using recycled materials or waste materials (which are harmful to the environment) as a replacement for cement, such as Rice Husk Ash (RHA), Fly ash (which is obtained from coal), Ground Granulated Blast Furnace Slag (which can be obtained from the steel industry), silica fume and so on. As a result, when natural resources are on the edge of extinction, green concrete will be a critical instrument [6]. The primary objective of this experimental investigation is to investigate how successfully these industrial waste materials can be used, as well as to develop the appropriate percentage of GGBS and fly ash replacement in cement. IS 10262:2019 & 456:2000 [11,17] are used to prepare the design mix for M25 grade concrete. The cubes are then tested for compressive strength at 7 and 28 days, and the results are analyzed and compared with the standard concrete mix.

## II. OBJECTIVES OF THE STUDY

1) To make concrete from an industrial waste product or By-product(e.g., Fly Ash, GGBFS )
2) The purpose of this study is to reduce the consumption of cement and use replacement of it using a waste product.
3) To minimize the cost of concrete.
4) To evaluate the strength parameters of concrete by partially replacing cement with GGBFS and Fly Ash.
5) To find out the optimum percentage of Fly Ash and GGBFS to be used in concrete.

## III. LITERATURE REVIEW

Some findings are summarized related to the literature papers. The effects of GGBS and Fly Ash on the strength and durability of concrete are discussed here:

1) Syed Asif Ali, Professor Shaik Abdullah (2014), carried out some investigations and discovered that the optimal value of compressive strength for M25 grade at 9% GGBS and 40% fly ash as partial replacement of cement was 31.59N/mm2 after 7 days of curing and 45.47 N/mm2 for 28 days of curing.[1]
2) R.K. Majhi, A.N. Nayak, B.B. Mukharjee (2018), investigated that concrete mix containing 50% RCA and 40% GGBFS produces values of these properties that are similar to those of the concrete mix containing no RCA or GGBFS. Finally, the concrete mix with 50% RCA and 40% GGBFS is regarded the optimal mix since it meets the target mean strength of the mix design while also creating sustainable concrete by saving 40% of cement and 50% of NCA.[2]
3) Abhishek Dixit, Yaman Hooda (2019), found that when the core components of the concrete are partially replaced with recycled materials , the compressive strength of the concrete mix can be increased. The cement and sand were partially replaced with 30% GGBS and 30% Fly ash, and coarse aggregates with 20% Recycled Aggregates. The compressive strength of the geopolymer concrete mix improved by 66.28% and 58.43% at 7 and 28 days, respectively, as compared to regular concrete.[3]
4) Abathar Al-Hamrani, Murat Kucukvar, Wael Alnahhal, et al.,(2021), except for concrete with 80% GGBFS at w/c of 0.5, GGBFS concrte had a compressive strength more than 40 MPa after 90 days. The investigation found that ehen the W/C range of 0.5 to 0.6 is abopted with an FA replacement of 10% to 30%, the 28 day strength of 20 to 35MPa is obtained.[4]
5) S.P Singh, M. Murmu (2010), The compressive strength of lime,fly ash, and GGBFS mortar was low during the early staged of curing, but it reached about the same strength as conventional cement mortar after 60 days of curing. The compressive strength of lime, fly ash, and GGBFS mortor cubes was determined to be 29 $N/mm^2$ at 28 days and 38.8 $N/mm^2$ at 60 days.[5]
6) Er Shiv Shakti, Gaurav Chaudhary, Akshat Saxena(2018), Silica fume is a byproduct of various businesses that can cause air pollution. The addition of micro silica to cement reduces air pollution while also making concrete more sustainable. Concrete strength increases from 5% to 15% replacement, whereas concrete strength decreases from 20% replacement. Because silica fume is finer than cement and more reactive to concrete materials, it improves cement consistency and produces higher strength in less time than conventional concrete.[6]
7) Anant Kumar, Nupoor Dewangan, et al.(2021), according to the results of the experiments, the compressive strength of fly ash concrete is greater than that of ggbs concrete and conventional concrete in both 7 and 28 days. When cement is partially replaced with GGBS and fly ash, the compressive strength increases in both periods. Fly ash-based concrete (FC3) has a strength of 45.2 MPa, which is 6% higher than GGBS-based concrete (GC3) and 12% more than ordinary concrete.[7]
8) Rishabh Joshi (2017), found that concrete compressive strength falls as the fly ash content increases, the drop in compressive strength of concrete at 28 days was found to be 4.57%, 12.20%, and 20.55% for 10%, 20%, and 30% replacement of cement with fly ash, respectively. The workability and consistency of concrete improves as the fly ash content rises. The compressive strength for normal concrete with no fly ash at 7 days was 67% of characteristic compressive strength, whereas the compressive strength for concrete with 30% fly ash at 7 days was 60% of characteristic compressive strength.[8]

## IV. MATERIALS AND THEIR PROPERTIES

The materials used for the mix design of $M_{25}$ grade of concrete were tested in the laboratory and are mentioned below with their Physical properties:

### A. *Cement*

The cement used was Ordinary Portland Cement (OPC) of grade 53 of conforming to IS12269:2013[15]. The physical properties are obtained from the cement supplier. The physical properties of cement are listed in Table-1.

Table-1: Physical Properties of Ordinary Portland Cement

| Properties | Test Values |
|---|---|
| Specific Gravity | 3.15 |
| Specific Surface | 339 $m^2$/Kg |
| Initial Setting Time | 135 min |
| Final Setting Time | 200 min |

### *B. Fine Aggregates*

The locally available sand was used as fine aggregate. Aggregate most of which passes 4.75 mm IS Sieve conforming to IS2386 (Part-1):1963 were used [10]. The physical properties of fine aggregate are listed in Table-2.

Table-2: Physical Properties of Fine Aggregates

| Properties | Test Values |
|---|---|
| Specific Gravity | 2.55 |
| Water Absorption | 0.5% |
| Fineness Modulus | 2.41 |
| Grading | Zone II |
| Moisture Content | 3% |

### *C. Coarse Aggregates*

Aggregate most of which retained on 4.75 mm IS Sieve conforming to IS383:1970 were used [14]. The coarse aggregate with a maximum size of 20 mm was used. The physical properties of coarse aggregate are listed in Table-3.

Table-3: Physical Properties of Coarse Aggregates

| Properties | Test Values |
|---|---|
| Specific Gravity | 2.63 |
| Water Absorption | 0.5% |
| Fineness Modulus | 7.84 |
| Moisture Content | 1% |
| Type | Crushed |
| Flakiness Index | 12.07% |
| Elongation Index | 19.65% |

### *D. Ground Granulate Blast Furnace Slag (GGBS)*

Ground granulated blast furnace slag, also known as GGBS or GGBFS, involves quenching molten iron slag from a blast boiler in water or steam to create a glassy, granular byproduct that is later dried and ground into a fine powder. Molten iron slag is a by-production of iron and steel [1]. The GGBFS were procured from magma industries located at MIDC (Butibori). The physical properties and chemical composition of GGBFS are listed in Table-4 & 5

Table-4: Physical Properties of Ground granulate blast furnace slag

| Properties | Test Values |
|---|---|
| Fineness | 419 $m^2$/Kg |
| Density | 2.90 g/cc |
| Retained on 45 µm wet sieving | 0.16% |

Table-5: Chemical composition (%) of Ground granulate blast furnace slag

| Properties | Test Values |
|---|---|
| Insoluble Residue | 0.47 |
| Silica Content | 34.92 |
| Aluminum Oxide | 19.83 |
| Iron Oxide | 1.89 |

| | |
|---|---|
| Calcium Oxide | 32.29 |
| Manganese Content | 0.11 |
| Glass Content | 94.5 |
| Magnesia Content | 9.92 |
| Sulphide as Sulphur | 0.26 |

### *E. Fly Ash*

In PCC applications, it is most frequently utilized as a pozzolan. Depending on the source, fly ash is regarded as a waste product or by-product produced during the energy generation process. It contains a sizable amount of silicon dioxide, which occurs naturally as calcium oxide (CaO), an amorphous form of silicon dioxide, and aluminum oxide, an amorphous form. Fly ash's particle size ranges from 1 um to 100 um, with more than half falling beneath 20 millimeters. When utilized to replace one or two of the main components of the concrete, the usage of fly ash provides significant environmental advantages [3]. The specific gravity was determined from Le Chatelier's Apparatus and shown in Table-6.

Table-6: Physical Properties of Fly ash

| Properties | Test Values |
|---|---|
| Specific Gravity | 2.14 |

## V. METHODOLOGY

### *A. Concrete Mix Design*

A mix of M25 grade was designed following IS 10262:2019 & 456:2000[11, 17].GGBFS and Fly Ash were added in different proportions as shown in Table-7(a).Concrete design mix proportions are shown in Table-7(b).

Characteristic Compressive Strength at 28 days, fck = 25N/mm$^2$

Nominal maximum size of aggregate = 20 mm

Table-7(a): Mix Proportions

| Mix | GGBFS (%) | Fly Ash (%) |
|---|---|---|
| Mx1 | 0 | 0 |
| Mx2 | 5 | 5 |
| Mx3 | 7.5 | 7.5 |
| Mx4 | 10 | 10 |
| Mx5 | 12.5 | 12.5 |

Table-7(b): Mix Proportions per cubic meter of concrete

| W/C ratio | Proportion | Cement (Kg) | Fine Aggregate (Kg) | Coarse Aggregate (Kg) | Water (Liters) |
|---|---|---|---|---|---|
| 0.5 | 1:1.98:2.52 | 394.32 | 783.875 | 994.73 | 151 |

### *B. Casting of Cubes*

Concrete uses a combination of cement, fine aggregate, coarse aggregate, and water. In accordance with the order, a combination of GGBFS and Fly Ash is used in concrete to the extent that 10%, 15%, 20%, and 25% of cement are replaced. Three cube samples were cast on a mould with dimensions of 150x150x150 mm for each 1:1.98:2.52 concrete mix with partial replacement of cement and w/c ratio of 0.5. After about 24 hours, the specimens were taken out of the mould, and water curing continued. After 7 and 28 days, they were tested for compressive strength. The weighted quantity of each ingredient is represented in Table-8.

Table-8: Material Quantities for Concrete

| Mix | GGBFS (%) | Fly Ash (%) | No. of Cubes | Cement (Kg/m$^3$) | GGBFS (Kg/m$^3$) | Fly Ash (Kg/m$^3$) | Fine Aggregate (Kg/m$^3$) | Coarse Aggregate (Kg/m$^3$) | Water (Liters) |
|---|---|---|---|---|---|---|---|---|---|
| Mx1 | 0 | 0 | 6 | 394.32 | 0 | 0 | 783.875 | 994.73 | 151 |
| Mx2 | 5 | 5 | 6 | 354.888 | 19.716 | 19.716 | 783.875 | 994.73 | 151 |
| Mx3 | 7.5 | 7.5 | 6 | 335.172 | 29.574 | 29.574 | 783.875 | 994.73 | 151 |
| Mx4 | 10 | 10 | 6 | 315.456 | 39.432 | 39.432 | 783.875 | 994.73 | 151 |
| Mx5 | 12.5 | 12.5 | 6 | 295.74 | 49.29 | 49.29 | 783.875 | 994.73 | 151 |

## VI. COMPRESSIVE STRENGTH

A compression Testing Machine was used to conduct tests on cube samples to determine the compressive strength of each batch. The cubes were tested after 7 and 28 days of curing. The load was applied gradually at the rate of 140 kg/cm2 per minute till the Sample fails. Ratio of failure load to area of cube specimen gives the compressive strength of concrete [13].

## VII. EXPERIMENTAL RESULTS

Experimental results of compressive strength test of cubes at 7 and 28 days are tabulated in table 9.

Table-9: Compressive Strength of Cubes at 7 and 28 Days

| Sr. No. | Mix | Average Compressive strength in N/mm$^2$ | |
|---|---|---|---|
| | | 7 Days | 28 Days |
| 1. | Mx1 | 20.75 | 32 |
| 2. | Mx2 | 20.45 | 30.1 |
| 3. | Mx3 | 19.25 | 28.45 |
| 4. | Mx4 | 17.10 | 27.05 |
| 5. | Mx5 | 15.15 | 23.8 |

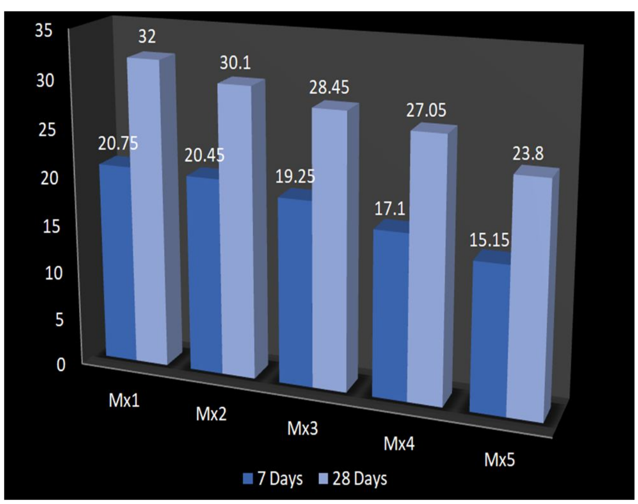


Fig.1**:** Graphical Representation of different mix at 7 and 28 days respectively

## VIII. COST ANALYSIS

The primary market cost is shown in Table-10 and is obtained by a local supplier. The change in cost due to the replacement of cement is worked out in Table-11.

Table-10: Primary Market Cost of Materials

| Sr.No | Materials | Rate (Rs/Kg) |
|---|---|---|
| 1 | Cement | 7 |
| 2 | Fine Aggregate | 1.2 |
| 3 | Coarse Aggregate | 0.6 |

Table-11: Cost Comparison

| Concrete Grade | Mix | Total cost | % Change in cost wrt Mx1 |
|---|---|---|---|
| 25 | Mx1 | 4298 | 0 |
| | Mx2 | 4022 | (-) 7 |
| | Mx3 | 3884 | (-) 10 |
| | Mx4 | 3746 | (-) 13 |
| | Mx5 | 3608 | (-) 16 |

10% substitution of cement for GGBFS and fly ash Gives desired compression strength results, so it can be used for construction, and using GGBFS and Fly Ash over ordinary cement can save money, and 5% each replacement of GGBFS and Fly Ash can save 6.42% of the total material budget. As GGBFS and Fly Ash are waste materials, the transportation factor is not been included in the determination of cost factor.

## IX. CONCLUSION

Following are the conclusions that have been made based on the results of the experimental study.

1) It is observed that at 5% each replacement of cement with GGBFS and Fly Ash, concrete attains its maximum compressive strength, at 7 and 28 days of normal curing. When the replacement of GGBFS and Fly Ash is increased beyond 5% each, the compressive strength is found to be decreasing slightly.
2) The use of GGBFS and Fly Ash in combination with cement can help to reduce waste and pollution. The goal of this project is to promote the use of waste products as building materials in low-income homes.
3) In terms of technical, environmental, and economic considerations, GGBFS and Fly ash in concrete have shown to be a valuable building resource.
4) The use of GGBFS and fly ash in concrete production is a sustainable solution that benefits both the environment and the construction industry. By reducing waste and emissions while improving the quality of the finished product, it represents a positive step towards a more sustainable future.

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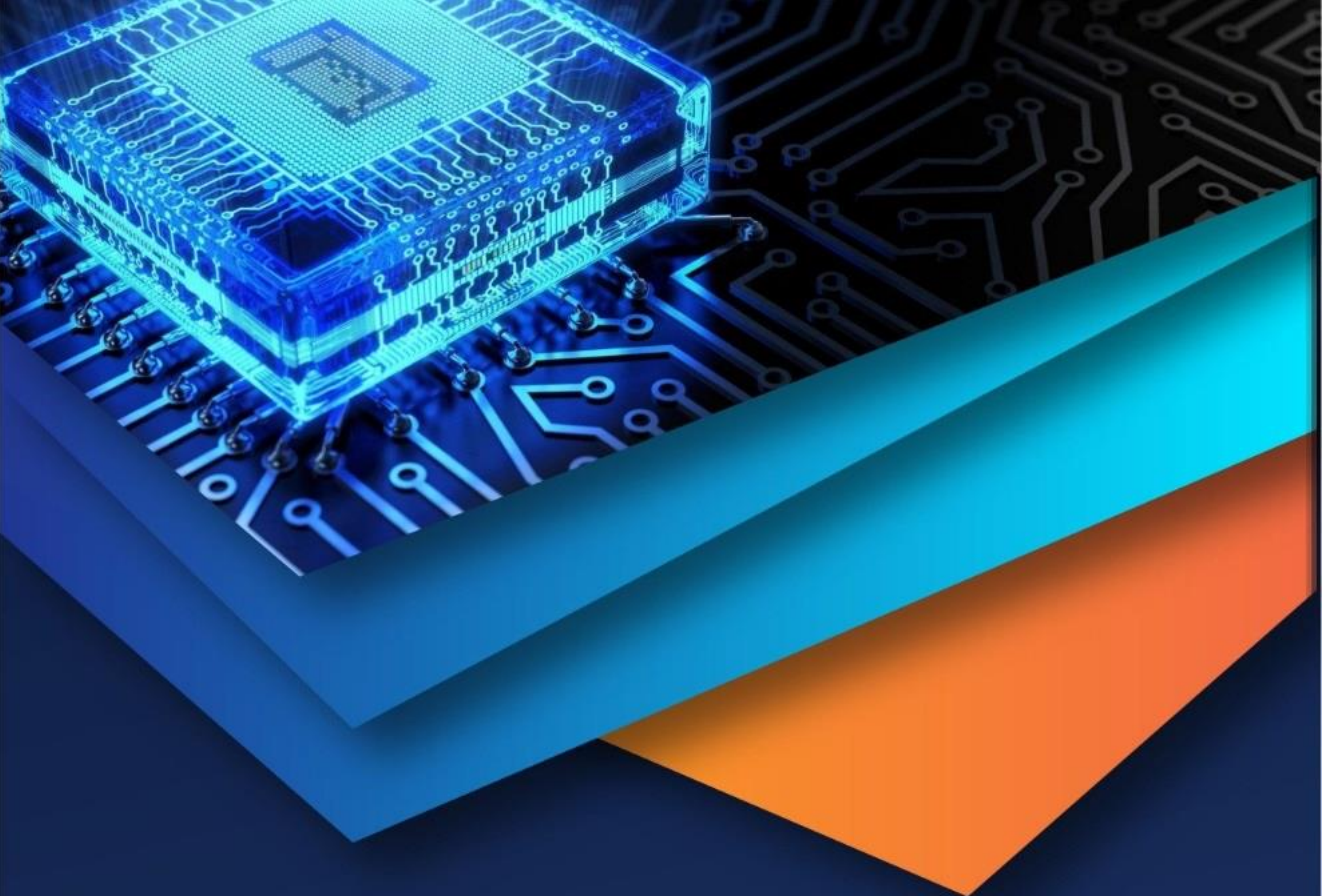


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