APPLICATIONS OF GEOPOLYMER SOLUTION IN BUILDING MATERIALS

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Abstract: *The method used to manufacture the ceramic tiles involves the burning process which requires high temperatures and hence high amount of heat energy and cement is used as binding material, hence the present study consist of developing low cost energy saving methods without using cement for manufacturing geopolymer tile by using geopolymerization as a new ceramic processing technique. Geopolymer tiles are developed using industrial waste such as flyash and geopolymer without using cement.*

Keywords: *Geopolymer, Geopolymer solution,Geopolymer concrete, Fly ash, Geopolymer Tile.*

1) Introduction to Geopolymer

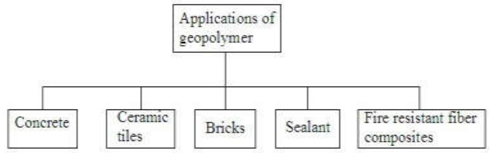
In 1978, Davidovits proposed that an alkaline liquid could be used to react with the silicon (Si) and the aluminium (Al) in a source material of geological origin or in byproduct materials such as fly ash and rice husk ash to produce binders. Because the chemical reaction that takes place in this case is a polymerisation process, Davidovits coined the term 'Geopolymer' to represent these binders. Geopolymers are members of the family of inorganic polymers. The chemical composition of the geopolymer material is similar to natural zeolitic materials, but the microstructure is amorphous instead of crystalline.

Geopolymerisation : The polymerisation process involves a substantially fast chemical reaction under alkaline condition on Si-Al minerals, that results in a three dimensional polymeric chain and ring structure consisting of Si-O-Al-O bonds.
The chemical reaction may comprise the following steps:

- Dissolution of Si and Al atoms from the source material (fly ash or GGBS) through the action of hydroxide ions.
- Transportation or orientation or condensation of precursor ions into monomers.
- Setting or polycondensation / polymerization of monomers into polymeric structures.

what are the constituents of geopolymer…???
Solution: Sodium hydroxide (NaOH)
Sodium silicate (Na_2SiO_3)
Water (H_2O)
Binder : Fly ash or GGBS

2) Applications of Geopolymer:



3) METHODOLOGY:

Geopolymer tiles:

- The present study involves the manufacturing of geopolymer tiles using geopolymer splution.
- Geopolymer tiles of size 200 X 200 X 10 mm are cast.
- Flexural strength, water absorption, abrasion resistance of the tiles will be tested.

Preparation of mixture

Freshly prepared tile using GP

Ceramic tile

5) EXPERIMENTAL PROGRAM:

A) MANUFACTURING OF GEOPOLYMER TILES:

The manufacturing of geopolymer tiles (G-tiles) are explained in the following Stages.

a) MATERIALS USED:

The materials used in the manufacturing of geopolymer tiles are listed below.

1. Industrial waste (fly ash)
2. Sodium hydroxide (NaOH)
3. Sodium silicate (Na_2SiO_3)

b) MANUFACTURING PROCESS :

First, geopolymer solution was prepared by using sodium silicate and sodium hydroxide in. This solution was kept at room temperature for 24hours.After 24 hours it was mixed with fly ash at some ratio to get a thyrotrophic paste in a mixer**.** The mixture was self-compacting and needed light vibration. This paste was transferred to the mould and it was kept on vibrator for few seconds. The freshly prepared tile was kept at 60ºc for 24 hours and then kept at room temperature for 7 days. These geopolymer tiles were tested for flexural strength and water absorption after 7 days of manufacturing.

c) Trials: We have done total 15 trials. Out of which the last 3 trials are discussed below.

Trial 13 :

Assume, Density = 1800 kg/m^3

Volume of tile = 0.2 x 0.2 x 0.01 m = $4x10^{-4}$ m^3

Weight of one tile = $4x10^{-4}$ x1800 = 720gm

Taking, (solution/Binder) = 0.25

Weight of **geopolymer solution** = 144 gm

Weight of **Fly ash** or GGBS = 576 gm

Geopolymer Solution:

Taking, (sodium silicate/sodium hydroxide) = 2.5 & Molarity of NaOH = 8M

NaoH Solution = (144/3.5) = 41.14 gm

Na_2Sio_3 solution = (144 – 41.14) = 102.86 gm

NaOH Pellets = (262 x41.14/1000) = 10.8 gm

Water = 30.34 gm

Extra water = 85 gm

Trial 13:

Taking (solution/Binder) = 0.25 and 8M NaOH solution.

Materials	Weight (gm)
Binder (fly ash	576
Geopolymer solution:	
a) Sodium silicate	102.86
b) Sodium hydroxide pellets	10.8
c) Water	30.34
3. Extra water	85

Trial 14:

Taking,(solution/Binder) = 0.3and 8M NaOH solution.

Materials	Weight (gm)
Binder (fly ash	553.8
Geopolymer solution:	
a) Sodium silicate	118.68
b) Sodium hydroxide pellets	12.43
c) Water	35.04
3. Extra water	65

Trial 15:

Taking(solution/Binder) = 0.35 and 10M NaOH solution.

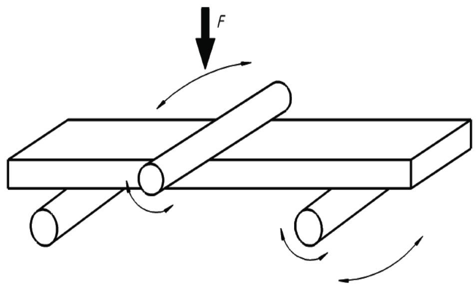
Materials	Weight (gm)
Binder (fly ash	533.3
Geopolymer solution:	
a) Sodium silicate	133.33
b) Sodium hydroxide pellets	13.97
c) Water	39.31
3. Extra water	30

Geo-polymer Tile Preparations

6) RESULTS AND DISCUSSION

Tests on Geopolymer Tiles (IS 13630:2006):-

1. Modulus of rupture (δ):



Flexural testing of tile

$$\delta = \frac{3FL}{2bh^2}$$

where,
F = load required to break the tiles ,in N.
L = Span of the support rods
b = width of the tile, in mm.
h = Thickness of the specimen along broken edge.

Table 1: Values of Modulus of rupture of tiles.

Trials	Molarity (M)	Solution/Binder	Breaking Load(N)	Modulus of rupture (δ) (N/mm^2)	Requirement as per IS 13754:1993 (N/mm^2)
1	8	0.25	680	9.18	Min 15
2	8	0.30	860	11.62	
3	8	0.35	1074	14.50	
4	**10**	**0.35**	**1190**	**16.30**	

The tiles manufactured using different molarities of NaOH solution and solution-to-binder ratio are tested in testing machine and the values of breaking load are noted as shown in table 1. Then the modulus of rupture is calculated using the formula. It is found that for molarity 10M and solution-to-binder ratio 0.35 the modulus rupture of tile is 16.3 Mpa which is more than the required as per IS 13754:1993.

Flexure strength testing machine

Geopolymer tile

Tile after flexure test.

2) **Water absorption test:** The percentage absorption of water is calculated using the following formula:

$$\text{Water absorption (\%)} = \frac{m2-m1}{m1}$$

Where, m1 = dry weight of tile.
m2 = wet weight of tile.

Table 2: Values of Water absorption of tiles.

Sl/No	**Molarity (M)**	**Solution/Binder**	**Water absorption (%)**	**Requirement as per IS 13754:1993**
1)	8	0.25	11.07	6-10
2)	8	0.30	8.77	
3)	8	0.35	8.50	
4)	10	0.35	7.23	

The values of water absorption of tiles are shown in table 2.The dry weight of tiles are noted down and are kept in a container completely filled with water for 24 hours. And after 24 hours tile is taken out and weighed. Then the water absorption is calculated using the above formula. It is found that for molarity 10M and solution-to-binder ratio 0.35 the water absorption of tile is 7.23% which is in the range of 6-10% as specified in **IS 13754:1993.**

3) ABRASION TEST:

Calculation of abrasive wear after 22 cycles as the mean loss in specimen volume ΔV, from the equation:

$$\Delta V = \frac{\Delta m}{\rho R}$$

Where,

ΔV = the loss in volume after 22 cycles in cubic millimeters.

Δm = the loss in mass after 22 cycles in grams.

ρR = the density of the specimen.

Table 3: Values of abrasion test of tiles.

Trials	Molarity	Solution/Binder	Loss in mass(gms)	Loss in volume (mm^3)	Requirement as per IS 13754:1993 (mm^3)
1	8	0.25	1.05	583.7	Max 540
2	8	0.30	0.94	522.2	
3	8	0.35	0.87	484.3	
4	10	0.35	0.83	461.1	

The values of abrasion resistance of tiles are shown in table 3.The loss in mass of specimens is noted down after the experiment. Then the loss in volume is calculated using the above formula. Abrasion resistance is expressed in terms of loss in volume. It is found that for molarity 10M and solution-to-binder ratio 0.35 the abrasion resistance of tile is 462 mm^3 which is less than 540 mm^3 as specified in **IS 13754:1993.**

<u>RATE ANALYSIS : (For 100 sq.ft)</u>

Table 4: Details of Rate Analysis.

Materials:	Quantity (kg)	Rate (Rs.)	Cost (Rs.)
Fly ash	128.6	2	257.2
Na_2SiO_3	**27.7**	**35**	**969.5**
NaOH	2.9	50	145.0
		Material cost	1371.7
		Labor cost	150 Rs
		Finishing coat	150 Rs
		Electric and other charges	120 Rs

	1791.7 Rs
Tax (14.5%)	260 Rs
Production cost	2051.7 Rs
Profit of manufacturer (30%)	616 Rs
	2668 Rs
Dealer's Profit	500 Rs
Total cost	**3168 Rs**
Therefore cost per sq.ft = 31.68 Rs	

7) CONCLUSIONS :

1. Manufacturing process of geopolymer tiles is simple and easy compared to conventional tiles.
2. Geopolymer tiles are cheaper than ceramic tiles and pavers.
3. Cost of geopolymer tiles mainly depends on sodium silicate solution.
4. Cost of geopolymer tiles can be further reduced by increasing the molarity of NaOH solution instead of increasing (sol/binder).
5. Automatic surface finish is obtained during vibration.
6. Very sensitive to changes of chemical composition of Secondary raw materials and application in fields are restricted by the performance.
7. Extra water added to mixture is important parameter which governs the surface finish.

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