

## Experimental Study on Strength and Sorptivity Properties of Geopolymer Mortar

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### ABSTRACT:

Geopolymer mortar is a new mortar that does not require the presence of Portland cement as a binder. Instead, the source of materials that are rich in Silicon (Si) and Aluminum (Al) like Fly ash, Granulated Blast Furnace Slag (GGBFS), Silica Fume (SF) are activated by alkaline liquids to produce the binder. This project presents the state-of-the-art information on fly ash-based geopolymer as binder in mortar. The experimental program involves casting of geopolymer mortar cubes and testing the same at different ages for compressive strength and sorptivity. Sorptivity is an indicator of durability of the material. The different parameters considered in the study are, the molarity of alkaline activator and age of curing. The results reveal that the geopolymer mortar develops the strength even in sunlight curing without any conventional curing. Strength increases with an increase in the molarity of Sodium hydroxide. Geopolymer mortar prepared with 12 molar sodium hydroxide is showing less sorptivity.

### Key words:

Cement, Coarse aggregate, Fine aggregate, Flyash, Sodium hydroxide, Stone dust.

### 1. Introduction:

Concrete usage around the world is second only to water. Ordinary Portland cement (OPC) is conventionally used as the primary binder to produce concrete. The environmental issues associated with the production of OPC are well known. The amount of the carbon dioxide released during the manufacture of OPC due to the calcination of limestone and combustion of fossil fuel is in the order of one ton for every ton of OPC produced. In addition, the extent of energy required to produce OPC is only next to steel and aluminum. On the other hand, the abundant availability of fly ash worldwide creates opportunity to utilize

this by-product of burning coal, as a substitute for OPC to manufacture cement products. When used as a partial replacement of OPC, in the presence of water and in ambient temperature, fly ash reacts with the calcium hydroxide during the hydration process of OPC to form the calcium silicate hydrate (C-S-H) gel. The development and application of high volume fly ash concrete, which enabled the replacement of OPC up to 60% by mass is a significant development.

### 2. Experimental Program:

#### Materials Used:

##### Cement:

The cement used was Ordinary Portland cement (53 grade) conforming to IS: 12269-1987 with a specific gravity of 3.15. Initial and final setting times of the cement were 20 min and 265 min, respectively.

##### Fine Aggregate:

The sand used for experimental program was locally procured and conforming to zone II. The sand was first sieved through 4.75 mm sieve to remove any particles greater than 4.75mm. The fine aggregates were tested as per Indian Standard Specifications IS: 383-1970. The bulk density of sand was found out to be 1.6 g/cm<sup>3</sup> and the specific gravity was found to be 2.6.

##### Coarse Aggregate:

The natural broken stone (coarse aggregate) used for the study was of 20mm size maximum. The size of Aggregates bigger than 4.75mm.

##### FLYASH:

Fly ash obtained from ramagundam thermal power station is used in the preparation of geo polymer mortar. Chemical properties of fly ash used are given below.

**Table 1: Chemical composition of fly ash**

Binder	L O I	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	MgO	SO <sub>3</sub>	Na <sub>2</sub> O	Chlorides	CaO
Fly ash	.9	31.3	1.5	61.12	.75	.53	1.35	.06	3.2

### STONE DUST:

Quarry dust (basaltic origin), sourced from local quarry/crusher industry specific gravity 2.65 were used in geopolymer mortar.

### Sodium hydroxide:

Sodium hydroxide, also known as caustic soda with the molecular formula NaOH is a caustic metallic base which is a white solid available in pellets, flakes, granules, and as a 50% saturated solution. Sodium hydroxide flakes were used in the experimental program.

Fig 1.



### WATER:

Water plays a vital role in achieving the strength of concrete. For complete hydration it requires about 3/10th of its weight of water. It is practically proved that minimum water-cement ratio 0.35 is required for conventional concrete. Water participates in chemical reaction with cement and cement paste is formed and binds with coarse aggregate and fine aggregates. If more water is used, segregation and bleeding takes place, so that the concrete becomes weak, but most of the water will absorb by the fibers.

Hence it may avoid bleeding. If water content exceeds permissible limits it may cause bleeding. If less water is used, the required workability is not achieved. Potable water fit for drinking is required to be used in the concrete and it should have pH value ranges between 6 to 9.

### 3. Mix Design:

- Unit weight of Geopolymer mortar = 2150kg/m<sup>3</sup>
- Aggregate to flyash ratio = 2:1
- Mass of Fine Aggregates = 66% of 2150 = 1419 kg/m<sup>3</sup>
- Mass of Fly ash = 2150-1419 = 731 kg/m<sup>3</sup>
- Assume, Alkaline liquid/ Fly ash = 0.45
- Mass of alkaline liquid = 328kg/m<sup>3</sup>
- Assume, sodium silicate/sodium hydroxide = 2.5
- Mass of sodium hydroxide = 328/3.5 = 88.57 kg/m<sup>3</sup>
- For 8 Molar, Sodium hydroxide solid = 26.23% of 88.57 = 23.31 kg/m<sup>3</sup>
- Water = 65.25 kg/m<sup>3</sup>
- Mass of sodium silicate = 328-88.57 = 239.43kg/m<sup>3</sup>
- Mass of sodium silicate gel = 44.1% of 120.4 = 53 kg/m<sup>3</sup>
- Mass of water = 67.4 kg/m<sup>3</sup>
- Super plasticizer = 5% of fly

**Table 2: Proportions for different molarities**

MOLARITY	Na <sub>2</sub> SiO <sub>3</sub> /NaOH	ALKALI LIQUID/FLY ASH	FINE AGGREGATE kg/m <sup>3</sup>	FLY ASH kg/m <sup>3</sup>	ALKALI LIQUID kg/m <sup>3</sup>	Sodium hydroxide solution	NaOH solution kg/m <sup>3</sup> (NaOH+Water)	NaOH Flakes (kg/m <sup>3</sup> )	WATER(kg/m <sup>3</sup> )
6	2.5	0.45	1419	731	310	221.43	88.57	19.18	69.39
8	2.5	0.45	1419	731	310	221.43	88.57	23.23	65.34
10	2.5	0.45	1419	731	310	221.43	88.57	27.78	60.79
12	2.5	0.45	1419	731	310	221.43	88.57	31.96	56.61

Nine cubes have been cast for each molarity and behavior of compressive strength and water absorption has been studied.

#### 4. Mixing, Compaction, Preparation of Specimen and Curing:

The main objective of this investigation is to replace the cement completely in Mortar and to use waste materials like fly ash to prepare Geopolymer mortar in Ambient curing conditions. The objective is achieved by conducting the following tasks. The demoulded specimens were left in sunlight until tested without any special curing regime. For each set of parameter, 6 cubes were cast, three each for determining 7 days, 28 days strengths.

#### 5. Test methods:

Geo-polymer mortar specimens were prepared using the same method as for OPC mortar. Quarry dust of 3 size fractions [passing through 2mm and retained on 1mm, passing through 1mm and retained on 0.5mm and passing through 0.5mm and retained on 75micron IS sieve, in equal proportion] is mixed with the binder component of pre-determined proportion. Then the activator solution of specified fluid binder ratio is added and mixed to get a homogeneous and uniform mix. This mortar is filled into 70.6mm cubes and compacted in a vibrator. Specimens could be de-moulded within about 24 hours of drying in ambient conditions after casting.

Fig 2:



#### Sorptivity:

Sorptivity test was conducted on specimens which were previously waxed for water proofing on all four sides such that only unidirectional uptake from the bottom is possible. A curve of cumulative mass gained per exposed surface area was drawn against square root of time and the slope of the linear portion was considered for determination of sorptivity

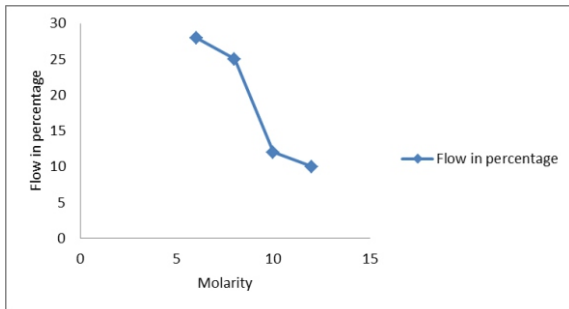
Fig 3:



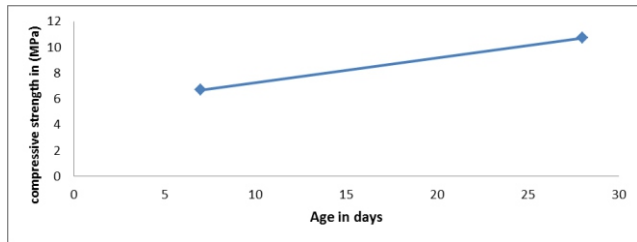
#### 6. Results and Discussions:

**Table 3: Percentage flow for mortar of various molarities**

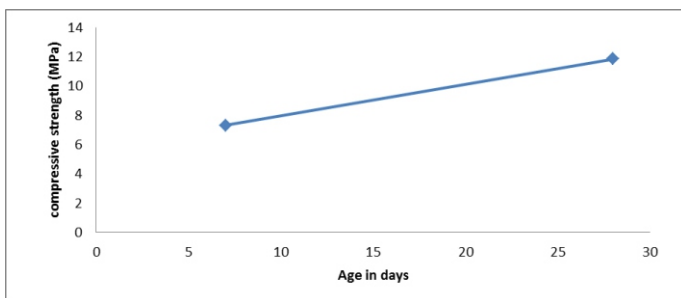
Molarity	Flow in percentage
6	28
8	25
10	12
12	10



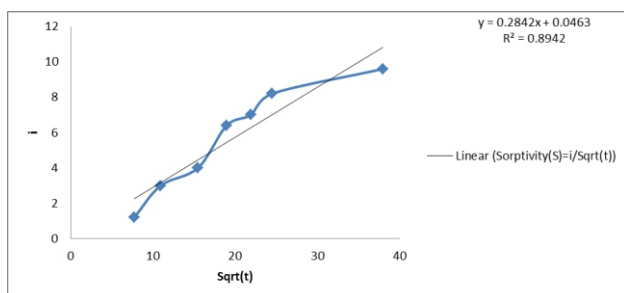
**Fig 4: Variation of Flow for different molarities**



**Fig 5: variation of compressive strength with age for 6 molar cubes**



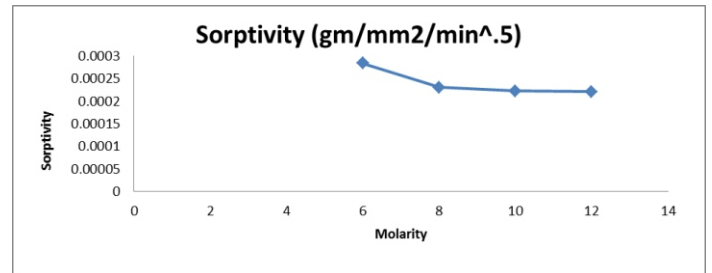
**Fig-6: variation of compressive strength with age for 8 molar cubes**



**Fig 7: Sorptivity for 6 Molarity geopolymer mortar**

**Table 4 -sorptivity for various molarities**

Molarity	Sorptivity (gm/mm <sup>2</sup> /min <sup>-.5</sup> )
6	2.84 x 10 <sup>-4</sup>
8	2.31 x 10 <sup>-4</sup>
10	2.23 x 10 <sup>-4</sup>
12	2.21 x 10 <sup>-4</sup>



**Fig-8: variation of sorptivity for various molarities**

**Table 5: Cost Comparison between Geopolymer Mortar and Ordinary Cement Mortar**

Materials	Rate in RS	Rate for 50 kg bag	Rate for m <sup>3</sup>	Portland cement mortar (rate for m <sup>3</sup> )	Geopolymer mortar 12 molarity (rate for m <sup>3</sup> )	Geopolymer mortar 10 molarity (rate for m <sup>3</sup> )	Geopolymer mortar 8 molarity (rate for m <sup>3</sup> )	Geopolymer mortar 6 molarity (rate for m <sup>3</sup> )	Total
Fly ash	.2/kg	300	150	0	150	150	150	150	
Cement	45/kg	300	0	3900	0	0	0	0	
Sodium Hydroxide	19/kg	45	0	0	1240	1120	920	760	
Na <sub>2</sub> SiO <sub>3</sub>		19	0	0	1800	1860	1860	1860	
<b>Total</b>				<b>3900</b>	<b>3200</b>	<b>3130</b>	<b>2930</b>	<b>2770</b>	

## 7. Conclusions:

It is observed that geopolymer mortar in ambient curing conditions can obtain good strength in 28 days. Compressive strength increases around 40% to 50% from 7 days to 28 days. Higher concentration (in terms of molarity) of sodium hydroxide solution results in higher compressive strength of fly ash-based geopolymer mortar. Workability of geopolymer mortar decreases with the increase in concentration of sodium hydroxide. Lesser sorptivity has been recorded for the cubes prepared with 12 molar sodium hydroxide when compared to the cubes prepared with 10 and 8 molar sodium hydroxide. 18% to 30% economy is achieved in geopolymer mortar when compared to cement mortar.

## 8. Future Study:

We used fly ash obtained from bituminous coal which contains 10% CaO. Fly ash from sub-bituminous coal shall also be determined. Rice husk ash and GGBS shall be tried instead of fly ash and properties shall be determined. Investigation should be made on structural members like beams, columns, and slabs using geopolymer as binder.

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