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Strength Characteristics of GGBS Based GEO Polymer Concrete with Partial Replacement of River Sand with M- Sand

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Abstract **–Various researchers are going worldwide to find a replacement to Portland cement because 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 partial replacement of river sand with M-sand. The fly ash and ground granulated 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 M40. The experimental study is indented to identify the behaviour of concrete with low calcium fly ash, furnace slag based Geopolymer concrete using M-Sand in ambient curing. For this purpose material properties, Optimized mix ratio and influence of various parameters like compression strength, flexural strength and split tensile strength in hardened state of concrete are tested.**

Keywords: Geopolymer,**M-sand,** ***Cementing Properties, Fly Ash, Ground Granulated Blast Furnace Slag.***

I. 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 CO_2, to the atmosphere by human activities. Among the greenhouse gases, CO_2 contributes about 65% of global warming (McCaffrey [2002])The cement industry is responsible for about 7% of all CO_2 emissions, because the production of one ton of Portland cement emits approximately one tone of CO_2into 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

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to OPC. In terms of reducing the global warming, the geopolymer technology could reduce the CO_2 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 OBJECTIVE FOR THE PROJECT

- To find an alternative binding material for the Ordinary Portland Cement.
- To find an alternative for the River Sand.
- To reduce CO_2 emission and produce eco-friendly concrete.
- To develop a cost efficient concrete.

1.3 SCOPE OF THE PROJECT

- To find out the effectiveness of (flyash + GGBS) based geo polymer concrete with partial replacement of river sand by M-Sand in ambient temperature.
- To find out the effective utilization industrial by products in construction.
- To study the mechanical properties of geo polymer concrete specimens.

II. MATERIALS USED

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 geo polymer concrete due to its role in the geo polymerization process. Fly ash is powder by pozzolana material. A pozzolana 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.

S.No.	Property	Value
1	Specific gravity	2.29
2	Consistency	36
3	Initial setting time	38 min
4	Final setting time	552 min

Table 1 Physical Properties of Fly Ash

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.

S.No	Property	Value
1	Specific gravity	2.9
2	Consistency	30
3	Initial setting time	30 min
4	Final setting time	505min
5	Bulk density	1000 kg /m^3
6	colour	Off white powder

Table 2 Physical Properties of GGBS

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 cheaper 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 600 minutes thus the alkaline liquid is ready as binding agent.

2.4 Fine Aggregate

2.4.1(RIVER SAND)

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

2.4.2 (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.

S.No	Properties	River Sand	M-Sand
1	Specific gravity	2.63	2.65
2	size	Passing through 4.75 mm sieve	Passing through 4.75 mm sieve
3	Fineness modulus	2.69	2.82
4	Bulk density	1668 kg/m^3	1750 kg/m^3
5	Water absorption	1%	0.9%

Table 3 Properties of River Sand and M-Sand

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

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S.No	Property	Value
1	Specific gravity	2.75
2	Type	Crushed
3	Maximum size	20 mm
4	Bulk density	1765 kg /m^3

Table 4 Properties of Coarse Aggregate

III. GEOPOLYMERCONCRETE

Geopolymer concrete is an innovative and eco-friendly construction material and an alternative to Portland cement concrete. Geopolymer cement concrete is made from utilization of waste materials such as fly ash and ground granulated blast furnace slag(GGBS). Fly ash is the waste product generated from thermal power plant and ground granulate blast furnace slag is generated as waste material in steel plant. Both fly ash and GGBS are processed by appropriate technology and used for concrete works in the form of geopolymer concrete. The use of this concrete helps to reduce the stock of wastes and also reduces carbon emission by reducing Portland cement demand. The main constituent of geopolymers source of silicon and aluminum which are provided by industrial byproducts (e.g. fly ash or slag) and an alkaline activating solution which polymerizes these materials into molecular chains and networks to create hardened binder. It is also called as alkali-activated cement or inorganic polymer cement.

3.1 Properties of geo polymer 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.

S. No.	Property	Value
2	Consistency	32
3	Initial setting time	33 min
4	Final setting time	512 min

Table 5 Properties of geopolymer paste

3.2 Formation of GPC

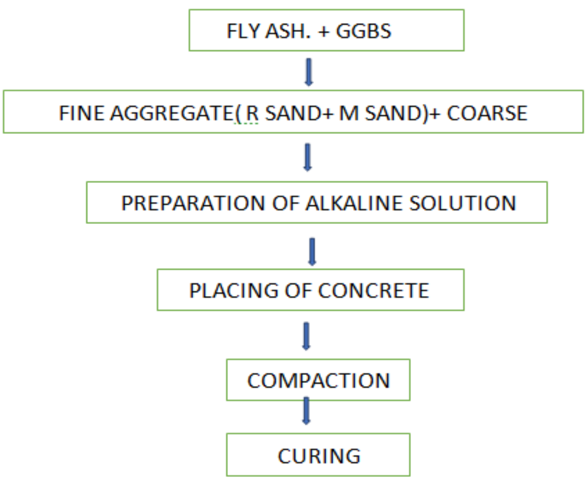

Figure 1 Formation of GPC

3.2.1 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 of Geo-polymer property concrete is higher than the nominal concrete mix.
- Geo polymer concrete reduced CO_2 emissions of geo polymer cement make them a good alternative to Ordinary Portland Cement.
- Geo polymer concrete has excellent properties within both acid and salt environments

3.2.2 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

3.2.3 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, electric power poles. Protective Coating .

IV. MIX PROPORTION

So far there is no proper standard mix design are available for GPC, since it is a new form of material in construction. Hence trial and error method is adopted. to arrive the mix proportion for the present study, the optimum values of different parameters were adopted from previous literature. The mix design for a geopolymer concrete of M40 grade is done by Indian standard (is 10262-2009), study on various trial mixes shows that this ratio provided near optimum strength and workability. Solid to liquid ratio poses huge impact in compaction and strength factor.

4.1 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 (alkaline solution /cement is 0.4)

Cement	Fine aggregate M SAND+ R SAND	Coarse aggregate	Water
457kg	322+322kg	1169kg	182.8 lit
1	1.391	2.26	0.4

Table 6 Mix ratio of concrete

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MIX ID	M-SAND +R - SAND	BINDER %	
		FLY ASH	GGBS
GPFGM1	50+50	100	-
GPFGM2	50+50	90	10
GPFGM3	50+50	80	20
GFGPM4	50+50	70	30
GPFGM5	50+50	60	40
GPFGM6	50+50	50	50

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

V. EXPERIMENTAL WORK

5.1 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.

5.2 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 remould the specimens without any damage.

Size of the mould for casting cubes is 150 mm x150 mm x150 mm.

Size of the mould for casting cylinderis 150 mm diameter and 300 mm height.

5.3 Curing

The test specimens are stored in a room temperature at 29degree for 24hrs from the time of addition of water for dry ingredients. The specimen is removed from the mould and it is kept for curing in room temperature of 29 degree celcius for 7days , 14 days and 28 days.

5.4 Testing

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

VI. RESULT AND DISCUSSION

6.1 Fresh 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.

MIX ID	Slump value in mm
CCM	91
GPFGM1	91
GPFGM2	91
GPFGM3	90
GFGPM4	88
GPFGM5	86
GPFGM6	85

Table 8 Slump value

The slump value shows that the fresh concrete is suitable constructions of beams ,reinforced walls, pavement, columns and slabs.

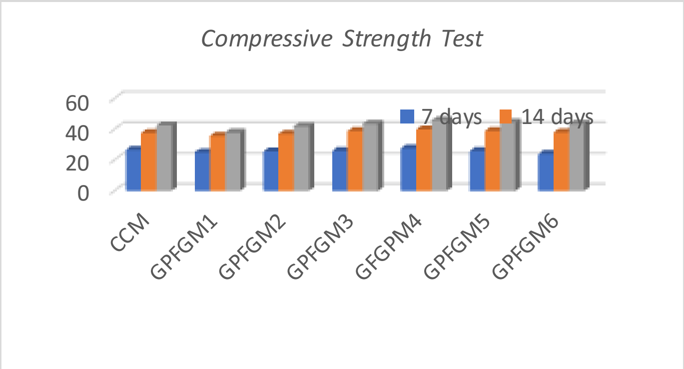
6.2 Hardened Concrete Test Results

6.2.1 Compressive Strength Test

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

Mix ID	7 days	14 days	28 days
CCM	26.6	37.5	42.5
GPFGM1	25.1	35.8	37.8
GPFGM2	25.5	37.0	42.0
GPFGM3	25.8	38.8	43.6
GFGPM4	27.7	39.8	45.8
GPFGM5	26.0	38.9	44.4
GPFGM6	24.0	38.0	43.5

Table 9 Compressive Strength Test



From the test results obtained for compressive strength, shows that there is 4.13% for 7 days, 6.13 % for 14 days and 7.76% for 28days increase in strength for GFGPM4 mix (70% fly ash + 30% GGBS and manufactured sand is partially replaced by river sand)when compared with CCM mix(conventional concrete) .

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.

Mix ID	7 days	14 days	28 days
CCM	1.65	2.25	3.45
GPFGM1	1.65	2.13	3.32
GPFGM2	1.85	2.45	3.82
GPFGM3	1.93	2.58	3.89
GFGPM4	1.98	2.65	4.21
GPFGM5	2.27	2.70	4.08
GPFGM6	1.93	2.50	3.63

Table 10 Split tensile strength test

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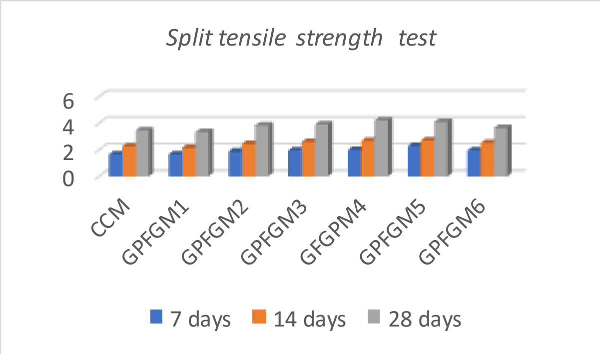

From the test results obtained for Split tensile strength, shows that there is 20% for 7days, 17 % for 14 days and 22 % for 28days increase in strength for GFGPM4 mix (70% fly ash + 30% GGBS and manufactured sand is partially replaced by river sand)when compared with CCM mix(conventional concrete).

VII. 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 partial replacement of natural sand at the age of 7,14 & 28 days.

2. The GPFGM 4 mix has better results in compressive strength test, Split Tensile Strength test respectively.

3. The degree of workability of concrete was normal with the addition of geopolymer paste and partial replacement M-sand for M40 grade concrete.

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 as an 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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