FLOW AND STRENGTH PROPERTIES OF GEOPOLYMER MORTAR

By

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ABSTRACT

Mortar is a basic ingredient of masonry which helps in binding together the masonry units. The strength and elasticity properties of masonry are not only dependent on the properties of constituent but also on the intricate interaction between the units and the mortar. Thus any study related to the performance of masonry should not exclude studies on mortar. There are quite a good number of mortars which are commonly used that possess relative advantages and disadvantages. These conventional mortars are generally 10-15 mm in thickness. Since these conventional mortars constitute to 7% - 25% of gross volume of masonry, there are manufacturers who have came out with alternative "Geopolymer Bricks" recently. So in this paper, the authors try to find the properties of a Geopolymer mortar. This can be made from alkaline solutions. In this study, an attempt has been made to understand the workability and strength properties of a Geopolymer Mortar. The study includes Geopolymer mortar with different molarities 4M, 8M, and 12M. And also fly ash has been replaced with 10%, 20%, and 30% of Ground Granulated Blast Furnace Slag (GGBS). 1:3 proportion of fly ash to sand ratio has been maintained throughout the work. Based on the study it is found that the workability of fresh Geopolymer mortar decreases with increase in the GGBS replacement. Increase in the compressive strength of the Geopolymer mortar increase with the increase in molarity and compressive strength of the cubes increases up to the replacement of 20% of GGBS for sun curing after which it decreases to a considerable amount.

Keywords: Geopolymer Mortar, Alkaline Activator, Molarity, Fly Ash, GGBS.

INTRODUCTION

In recent days, the concrete is the major part of the construction industry because of which the production and demand for the cement has been increased up to a great extent around 3% annually which is diverting the present day requirement of sustainable construction [1,11].

The manufacturing of OPC releases large quantity of carbon dioxide (Co_2). Every ton of OPC production will release around a ton of CO_2 into the atmosphere which directly contributes to the global warming [2,10,13] Along with this, the raw material lime stone and the energy required such as electrical and fuel required is also high about 1.5 tons for 1 ton of OPC. Hence there is a great requirement of alternative binding materials which would be an environmentally friendly material. One of such material is fly ash (a coal combustion waste product) and GGBS.

In the view of binder, geopolymer is the next generation binder which will be activated by an aluminosilicate source material in a highly alkaline medium [3,6,7] and also noted that it will poses high early strength with better durability.

Geopolymer shows good bond strength and abrasion resistance which will make it as a good material for repairing work [4].

One more important factor is the curing condition. To obtain a good amount of strength, the temperature should be at 40 to 75 °C [5,12]. In case of low-calcium fly ash-based geopolymer, compressive strength of concrete is excellent, and also it suffers a very little drying shrinkage and a low creep which can be related to the mortar [8] Compared to the waste-based geopolymer, a metakaolin-derived geopolymer exhibits higher compressive strength. Both of these contain a significant amount of voids and unreacted phases as inactive fillers within the geopolymer binder, resulting in variability and complexity in their mechanical behavior [13].

'Geopolymer' comprises of mineral binders that have a polymeric silicon-oxygen-aluminium framework structure. These binders could be generated by a polymeric reaction of alkaline liquids with the silicon and the aluminum in source materials of geological origin or by-product materials such as rice husk ash and fly ash. It has been observed that activation of pozzolans such as blast furnace slag can be done by using alkaline liquids to form a binder and hence totally replace the use of OPC in concrete. The main constituents of Geopolymer are source materials (such as fly ash, silica fume, GGBS, red mud) and alkaline liquids (such as combination of potassium hydroxide (KOH) sodium hydroxide (NaOH) or and potassium silicate or sodium silicate).

1. Objectives of the Study

The present investigation mainly deals with the performance of "Geopolymer mortar", with the proportion of fine aggregates,

The objectives are,

- Basic tests on Geopolymer Mortar with different molarity.
- Strength of Geopolymer Mortar with 1:3 proportions of fine aggregates with the replacement of Fly Ash with GGBS.

2. Experimental Work

2.1 Materials

2.1.1 Fly Ash

Source of the fly ash is from Raichur thermal Power Station (RTPS) Karnataka, through CASHUTEC. It is a class F fly ash according to its properties (the fly ash which contains less than 10% of the calcium), fly ash is tested for its chemical properties and the outcome results are presented in Table 1.

2.1.2 Ground Granulated Blast Furnace Slag (GGBS)

Ground Granulated Blast Furnace Slag (GGBS) used in this experimental work is brought from prism cement limited, the RMC plant near KSIT Engineering College, Kanakapura road, Bangalore and the results are presented in Table 2.

Chemical composition	SiO_2	Al_2O_3	Fe_2O_3	$SiO_2 + Al_2O_3 + Fe_2O_3$	MgO	CaO	SO_3	Na_2O	LOI
Percentage mass	60.98	28.92	4.98	94.88	0.80	2.74	0.20	0.93	0.48
Requirement as per IS:3812:2003	35	--	--	70	5	5	3	1.5	5

Table 1. Chemical Composition of Fly ash

Sl.No	1	2	3	4	5	6	7	8	9
Parameters	Insoluble residue	Si	SiO_2	Al_2O_3	Fe_2O_3	Cao	Mgo	Manganous oxide	Chloride content
Results	0.84	0.72	33.88	18.02	1.52	34.98	9.62	0.32	0.030

Table 2. Chemical Compositions of GGBS

2.1.3 Fine Aggregates

Locally available sand passing through IS Sieve 4.75mm is used. The specific gravity of 2.62 and fineness modulus of 3.06 are used as fine aggregate.

2.1.4 Alkaline Solutions

A combination of sodium silicate and sodium hydroxide was used to prepare the solution with different molarity.

2.2 Preparation of Alkaline liquids

The sodium hydroxide flakes were mixed with water to make the solution. The variation in weight of sodium hydroxide solids in a solution depends upon the concentration of the solution expressed in terms of molar and NaOH solution with a concentration of 8M consisted of 320 grams of NaOH solids (in flake or pellet form) per liter of the solution, (40 is the molecular weight of NaOH). The sodium silicate and sodium hydroxide solution were mixed atleast one day prior to use. The chemical mix has to be kept in the room temperature up to 48 hours . On the day prior to casting of the specimens, the alkaline liquid will be mixed with extra water (if any) to prepare the liquid component of the mixture for workability.

3. Methodology

Basic tests on Geopolymer mortar are,

3.1 Flow Test (IS: 5512-1983) [14]

- The main objective of this test is to find the amount of solution required to make the moulds.
- Percentage of flow is 110.
- To get the percentage of flow, different percentage of solutions will be added to the 800 gm of dry mix. It

will be increased till the flow diameter of mortar 210 mm is obtained.

- %Flow = Flow diameter of mortar (mm) - Bottom diameter of mould (mm) / Bottom diameter of mould (mm) X 100

Results of the flow tests are tabulated in Table 3.

3.2 Compressive strength (IS: 2250 – 1981 [9])

- Cubes of size 70.6mm x 70.6mm x 70.6mm as per IS: 10080 –1982 are cast for conducting the compression test.
- As per IS: 2250 – 1981 specifications, the tests are conducted
- Cubes are cast for 4 molar, 8 molar and 12 molar with replacement of fly ash with GGBS of 0%, 10%, 20%, 30% and will be tested after 7, 14, and 28 days.
- Compressive strength (N/mm^2) = Ultimate Load at failure (N) / Area of loading (mm^2)

Results of the compressive strength of geopolymer mortar having varoius mix proportions are tabulated in Table 3, 4, 5 and 6 and represented graphically in Graph 1,2,3,4,5 and 6.

Conclusions

Based on the experimental results, the following conclusions are drawn.

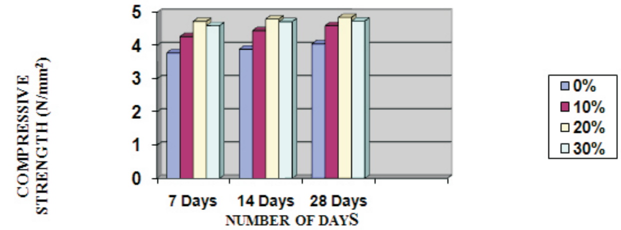
- The workability of fresh Geopolymer mortar decreases with the increase in the GGBS replacement and it

Molarity	4M				8M				12M			
Percentage Replacement of GGBS	0	10	20	30	0	10	20	30	0	10	20	30
% of water	30	30	30	30	32	32	32	32	34	34	34	34
Flow diameter	210	209	209	209	210	209	209	210	210	210	210	210
% of flow	110	109	109	109	110	109	109	110	110	110	110	110

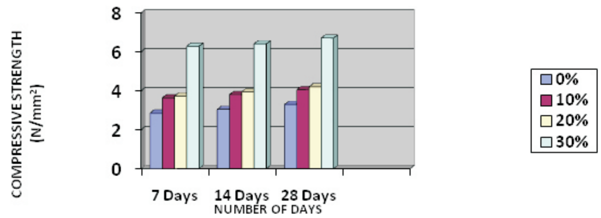
Table 3. Slump Test Results for Geopolymer mortar

% age replacement of GGBS	Sun-Dried (N/mm^2)			Oven-Dried (N/mm^2)		
	7 Days	14 Days	28 Days	7 Days	14 Days	28 Days
0	3.78	3.89	4.05	2.85	3.04	3.29
10	4.27	4.45	4.60	3.63	3.80	4.05
20	4.73	4.80	4.85	3.72	3.94	4.20
30	4.60	4.72	4.74	6.28	6.40	6.70

Table 4. Results for 4 Molarity



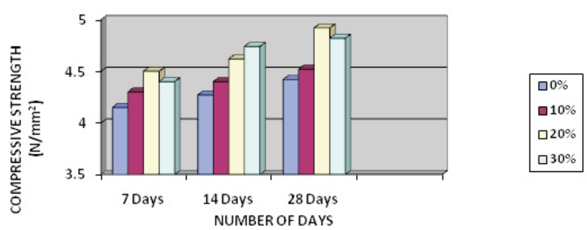
Graph 1. Compressive Strength Variation for different %age of Variation of GGBS (Sun-dried)



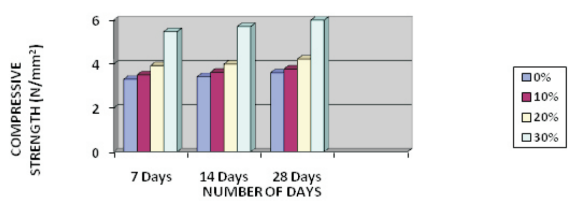
Graph 2. Compressive Strength Variations for different %age of Variation of GGBS (Oven-dried)

% age replacement of GGBS	Sun Dried (N/mm^2)			Oven Dried (N/mm^2)		
	7 Days	14 Days	28 Days	7 Days	14 Days	28 Days
0	4.15	4.27	4.42	3.30	3.42	3.60
10	4.30	4.40	4.52	3.50	3.60	3.77
20	4.50	4.62	4.92	3.92	3.99	4.22
30	4.40	4.74	4.82	5.47	5.70	5.99

Table 5. Results for 8 molarity



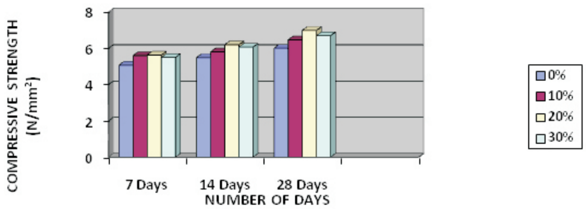
Graph 3. Compressive Strength Variations for different %age of Variation of GGBS (Sun-dried)



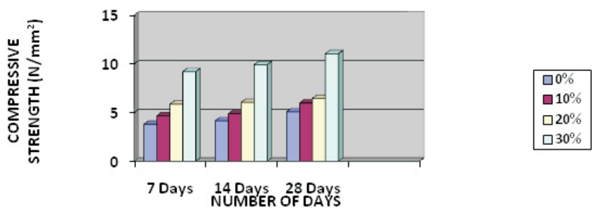
Graph 4. Compressive Strength Variations for different %age of Variation of GGBS (Oven-dried)

% age replacement of GGBS	Sun Dried (N/mm^2)			Oven Dried (N/mm^2)		
	7 Days	14 Days	28 Days	7 Days	14 Days	28 Days
0	5.07	5.49	6.01	3.80	4.15	5.07
10	5.60	5.81	6.47	4.67	4.87	5.97
20	5.63	6.20	6.99	5.84	6.03	6.45
30	5.50	6.07	6.70	9.19	9.90	11.03

Table 6. Results for 12 Molarity



Graph 5. Compressive Strength Variations for different %age of Variation of GGBS (Sun-dried)



Graph 6. Compressive Strength Variations for different %age of Variation of GGBS (Oven-dried)

depends on the amount of total solution in the mix, fly ash content, and GGBS. While mixing for 12M it was difficult because it sets quickly when the solution is poured into the mix and in order to make it fluidy some amount of water is added.

- Increase in the compressive strength of the Geopolymer mortar increase with increase in molarity and compressive strength of the cubes increases up to the replacement of 20% of GGBS for sun curing. The compressive strength of the cubes decreases when %age of replacement increases to 30% for sun curing.
- In the case of oven curing, the strength keeps on increasing from 0% to 30%. For oven curing, maximum compressive strength obtained for 30% replacement is nearly twice of the 20% replacement.
- Compressive strength of the sun curing is more than oven curing up to the 20% replacement of GGBS. For 30% replacement of GGBS, oven curing strength is more than sun curing.

Future Scope

- The work can be continued on masonry prisms and wallets to study the interaction of mortar and masonry unit.
- Studies can be continued to obtain improved workability of the mortar.

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