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# STRENGTH AND DURABILITY STUDY ON COAL ASH-GGBS BASED GEOPOLYMER CONCRETE

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**Abstract** — concrete is till now most fashionable material in construction industries and one of the most environmentally harmful materials. Due to environmental concerns of cement, there arises a strong need to make use of alternate technology which is sustainable. Geopolymer concrete (GPC) is an alternative material which can act as a binder by replacing cement. In this investigation analysis of the strength and durability on Coal ash and ground granulated blast furnace slag (GGBS) based geopolymer concrete. This paper mainly focuses on the strength and durability study on coal ash and GGBS based geopolymer concrete at different replacement levels (Coal ash20-GGBS20, Coal ash25-GGBS25, Coal ash30-GGBS30, Coal ash35-GGBS35) using Sulphonated Naphthalene Formaldehyde (SNF) and Styrene-Butadiene Rubber (SBR) polymer solutions. Specimens were cast and cured for different curing periods at 28 and 56 days and to determine the geopolymer concrete (GPC) mechanical properties viz., compressive, split tensile and flexural strength respectively in comparison with the control mix. The properties of concrete investigation include porosity, sorptivity, permeability and acid resistance test. The test results shows that strength is increasing with the increase of coal ash and GGBS up to optimum value beyond which strength value start decreasing with further addition of Coal ash and GGBS.

**Keywords—** Geopolymer concrete; Coal ash, GGBS, Mechanical property, Durability Property.

## I. INTRODUCTION

Concrete is the most commonly used construction material, the concrete is produced by using ordinary Portland cement as a binder a highly energy intensive product which causes pollution to the environment due to emission of carbon dioxide. Attempts to reduce the use of Portland cement in concrete are receiving much attention due to the environment. Coal ash and GGBS is a binder material that replaces cement for greater binder. Geopolymer concrete is considered as future concrete as it is encouraging new cement alternative in the present construction materials.

Looking forward, growing investment in infrastructure will lead to increased cement and concrete use. At the same time, using current technologies, rising energy costs, and stricter energy and emission policies will significantly increase the cost of these materials. In response, sustainable alternatives to currently employed materials will become critical. Alternatives include concrete mixes with greater percentage of cement reducing ingredients which will produce a sustainable concrete.

## II. MATERIALS USED

**Cement** - Cement is the important binding material in concrete. Ordinary Portland cement is the common form of the cement. It is the basic ingredient of concrete, mortar and plaster. Ordinary Portland cement (OPC) – 53 grades confirming to IS 12269 – 1987 was used.

**GGBS** - Ground Granulated Blast Furnace Slag which is a by-product from the blast furnaces used to make iron. GGBS is produced by quenching process that is the process of sudden cooling of the ions slag from a blast furnace using water or stream. This granulated material when further ground to less than 45micron is called Ground Granulated Blast Furnace Slag (GGBFS).

**Coal Ash** – Coal Ash is a byproduct of coal-fired electric generating plants. For immediate combustion of the pulverized coal is blown into the burning chamber of the furnace. After the burning of coal the ash that is heavier in weight would fall down but the lighter weight ash would fly out thus it is known as fly ash.

**Fine Aggregate -** Sand is essentially quartz whereas clay is made of many other chemically active minerals like kaolinite. Sand between 4.75mm (about 5mm) and 0.15mm in size is called fine aggregate. Natural sand is available from local river beds or pits.

**Coarse Aggregate** - Material which are large to be retained on 4.7mm sieve size (say 5mm for convenience) are called coarse aggregate. A maximum size of 10mm is usually selected as coarse aggregates up tp20mm.

**Water** - Portable tap water is available in the laboratory with pH value of 7.0 and conforming to the requirements of IS 456-2000 is used for the making concrete and curing the specimen as well. Water is an important ingredient of concrete.

**Polymer** – styrene-butadiene or styrene-butadiene rubber polymer used. These materials have good abrasion resistance and good stability when protected by additives. It should be 1% used.

**Super plasticizer -** Super plasticizer to improve the workability of the mixes, a high range water reducing agent Fosroc conplast SP430 (SNF- Sulphonated Naphthalene Formaldehyde) 1% used.

## III. MIX DESIGN AND MIX

### PROPORTIONS 3.1 Mix design for M30 grade concrete

Mix design for M30 cement concrete as per IS10262:2009 was prepared as control mix with ratio of 1:1.85:2.89 and 0.4 w/c ratio. The control specimens were water cured for 28 and 56 days.

Table 3.1 Mix design

| Material | Weight kg/m$^3$ |
|---|---|
| Cement | 394 |
| Fine aggregate | 732 |
| Coarse aggregate | 1139 |
| Water | 158 |

**Mix ratio 1:1.85:2.89**

### 3.2 Mix proportions

Table 3.2 Mix proportions

| MIX | CEMENT% | GGBS% | COAL ASH% |
|---|---|---|---|
| M1 | 60 | 20 | 20 |
| M2 | 50 | 25 | 25 |
| M3 | 40 | 30 | 30 |
| M4 | 30 | 35 | 35 |

## IV. EXPERIMENTAL TEST

### 4.1 Compressive strength test

The compressive strength test was carried out as per IS 516-1968 (Methods of Tests for Strength of Concrete) on 150mm x 150mm of cube specimens to find the strength of the developed concrete mix. Compressive strength of cube was found at the age of 28 days & 56 days. Totally 4 mix proportion of specimens were tested. Compression Testing Machine of capacity 1000KN was used for the test. Test was continued and the failure load was noted.

Fig 4.1 compressive strength test

### 4.2 Splitting tensile strength test

The split tensile strength test was carried out as per IS 516-1968 (Methods of Tests for Strength of Concrete) on 150mm diameter of cylindrical specimens to find the strength developed concrete mix. Split Tensile Strength of cylinder was found at the age of 28 days & 56 days. Totally 4 mix proportion of specimens were tested. Compression Testing Machine of capacity 1000KN was used for the test. Test was continued and the failure load was noted. The split tensile strength can be calculated by $F_{st} = 2P/\pi LD$, P=Maximum load carried by the specimen L= length of the cylindrical specimen D=Diameter of the specimen.


Fig 4.2 split tensile strength test

### 4.3 Modulus of elasticity test

Modulus of elasticity (E) was tested on 15 x 30cm cylinders (5 samples) at the age of 28 days according to SRPS ISO 6784 and the test results are shown.

Fig 4.3 Modulus of elasticity

## V. RESULT AND DISCUSSION

### 5.1 Compressive strength

The 28, 56 days compressive strength of the different mix proportions are shown in the table 5.1.

| Mix Designation | Compressive Strength N/mm$^2$ | |
|---|---|---|
| | 28 days | 56 days |
| Control | 38.496 | 39.624 |
| M1 (Cement 60%, GGBS 20%, Coal ash 20%) | 39.24 | 40.676 |
| M2 (Cement 50%, GGBS 25%, Coal ash 25%) | 44.036 | 44.972 |
| M3 (Cement 40%, GGBS 30%, Coal ash 30%) | 46.216 | 48.716 |
| M4 (Cement 30%, GGBS 35%, Coal ash 35%) | 45.78 | 46.728 |

Table 5.1 compressive strength

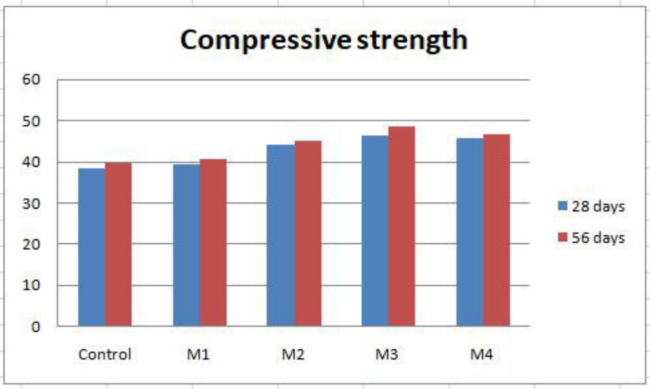



Fig 1.compressive strength

### 5.2 Splitting tensile strength

The 28, 56 days split tensile strength of the different mix proportions are shown in the table 5.2.

| Mix Designation | Split Tensile Strength N/mm$^2$ | |
|---|---|---|
| | 28 days | 56 days |
| Control | 2.89 | 2.93 |
| M1 (Cement 60%, GGBS 20%, Coal ash 20%) | 2.47 | 2.82 |
| M2 (Cement 50%, GGBS 25%, Coal ash 25%) | 2.64 | 2.88 |
| M3 (Cement 40%, GGBS 30%, Coal ash 30%) | 2.94 | 2.99 |
| M4 (Cement 30%, GGBS 35%, Coal ash 35%) | 2.51 | 2.71 |

Table 5.2 split tensile strength

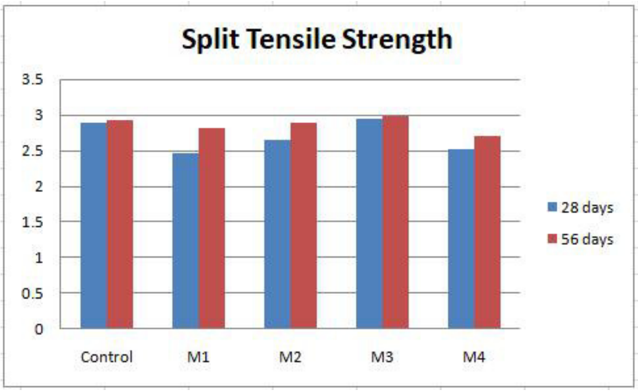



Fig 2. Split tensile strength

### 5.3 Modulus of elasticity

The 28 days modulus of elasticity of the different mix proportions are shown in the table 5.3.

| Mix Designation | Modulus of Elasticity (GPa) |
|---|---|
| Control | 33.28 |
| M1 (Cement 60%, GGBS 20%, Coal ash 20%) | 34.57 |
| M2 (Cement 50%, GGBS 25%, Coal ash 25%) | 32.87 |
| M3 (Cement 40%, GGBS 30%, Coal ash 30%) | 35.48 |
| M4 (Cement 30%, GGBS 35%, Coal ash 35%) | 28.89 |

Table 5.3 Modulus of elasticity

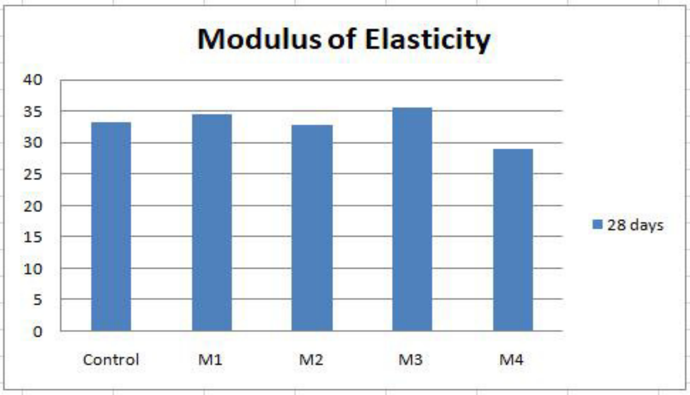



Fig 3. Modulus of elasticity

### 5.4 Water absorption percentage

Water absorption is measured by measuring the increase in mass as a percentage of dry mass. Saturated water absorption test was conducted at the age of 28 days on 150 mm cubes in accordance with IS 2185 - 1979.

$$\text{Water absorption} = W_s – W_d / W_d \times 100$$

Where,
$W_s$ - Weight of specimen at fully saturated
condition $W_d$ - Weight of oven dry specimen.

| Mix Designation | Water absorption % |
|---|---|
| Control | 3.35 |
| M1 (Cement 60%, GGBS 20%, Coal ash 20%) | 4.23 |
| M2 (Cement 50%, GGBS 25%, Coal ash 25%) | 4.01 |
| M3 (Cement 40%, GGBS 30%, Coal ash 30%) | 3.03 |
| M4 (Cement 30%, GGBS 35%, Coal ash 35%) | 4.13 |

Table 5.4 Water absorption

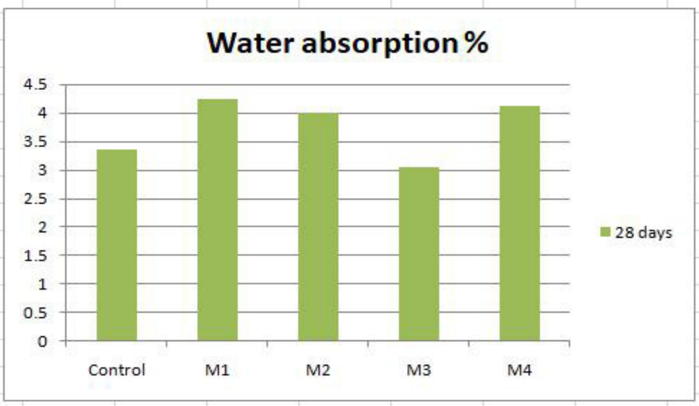



Fig 4. Water absorption

### 5.5 Sorptivity

This test method is used to determine the rate of absorption (sorptivity) of water by measuring the increase in the mass of a specimen resulting from the absorption of water as a function of time when only one surface of the specimen is exposed to the water. The exposed surface of a specimen is immersed in the water and water ingress of unsaturated concrete dominated by capillary suction during initial contact with water is recorded.

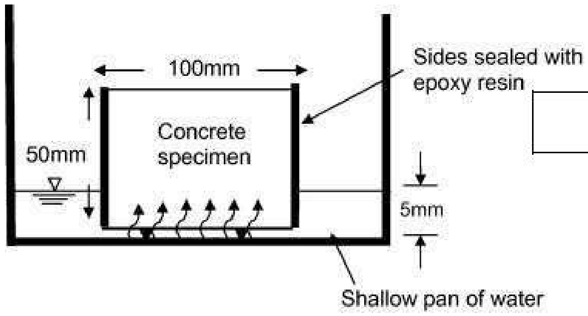
$$I = S.\, t^{½}$$

Where,

S = Sorptivity value

($m/s^{½}$) t = time in sec (s)

I = surface area which is conduct with water ($mm^2$)




Sorptivity setup

| Mix Designation | Sorptivity value |
|---|---|
| Control | 9.121 |
| M1 (Cement 60%, GGBS 20%, Coal ash 20%) | 7.83 |
| M2 (Cement 50%, GGBS 25%, Coal ash 25%) | 9.98 |
| M3 (Cement 40%, GGBS 30%, Coal ash 30%) | 7.78 |
| M4 (Cement 30%, GGBS 35%, Coal ash 35%) | 10.01 |

Table 5.5 sorptivity

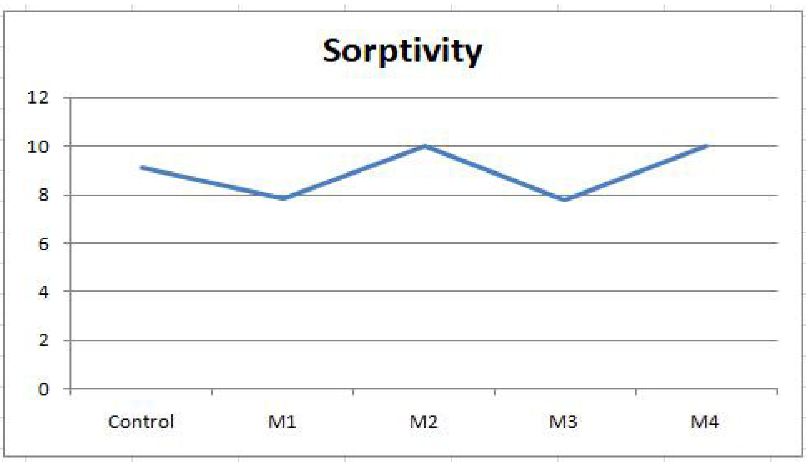



Fig 5. sorptivity

## VI. CONCLUSION

Based on the results obtained in the experimental investigations, the following conclusions are below.

- The strength and durability properties got increased by M3 mix (Cement 40%, GGBS 30% & Coal ash 30%) using in concrete.
- With the addition of 30% GGBS & Coal ash there is increase in compressive strength of geopolymer concrete.
- Concrete acquires maximum increase in split tensile strength at 30% ggbs and coal ash replacement of cement in M30 grade.
- The M30 grade of concrete has attain the compressive strength of 49 Mpa in 56 days and tensile strength of 3 Mpa in 56 days curing.
- The addition of SBR polymer gives good result in compressive strength.
- From the above the results we can conclude the replaced cement concrete shows high durability and strength properties for 30% ggbs and coal ash replacement of geopolymer concrete.

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