An Experimental Investigation of Geopolymer Concrete using Manufactured Sand

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Abstract - **The increasing of world's cement industry results in emission of many greenhouse gases in atmosphere, which are responsible for global warming. Hence, the project is focused on use of waste material having cementing properties, which can be added in concrete as full replacement of cement. In this study, Geopolymer concrete mixes were manufactured using class F fly ash and Ground granulated blast furnace slag in different proportions with 100% M-sand. The fly ash and furnace slag are the waste products it was obtained from the iron manufacturing industry and thermal power plants. All mixes had a fixed water to geopolymer solids ratio as 2.5. Quality is determined from the experimental test values. The required specimen are cast to test the workability, mechanical properties of the produced concretes of mix M_{40}.The experimental study is intented to identify the behaviour of Reinforced beam with low calcium fly ash, furnace slag based Geopolymer concrete using M-Sand in ambient curing. For this purpose material properties, Optimised mix ratio and influence of various parameters like compression strength, flexural strength and split tensile strength in hardened state of concrete. Further using Optimised mix ratio in structural member such as flexural behavior of beam, since the failure occurs inelastic range. Hence the aim of this study is to present a rational, realistic and simple method to optimize mix ratios and design of beam.**

Keywords: Global Warming, Cementing Properties, Fly Ash, Ground Granulated Blast Furnace Slag, Geopolymer.

1. INTRODUCTION

1.1 GENERAL

Concrete, as a major construction material, is being used at an ever increasing rate all around the world. Almost all of the concrete is currently made using OPC, leading to a massive global cement industry with an estimated current annual production of 3.8 billion cubic meter and increasing by 3% annually. OPC production is an extremely energy-intensive process, and therefore there has been a significant push in the past two decades to develop alternative binders, other than OPC, to make concrete. This has largely been due to the requirement to address the environmental effects associated with OPC concrete.

On the other hand, the climate change due to global warming, one of the greatest environmental issues has become a major concern during the last decade. The global warming is caused by the emission of greenhouse gases, such as CO2, to the atmosphere by human activities. Among the greenhouse gases, CO2 contributes about 65% of global warming (McCaffrey [2002]). The cement industry is responsible for about 7% of all CO2 emissions, because the production of one ton of Portland cement emits approximately one tone of CO2 into the atmosphere (Davidovits [1994], McCaffrey [2002]).

Although the use of Portland cement is still unavoidable until the foreseeable future, many efforts are being made in order to reduce the use of Portland cement in concrete. The fly ash and GGBS is one of the promising pozzolanic materials that can be blended with Portland cement for durable concrete. The geopolymer concrete is produced by total replacement the Ordinary Portland Cement (OPC) by fly ash and GGBS. Consumption of fly ash and GGBS in the manufacture of geopolymer is an important strategy in making concrete more environmental friendly.

In this respect, the geopolymer technology proposed by Davidovits shows considerable promise for the concrete industry as an alternative binder to OPC. In terms of reducing the global warming, the geopolymer technology could reduce the CO2 emission to the atmosphere caused by cement and aggregate industries by about 80%. One of the efforts to produce more environmentally friendly concrete is to reduce the use of OPC by replacing the cement in concrete with geopolymers (i.e. 100% fly ash and GGBS in place of OPC).

1.2 NEED FOR THE PROJECT

- To find an alternative for the Ordinary Portland Cement.
- To find an alternative for the River Sand.
- To reduce CO2 emission and produce eco-friendly concrete.
- To develop a cost efficient product.

1.3 SCOPE OF THE PROJECT

- To find out the effectiveness of (flyash+GGBS) based geopolymer concrete using M-Sand by ambient temperature.

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- To find out the effective utilization of these waste materials in the construction industries.
- To study the mechanical properties of geopolymer concrete specimens.
- Design and experimental investigation on behaviour of reinforced geopolymer concrete beam.

2. MATERIALS

2.1 Low Calcium Fly Ash

Fly ash is one of the abundant materials on the earth. It is also a crucial ingredient in the creation of geopolymer concrete due to its role in the geopolymerization process. Fly ash is powder by pozzolan material. A pozzolan is a material that exhibits cementious properties when combined with calcium hydroxide. Fly ash is the main by-product created from the combustion of coal in coal-fired power plants.

Table 1 Physical Properties of Fly Ash

S.No	Property	Value
1	Specific Gravity	2.44

2.2 Ground Granulated Blast Furnace Slag ***(GGBS)***

Ground granulated slag is a by- product obtained during the process of purification of iron ore. It is a non-metallic powder having chemical composition of silicates and aluminates of calcium and other bases. The chemical composition of GGBS is nearer to that of cement clinker. The performance of slag depends on the chemical composition and fineness of grinding. The quality of slag is governed by IS: 12089-1987.

Table 2 Physical properties of GGBS

Colour	Off –white powder
Bulk density (loose)	1.0-1.1 tonnes/m^3
Specific gravity of GBBS	2.9
Bulk density (vibrated)	1.2-1.3 tonnes/m^3
Relative density	2.85-2.95

2.3 Activator Solution

A combination of alkaline silicate solution and alkaline hydroxide solution was chosen as the alkaline liquid. Sodium-based solutions were chosen because they were cheeper than potassium-based solutions.

The alkaline liquids are prepared by mixing of the sodium hydroxide solution and sodium silicate at the room temperature. When the solution mixed together the both solution start to react that is polymerization take place. It liberate large amount of heat so it is recommended to leave it for about 20 minutes thus the alkaline liquid is ready as binding agent.

2.4 Fine Aggregate (M-SAND)

In the present investigation, the manufacture sand, which belong zone II was used as fine aggregate and the following tests were carried out as per IS:2386-1968 Part III.

Table 3 Properties of Manufactured Sand

Properties	Value
Specific gravity	2.65
Size	Passing through 4.75 mm Sieve
Fineness Modulus	4.26

2.5. Coarse Aggregate

Locally available coarse aggregate having the maximum size of 20mm were used in this project. The aggregates were washed to remove dust and dirt and were dried to surface dry condition. The shape of the aggregate affects the workability of concrete. Properties of the coarse aggregate are tabulated in Table 4.

Table 4 Properties of Coarse Aggregate

S.No	Property	Value
1	Type	Crushed
2	Specific Gravity	2.78
3	Bulk Density	1765 Kg/m^3
4	Maximum Size	20mm

3. GEOPOLYMER CONCRETE

3.1 Properties of Gp Paste

The normal consistency and setting times are determined for combination of fly ash and GGBS pastes using Vicat‘s apparatus. Here alkaline solution is used instead of water. Normal consistency conducted is similar as we determined for cement normal consistency.

Table 5 Properties of Geopolymer Paste

S.No	Properties	Value
1	Normal Consistency	38
2	Initial Setting Time	35Min
3	Final Setting Time	10Hrs

3.2 FORMATION OF GPC

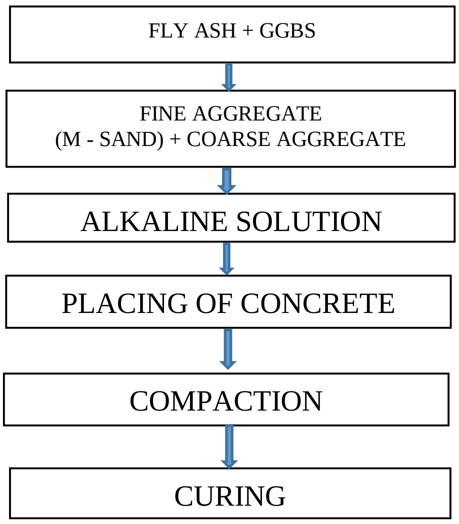

Figure 1 Formation of GPC

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3.2 Properties of GPC

- Curing is done in ambient temperature, Nontoxic, bleed free.
- Low drying shrinkage, low creep and good resistance against acid and sulphate attacks.
- Durability property of Geo-polymer concrete is higher than the nominal concrete mix.
- Geopolymer concrete reduced Co2 emissions of geopolymer cement make them a good alternative to Ordinary Portland Cement.
- Geopolymer concrete has excellent properties within both acid and salt environments.

3.2 Advantages of GPC

- It reduces permeability and gives high life span.
- It is stronger, more resistant to chemicals and corrosion.
- It has abundant raw materials resources.
- Eco-friendly to environment and energy saving.

3.3 Applications f GPC

- Fire resistance
- Insulated panels and walls
- Foamed Geo-polymer panels for thermal insulation
- Energy low ceramic tiles
- Geo-polymer cement and concrete
    - Precast concrete products like railways sleepers, electrical power poles
    - Protective coating

3. MIX PROPORTION

3.1 Design Mix

IS Code Method is used for Mix Design. The final Mix proportion obtained for M30 grade concrete is 1: 1.391: 2.26 (W/C is 0.4)

Table 6 Mix Ratio of Concrete

Cement	Fine aggregate	Coarse aggregate	Water
493kg	650.52kg	1113.44kg	197.16lit
1	1.391	2.26	0.4

Table 7 Proportion of Adding Cementitious Materials for Preparation of Geopolymer Concrete

MIX ID	M-SAND	BINDER %	
		FLY ASH	GGBS
GPM1	100	100	-
GPM2	100	90	10
GPM3	100	80	20
GPM4	100	70	30
GPM5	100	60	40
Conventional Concrete Specimen			

4. EXPERIMENTAL WORK

4.1 MIXING

Thorough mixing of materials is essential for the production of uniform concrete. The mixing should be ensured that the mass becomes homogeneous, uniform in colour and consistency.

4.2 Casting

The mould specimens were applied with oil in all inner surface of the mould and to be dumping the mixed fresh concrete in required steel mould. After 24hrs demould the specimens without any damage.

4.3 Curing

The test specimens are stored in a room temperature at 27oc for 24hrs from the time of addition of water for dry ingredients. The specimen is removed from the mould and it is immersed in water for curing.

4.4 Testing

Specimens are tested after completion of curing and for 7days, 14days and 28days these are tested by UTM.

5. DESIGN OF BEAM

5.1 Design of Rcc Beam

Simply supported beam
Grade of concrete M40
Size of Beam 1000x200x300
Imposed load 5KN/m
Ultimate Load 9.75KN/m
Bending Moment 1.97KNm
Shear Force 6.2KN
Under Reinforced Section
Ast 452.4mm2

The check for shear stress and deflection of the beam is with in permissible limits.

6. RESULT AND DISCUSSION

6.1 Fress Concrete Test Result

6.1.1 Slump Cone Test

The slump cone test is to be carried out to identify the workability of the concrete.

Table 8 Slump Test Value

Mix ID	Slump Value in mm
CCM	98
GPM1	91
GPM2	94
GPM3	95
GPM4	96
GPM5	88

6.2 Hardened Concrete Test Results

6.2.1 Compressive Strength Test

The compressive strength test is carried out for various age of 7days, 14days, and 28days of concrete cube specimens.

Fig 2 Compressive Strength Test

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Table 9 Compressive Test Value

Mix ID	7Days	14Days	28Days
CCM	26.6	37.5	42.5
GPM1	25.1	37.8	38
GPM2	25.5	37.8	40
GPM3	25.8	38	41
GPM4	27.7	39.8	43.6
GPM5	26	34.8	39

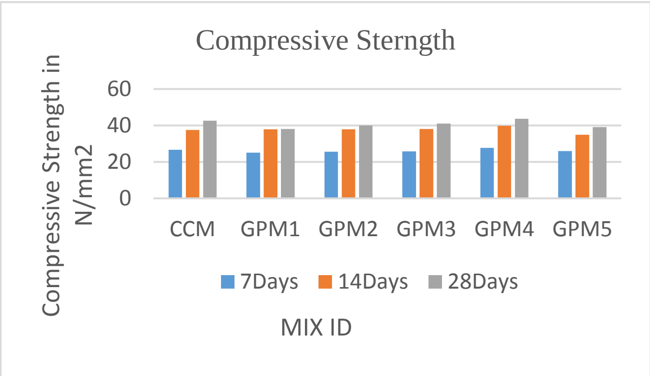

Fig 3 Compressive Test Value

6.2.2 Split Tensile Strength Test

The split tensile strength test is carried out for various age of 7days, 14days, and 28days of concrete cylindrical specimens.

Fig 4 Split Tensile Strength Test

Table 10 Split Tensile Test Value

Mix ID	7Days	14Days	28Days
CCM	1.93	2.138	3.78
GPM1	1.6	1.73	3.33
GPM2	1.68	1.73	3.28
GPM3	1.93	2.24	4.21
GPM4	2.27	2.70	4.21
GPM5	1.91	2.4	3.60

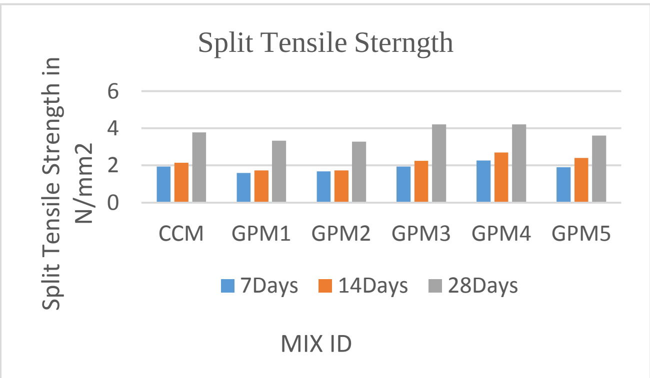

Fig 5 Split Tensile Test Value

6.2.3 Flexural Strength Test

The compressive strength is carried out for various age of 7days, 14days, and 28days of concrete beam specimens.

Fig 6 Flexural Strength Test

Table 11 Flexural Test Value

Mix ID	7Days	14Days	28Days
CCM	1.53	3.2	5.3
GPM1	1.34	2.8	4.28
GPM2	1.50	3.2	4.3
GPM3	1.66	3.24	5.4
GPM4	2.06	3.5	5.39
GPM5	1.71	3	4.98

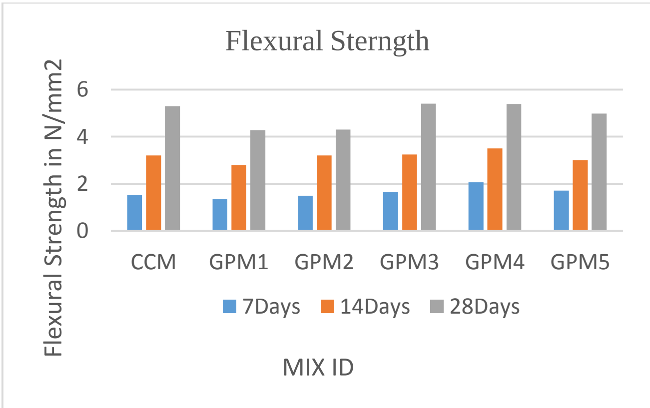

Fig 7 Flexural Test Value

6.3 Deflection Test for Beams

6.3.1 Test for Conventional Concrete Beam

The deflection was measured at three points using the dial gauge, one at the mid span and other two at one-third point from the support. The deflection increased according to load increases.

Table 12 Load Vs Deflection Test Value

S.No	Load in KN	Deflection In mm (At Centre)
1	0	0
2	5	0.95
3	10	1.68
4	15	2.76
5	20	3.94
6	25	4.73
7	30	5.83
8	35	7.85
9	38	9.23

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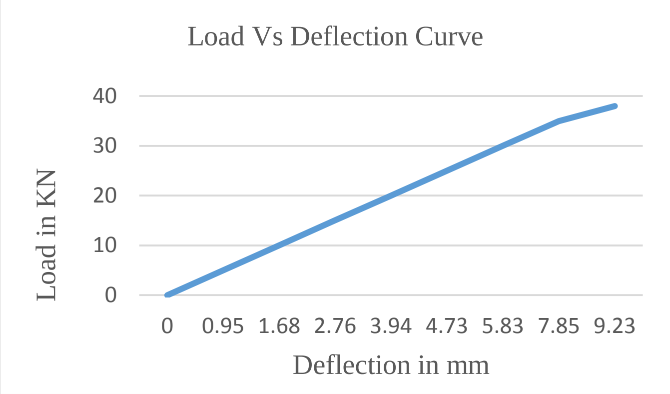

Fig 8 Load deflection curve for conventional beam

6.3.2 Test for Geopolymer Concrete Beam

From the above concluded mix GPM4 can be used to cast the beam. The deflection was measured at three points using the dial gauge, one at the mid span and other two at one-third point from the support. The deflection increased according to load increases.

Table 13 Load Vs Deflection Test Value

Sl.No.	Load In Kn.	Deflection In Mm (At Centre)
1	0	0
2	10	0.5
3	20	1.40
4	30	2.30
5	40	3.75
6	50	5.45
7	60	7.55

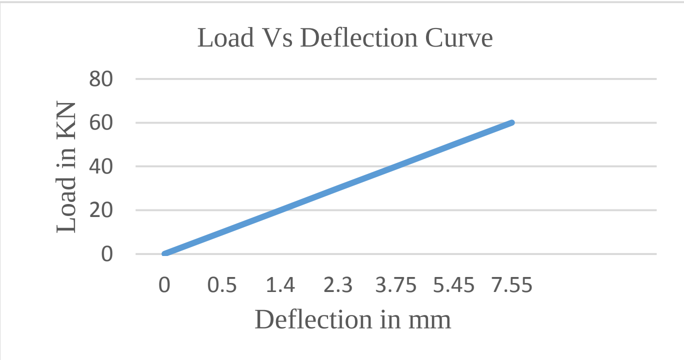

Fig 9 Load deflection curve for GPC beam

Fig 10 Load deflection curve for GPC beam

CONCLUSIONS

Based on the experimental investigation, the following conclusions can be drawn:

1. It is observed that the Geopolymer concretes has been achieved an increase in strength for 100% (70%Flyash+ 30% GGBS) replacement of cement and natural sand at the age of 28 days.
2. The degree of workability of concrete was normal with the addition of geopolymer paste and M-sand GPM4 replacement level for M40 grade concrete.
3. On loading, the ultimate load taken by the conventional beam is 38KN and the corresponding deflection is 9.23mm and GPC beam is 60KN and the deflection is 7.55mm.
4. From the above experimental results, it is proved that geopolymers can be used as an alternative material for cement, it reducing the cement consumption and the M-sand can alternate to natural sand those are reducing the cost of construction. Use of industrial waste products saves the globe and conserves natural resources.

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