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Experimental Investigation on Blended Geopolymer Mortar Dome Using GGBS

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Abstract: Cement a byproduct of the natural resources is at a high requirement, which is both economically and environmentally backward. Taking up this issue and considering various supplementary materials, of which fly ash and GGBS (Ground Granulated Blast Furnace Slag) on combination provides much better results. Fly ash is a common supplementary pozzolanic material, which is a byproduct from Thermal Power Plants. It enhances the mechanical properties of mortar without altering the conventional properties. GGBS, which is also a supplementary pozzolanic material, admixture and a byproduct from production of Iron and steel-making. It enhances the mechanical properties, increases cohesion and reduces bleeding and permeability. Geopolymer mortar is an innovative and green sense composite material for construction, which is obtained by chemical action of inorganic molecules. This composite material does not utilize ordinary Portland cement where in place fly ash and GGBS is used in a blended form. Geopolymer is a low carbon dioxide cementitious material when compared to 1ordinary Portland cement, as it does not depend on calcination process of limestone that produces carbon dioxide. The binder used in geopolymer is sodium based alkaline activators. Studies were carried on various combinations with GGBS blending on 25% – 75%. Engineering properties were evaluated and the optimum mix was obtained. Thus the results 25 % GGBS & 75 % FA was found good. Dome structure is constructed by using this optimum mix.

Keywords: *Geopolymermortar, Fly ash , GGBS , Alkaline Liquid ,Ferro cement*

1. Introduction

Concrete is one of the widely used materials all over the world. Ordinary Portland cement (OPC) is used as the primary binder to produce the concrete. The demand of concrete is increasing day by day for the need of development of infrastructure facilities. The production of geopolymer concrete is carried out using the conventional concrete technology methods. The fly ash based geopolymer concrete consists 75% to 80% by mass of aggregate, which is bound by a geopolymer paste formed by the reaction of the silicon and aluminum within the fly ash and the alkaline liquid made up of sodium hydroxide and sodium silicate solution with addition of superplasticiser. Geopolymer is an inorganic alumino-silicate compound, synthesized from materials of geological origin or from by-product materials such as fly ash, rice husk ash, etc., that are rich in silicon and aluminum. Fly ash is one of the residues generated from the combustion of coal. Fly ash is generally captured from the chimneys of coal-fired power plants.

Consumption of fly ash in the manufacture of geopolymer is an important strategy in making materials more environments friendly. For this reason, fly ash has been chosen as a base material for this project in order to utilize this industrial waste in a better way.

2. Material Properties

The properties of materials used in the Geopolymer mortar are discussed below:

2.1 Class F Fly Ash

Fly ash is the waste obtained as a residue from burning of coal in furnaces and locomotives. It is obtained in the form of powder. It is a good pozzalona the color of fly ash is either grey or blackish grey. The chemical composition is mainly composed of the oxides of silicon (SiO_2), aluminum (Al_2O_3), iron (Fe_2O_3), and calcium (CaO), whereas magnesium, potassium, sodium, titanium, and sulphur are also present in a lesser amount.

2.2 Ground Granulated Blast Furnace Slag (GGBS)

Granulated Blast furnace Slag (GGBS) is obtained by quenching molten iron slag (a by-product of iron and steel making) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder.

2.3 Fine Aggregate

The sand sieved through 4.75 mm sieve is used having specific gravity of 2.6. The fine aggregates belonged to grading zone I.

2.4 Alkaline Activators

The combination of Sodium hydroxide and Sodium silicate or Potassium hydroxide or Potassium silicate is used as the alkaline activators.

2.5 Water

Casting of specimens were done with minimum quantity of potable water which is required to mix the geopolymer

3. Mix Proportion

A mixture of fly ash, sand and alkaline solution is called Geopolymer mortar. Fly ash and GGBS in its original form acts just as a filler material and hence cannot function as binder silicate is used. The activated fly ash-GGBS blend is rich in silica and aluminium which function as a binder.

Table 1: *Constituents of the study*

Low calcium dry Fly ash(Class F)	25% to 75% by weight of geopolymer mix
GGBS	25% to 75% by weight of Fly ash
Ratio of activator solution to Fly ash-GGBS blend	0.40 by weight of geopolymer mix kept constant
Alkali content(%Na_2O)	8.5% to 10% by weight of Fly ash
Silica(%SiO_2)	1.46% to 12.46% by weight of Fly ash-GGBS blend
Fine aggregate	2 times by weight of Fly ash-GGBS blend

The geopolymer mortar is prepared by taking fluid to binder ratio as 0.416. The Fly ash-GGBSblend:sand ratio is maintained as 1:2. 16 molar concentration of NaOH is used. Ratio of Na_2SiO_3:NaOH is adopted as 1 : 3

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Table 2: *MIX RATIO 1:2(FLY ASH-GGBS:SAND)*

Mix	Mix Constituents in percentage (%)			Binder Blend Ratio	Na_2SiO_3/NaOH
	FA	GGBS	Sand		
Ref Mix(RM)	100	0	2	0.40	3.0
Mix 1(M_1)	75	25	2	0.40	3.0
Mix 2(M_2)	50	50	2	0.40	3.0
Mix 3(M_3)	25	75	2	0.40	3.0

Binder - Alkaline solution (Sodium Hydroxide & Sodium Silicate)

Blend –Fly ash (FA) & GGBS
NaOH = 10 % of binder
Na_2SiO_3 = 3.0 times of NaOH = 30% of binder
Ref Mix(RM) = 100% Fly ash + 0% GGBS
Mix 1(M_1) = 75% Fly ash + 25% GGBS
Mix 2(M_2) = 50% Fly ash + 50% GGBS
Mix 3(M_3) = 25% Fly ash + 75% GGBS

3.1 Preparation Process of Test Specimens

- Sodium hydroxide(40M) pellets are generally used to prepare alkaline liquid.
- In this research NaOH solution of 16 Molar concentration were used which consists of16x40=640 grams of NaOH pellets per litre of solution, where 40 is the molecular weight of NaOH.
- To make the solution, a mass of 444 grams of NaOH solids are measured and dissolved in556 ml of water.
- Once the pellets gets dissolved sodium silicate solution of 3.0times of NaOH solution is mixed to prepare the alkaline liquid.
- It is to be noted that the solution is prepared at least one day prior to casting.

3.2 Curing

Geopolymer mortar specimens are heat cured in an oven at a temperature of 60ºC for 24hrs and then left in ambient condition prior to testing.

4. Experimental Investigation

In this investigation the hardened properties of geopolymer mortar specimens were found by conducting different tests

4.1 Hardened Properties

In order to find the mechanical properties Compressive strength tests were conducted at 7 and 28 days of cube (50 X 50 X 50 mm) specimens. For each combination, two specimens were tested.

Figure 1: *Testing for Compression strength*

Table 3: *Compressive strength of cube*

Mix	Percentage of replacement		Average compressive strength (N/mm^2)		
	Fly ash in %	GGBS in %	7 Days	14 Days	28 Days

RM	100	0	10.5	23.5	41.0
M_1	75	25	12.30	27.58	48.00
M_2	50	50	9.21	20.11	35.00
M_3	25	75	6.84	14.94	26.00

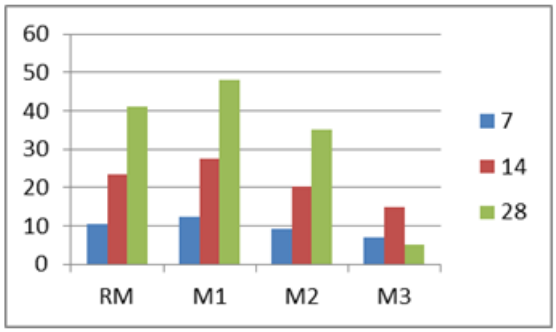

Chart 1: *Chart for Compression strength of Geopolymer mortar cube*

In order to find the split tensile strength of concrete 7 and 28 days of cylinder (50 X 100 mm) specimen are cast. For each combination, two specimens were tested. The test results are discussed in the following Tables.

Table 4: *Split tensile strength of cylinder*

Mix	Percentage of replacement		Average split tensile strength (N/mm^2)		
	Fly ash in %	GGBS in %	7 Days	14 Days	28 Days
RM	100	0	1.65	2.62	4.12
M_1	75	25	1.28	2.049	3.21
M_2	50	50	1.02	1.73	2.54
M_3	25	75	0.502	1.05	1.27

Figure 2: *Testing for Split tensile strength*

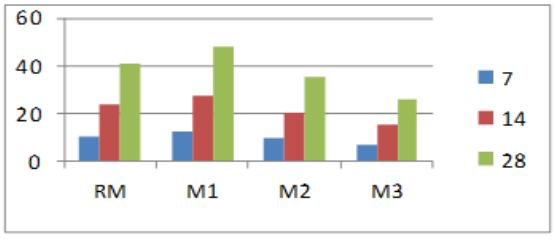

Chart 2: *Chart for split tensile strength of Geopolymer cylinder*

4.2 Scanning electron microscope results (SEM)

SEM analysis test results for geoplymer mortar specimen after curing.

Images showing the results that have arrived from different magnitudes.

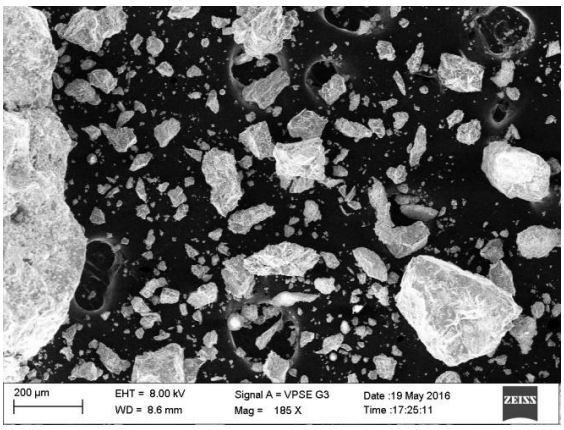

Fig.3 (a)

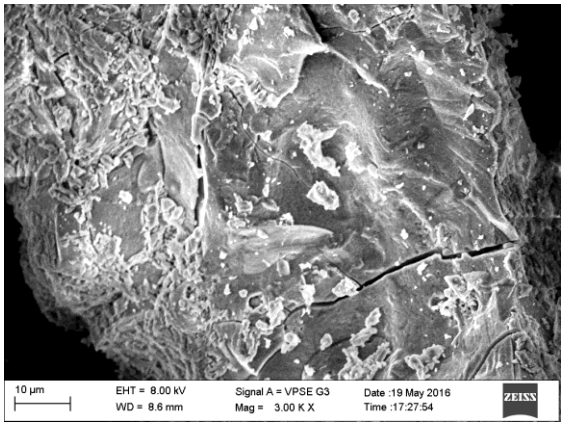

Fig.3 (b)

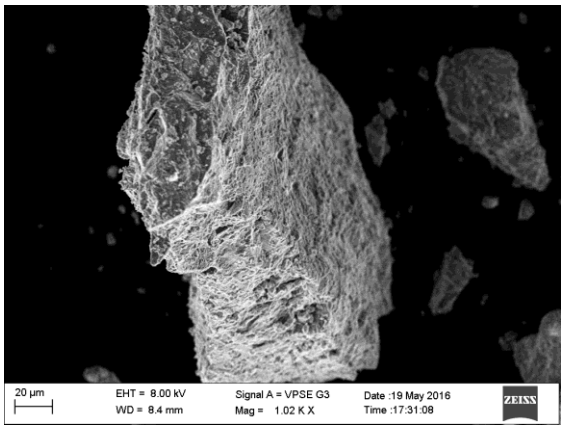

Fig.3 (c)

Fig 3: *SEM analysis results*

4.3 Analysis results by ansys

4.3.1 Rome specification

Diameter = 10.00 m
Rise = 5.00 m
Thickness = 0.10 m

4.3.2 Reinforcement details

For dome 10 mm dia bars at 200 mm c/c

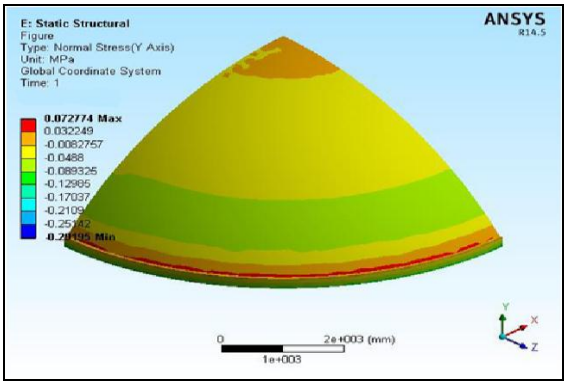

Figure 4: *Normal stress at Y axis*

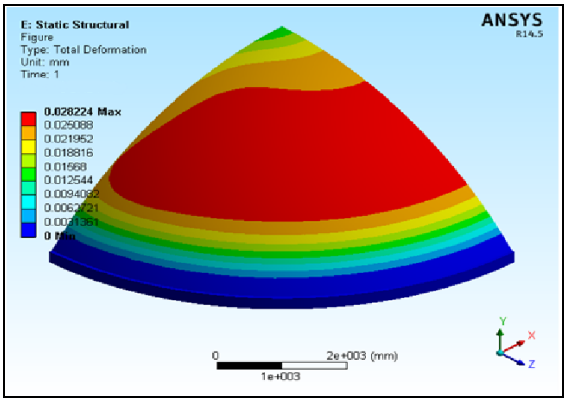

Figure 5: *Total deformation of a body*

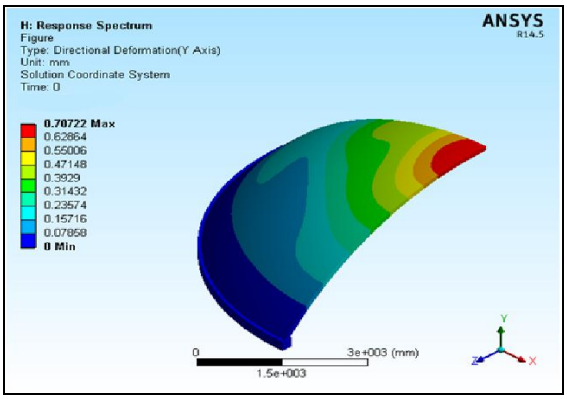

Figure 6: *Directional deformation about Y axis*

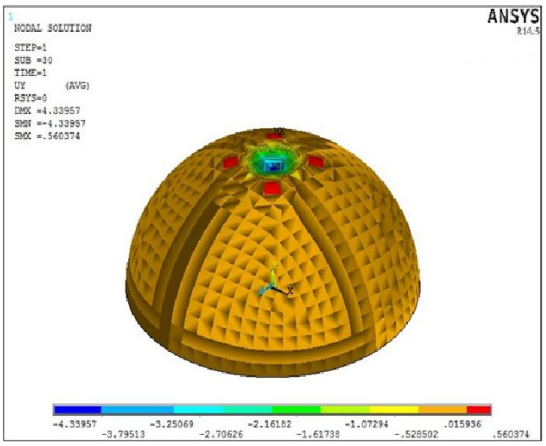

Figure 7: *Deflection to the corresponding load*

Table 5: *Table for stress and deflection*

Stress (Mpa)	Deflection (mm)
0.256	-4.3
-0.607	-1.1
-0.0964	-0.13
-0.169	-0.1
-0.145	-0.01
-0.146	-0.034
-0.134	-0.021

5. Conclusion

Based on the experimental work reported in this study, the following conclusions are made

- The working ease of the geopolymer mortar prepared by blending GGBS with Fly ash was found to be good.
- Better results are obtained for compressive strength and split tensile strength of cubes and cylinders on heat curing at 80ºC
- Blending GGBS with Fly ash increases the serviceability.
- From the test results it was found that both Split tensile and compressive strength increases when 75 percentage of Fly ash blended with 25 percentage of GGBS.
- It has found that increasing the percentage of GGBS above 30 percentage of Fyash will reduces the strength.

6. Acknowledgements

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