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Investigating the Possibility of Using Clay and Fly Ash in the Production of Geopolymer Mortar

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Abstract. The concept polymer concrete has numerous advantages over the convention concrete similarly in mortar also which uses reactive silica presented in the pozzolanic materials which is activated using alkaline materials. This paper focused on the Geopolymer mortar with fly ash and clay as raw materials and M-Sand for fine aggregate instead of river sand. Different combinations of mixtures were prepared and compared with ordinary cement mortar. The objective of this research is to identify the properties of different combinations of geopolymer mortars with conventional cement mortar, in which the fine aggregate sourced from riverbeds is replaced by Fine aggregate manufactured using Crushing stones and testing it for compressive strength, water absorption, residual alkalinity, and acid resistance. Fly ash- clay based geopolymer shows good acid resistance and shows less reduction in weight and compressive strength than ordinary cement mortar. Permeability of geopolymer mortar is less that of ordinary cement mortar. Alkalinity of geopolymer mortar is 4-20 % higher than that of ordinary cement mortar. Fly ash- clay based geopolymer has excellent compressive strength (75.7% for red clay and 52.6% for fire clay) than the conventional cement concrete and is suitable for structural applications.

Introduction

The industry that uses maximum number of natural resources is concrete industry. The carbon dioxide share of construction industry is about 7% and Class C Fly Ash utilization in Geo polymer concrete indirectly reduces the greenhouse effect [1]. Geopolymer concrete using pozzolanic materials and recycled aggregate have more advantages than other [2]. The self-cementing property of Ground Granulated Blast Furnace Slag will require less Calcium activator than the other type of pozzolanic materials [3]. Ordinary Portland Cement (OPC) has long been the dominant binder in concrete production. The environmental issues associated with FOS pollutants are well known.[4]. The amount of carbon dioxide released during the production of OPC due to limestone calcination and fossil gas burning is on the order of one tenth of a tonne of OPC produced[5]. Inorganic materials abundantsilicon (Si) and aluminum (Al) that change with alkaline activators to make cementitious geopolymers were first described by "Davidovits" as inorganic materials rich in silicon (Si) and aluminium (Al). Glassy silicates composed of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium or potassium silicate are the most common alkali activators used in geopolymers, while sodium hydroxide and sodium silicate are the most common due to their cost and availability.[6–8].Geopolymers are chemically like zeolites but has an amorphous microstructure. They are formed by copolymerization of individual particles of alumina and silicate by dissolving a starting material containing silicon and aluminum at a high pH of in the presence of a soluble alkali metal silicate.[9–11]. Geopolymers are well known for their exceptional mechanical properties, resistance to outbreak of fire, and acid defiance[12]. These things make geopolymers a potential construction material. In its place of OPC or other hydraulic adhesive cement paste, a low-calcium (ASTM Class F) fly ash-clay based geopolymer is used as the binder in this work to produce concrete[13, 14]. Without the presence of admixtures, the fly ash-clay based completely geopolymer paste binds the loose coarse mixture, satisfactory mixture, and various unreacted substances together to form the geopolymer concrete. Geopolymer concrete is created using conventional concrete technology methods.

Experimental procedure

The objective of this research is to experimentally observe the natural Clay and fly ash primarily based geopolymer concrete for various combos of binder and fine aggregate with exceptional proportions of alkali activator to binder ratios.

Materials:

Fly ash

M. Sand

Clay

Alkaline liquids

Fig 1: *Materials for making geopolymer mixtures*

Fly ash

Fly ash was acquired from Mettur thermal power plant. Fly ash is a thermal industrial by-product, generated in the stage of combustion of coal in the power plants. Standard consistency of the fly ash sample is 29 %.

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M-Sand (manufactured Sand)

Manufactured sand conformed to zone II with the specific gravity of 2.65 is used as replacement for the fine aggregate that is sourced from Riverbeds. M-Sand is used because of the scarcity in river sand.

Clay

The studied soil sample is silty clay collected from nearby Karunya University campus which act as the binder material with Fly ash from thermal power plants. The soil contains 2%, 46% and 52% of sand, silt and clay, respectively. Its liquid limit is approximately 52 %.

Alkaline liquids

As activators, the alkaline liquid used in Geo polymerization is a mixture of sodium hydroxide and sodium silicate. A large quantity of sodium silicate solution was purchased in bulk from a local supplier. Sodium hydroxide flakes or pellets with 97-98 percent purity were also purchased in bulk from a local supplier.

Mix proportions

The manufacture of geopolymer mortar specimens was carried out using the usual concrete technology methods. The mix proportions for geopolymer mortar for different combinations are shown in table below.

Table 1: *Mix proportions for 1:1 mortar (8M 1:1 alkali activator ratios)*

Mix ID	Cement Kg/m³	Fly ash Kg/m³	Clay Kg/m³	Fine aggregate			Sodium Silicate	Sodium Hydroxide	
				River Sand	M-Sand	Clay Kg/m³		$\frac{Kg}{m^3}$	$\frac{mol}{l}$
CM1	1.166	-	-	1.166	-	-	-	-	-
GP1	-	1.166		-	1.166	-	0.19	0.19	8M
GP2	-	0.583	0.583	-	1.166	-	0.23	0.23	8M
GP3	-	-	1.166	-	1.166	-	0.26	0.26	8M
GP4	-	1.166	-	-	0.583	0.583	0.22	0.22	8M
GP5	-	1.166	-	-		1.166	0.26	0.26	8M

Geopolymer mortar combination details:
GP 1----- [100 % fly ash + 100 % M-Sand
GP 2----- [(50 % fly ash + 50 % Clay) + 100 % M-Sand
GP 3----- 100 % Clay + 100 % M-Sand
GP 4----- [100 % Fly ash + (50 % Clay+ 50% M-Sand)]
GP 5----- [100 % fly ash + 100 % Clay]

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Mixing, casting, and curing:
The binders i.e., fly ash and clay and the aggregate were first mixed. The alkaline liquid prepared before one day before the casting and then added to the dry materials that is Natural Clay and Fly ash and thoroughly mixed using mixer machine.

The cube size of 70 x 70 x 70 mm and cylinder of 50 mm diameter and 100 mm height were casted for mortars. The specimens were demolded without disturbing and cured at room temperature for 1 day and the Geo polymer concrete specimens were kept in oven curing at 80°C for 24 hours.

Findings and analysis

Compressive strength

Table 2: *Compression test of mortar (8 M, 1:1 Binder to Fine aggregate ratio, 1:1 Alkali Activator ratio) by using cube of size 70x70x70 mm*

Sl. No	Mix ID	Average Ultimate Load(kN)		Compressive Strength(N/mm2)	
		3	7	3	7
1	CM1	-	106		21.63
2	GP1	205.8	215.6	42	44
3	GP2 with red clay	166.6	186.2	34	38
4	GP2 with fire clay	142.1	161.7	29	33

Table 3: *Compression test (8 M, 1:1 Binder to Fine aggregate ratio, 1:1 Alkali Activator ratio) by using cylinder of size 50 mm diameter and 100 mm height*

Sl.No	Mix ID	Average Ultimate Load(kN)			Compressive Strength(N/mm2)		
		3	7	14	3	7	14
1	CM1	-	40	73		20.38	37.20
2	GP1	76.97	84.72		39.2	43.15	
3	GP2	72.66	80.15		37.01	40.82	
4	GP3	68.96	76.67		35.12	39.05	
5	GP4	76.38	81.33		38.90	41.42	
6	GP5	74.85	78.97		38.12	40.22	

It is examined from the above tables, that the 7 days compressive strength of natural Clay and Geopolymer Mortar made with Flyash (GP2) is furthermore than ordinary Portland cement mortar by 75.7 % for red clay and 52.6 % for fire clay. Hence, it is presumed that compressive strength of geopolymer mortar is better than the OPC based concrete mixtures. It can also be observed that 3rd day strength of geopolymer concrete specimenis lesser than that of ordinary Portland cement specimen at the age of 28 days.

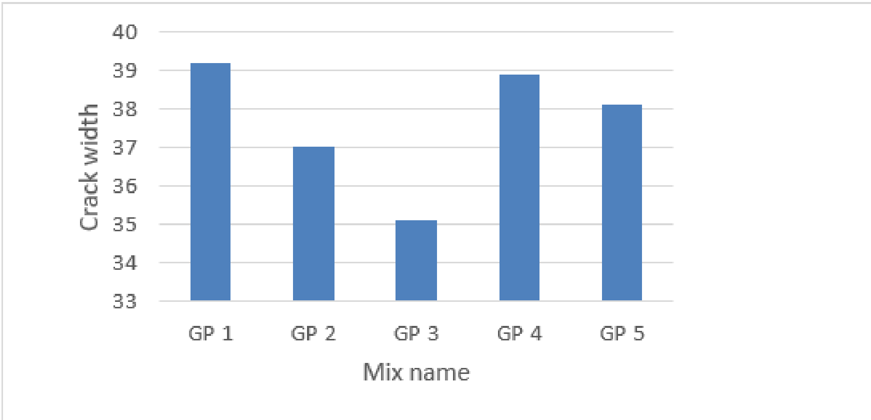

Fig 2: *Crack pattern*

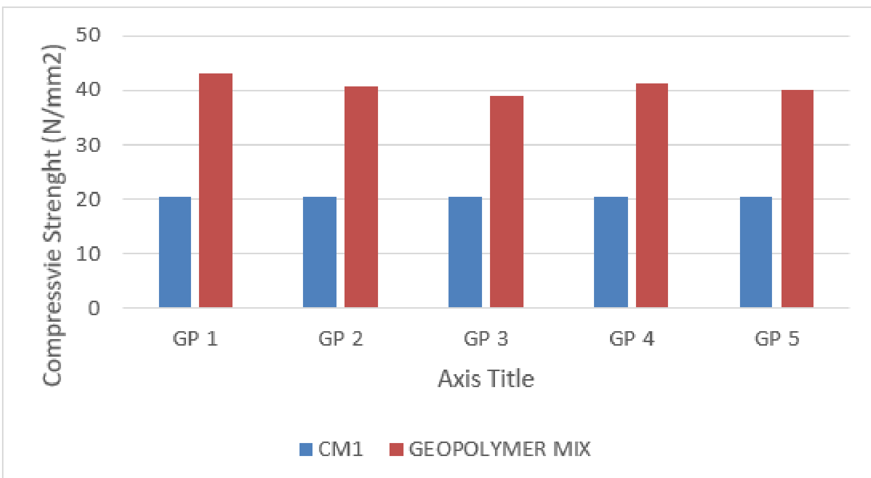

Fig 3: *3rd day compressive strength*

Fig 3 and 4 reveals the compressive strength loss of ordinary cement mortar and geopolymer mortar. It can be seen that the compressive strength of geopolymer mortar is higher than that of ordinary cement mortar.

Acid resistance test

Table 4: *weight reduction (5 % HCl)*

Mix proportion	Average reduction in weight (%)	
	7 days	**14 days**
CM 1	0.324	0.354
GP 1	0.112	0.121
GP 2	0.188	0.196
GP 3	0.249	0.260
GP 4	0.164	0.170
GP 5	0.152	0.161

Table 5: *Strength reduction (5 %HCl)*

Mix proportion	Average loss of compressive strength (%)	
	7 days	**14 days**
CM 1	68	70
GP 1	38	42.8
GP 2	41.5	46.72
GP 3	43	48.11
GP 4	41	45.9
GP 5	39.5	44.2

Table 5 and 6 shows the weight and strength reductions of ordinary cement mortar and geopolymer mortars in the presence of 5% of hydrochloric acid at 7 and 14 days. It can be seen that weight loss is lesser in the case of geopolymer mortar by 30- 70% by ordinary cement mortar at 7th day and 34-74% at 14th day. That is the performance of geopolymer mortar against acid is better than that of conventional cement mortar. In addition, the strength reduction ofgeopolymer mortar was reduced by 58-78% on the 7th day and 48-63% on the 14th daycomparedto the conventional cement mortar.

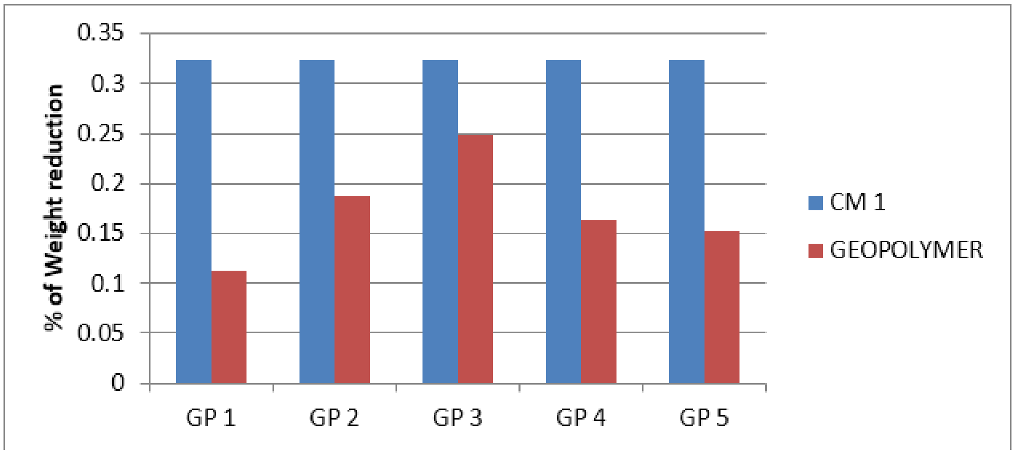

Fig 5: *Average reduction in percentage weight after 7 days*

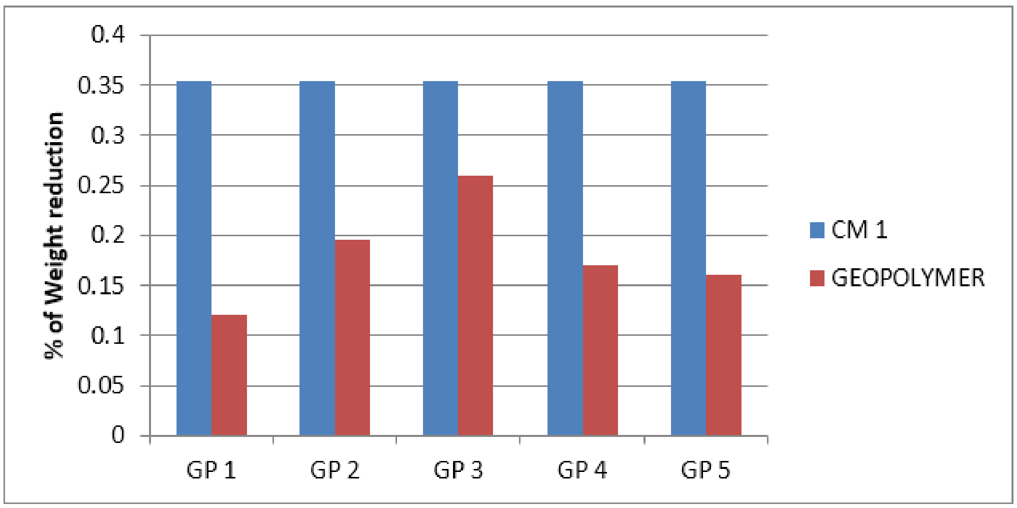

Fig 6:*Average reduction in percentage weight after 14 days*

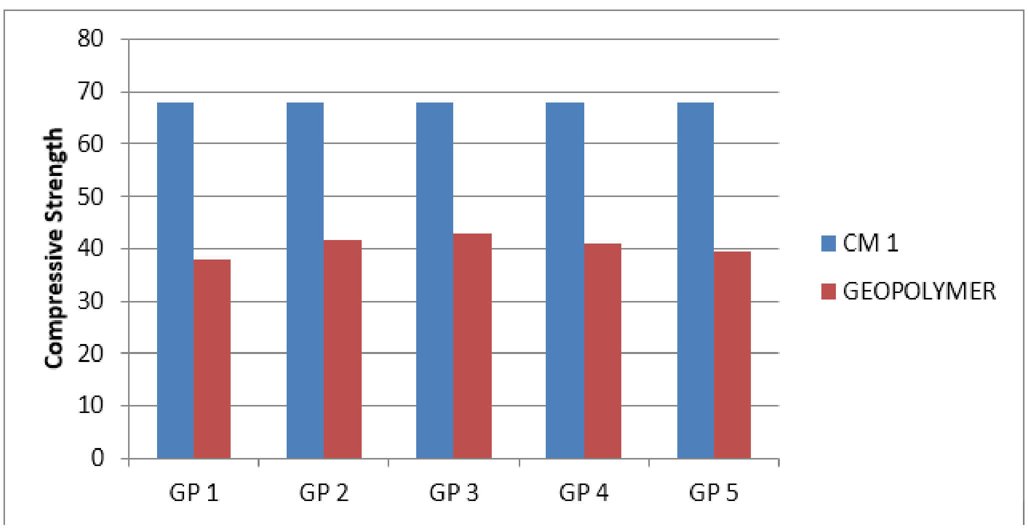

Fig 7: *Average compressive strength loss after 7 days*

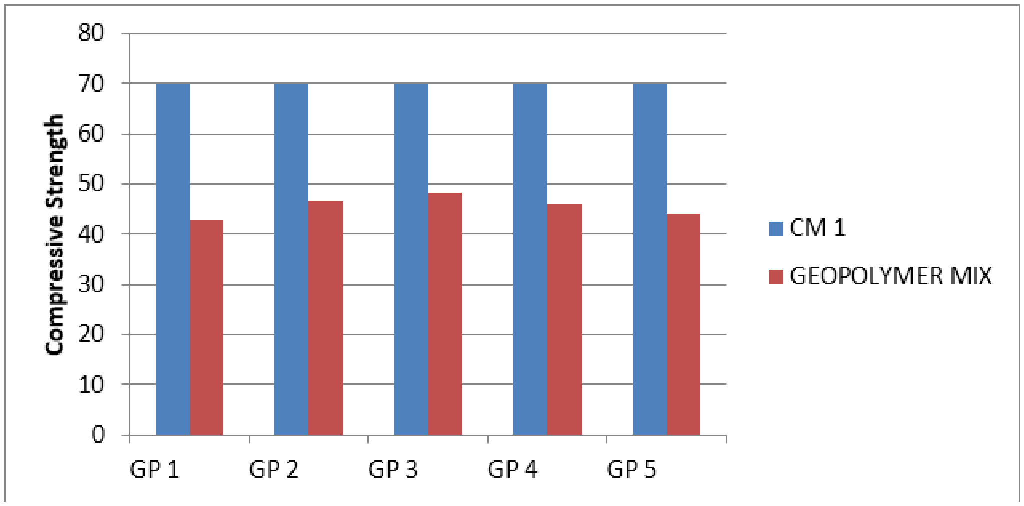

Fig 8: *Average compressive strength loss after 14 days*

Water absorption

Table 6: *Saturated water absorption*

Mix id	Weight Of saturated specimen(g)	Weight of Oven dried specimen (g)		Saturated water absorption @ 7 days (%)	Saturated water absorption @ 14 days (%)
		7 days	14 days		
CM1	458	443	444.57	3.31	3.02
GP1	515	504.85	505.15	2.01	1.95
GP2	557	544.96	545.86	2.21	2.04
GP3	568	554.42	556.15	2.45	2.13
GP4	502	490.38	491.29	2.37	2.18
GP5	535	520.38	521.85	2.81	2.52

The table shows that the saturated absorption rate of geopolymer slurries is lower than that of conventional cement slurries. The absorption rate of geopolymer mortar decreases by 15 - 40% after 7 days and 17 - 35% after 14 days. This means that geopolymer slurries are less permeable than conventional cement slurries.

Residual alkalinity

Table 8 shows the residual alkalinity. Due to the alkali activated binder, the alkalinity of geopolymer slurry is higher than that of conventional cement slurry. The alkalinity of geopolymer slurries is 420% higher than that of conventional cement slurries.

Table 7: *Residual alkalinity*

Mix ID	pH value in 14 days
CM1	10.08
GP1	12.12
GP2	11.52
GP3	10.58
GP4	11.87
GP5	10.98

Conclusion

Natural Clay and Fly Ash based geopolymer has exceptional compressive strength (75.7 % for red clay and 52.6 % for fire clay) than the conventional cement concrete and is suitable for structural applications. Natural Clay and Fly Ashmixed geopolymer shows good acid resistance and shows minimum weight reduction in compressive strength and weight than ordinary cement mortar. The permeability of geopolymer slurries is lower than that of conventional cement slurries. The alkalinity of geopolymer slurries is 4-20% higher than that of conventional cement slurries. The properties of geopolymer slurries are no worse than those of conventional cement slurries. Low-calcium, natural clay-based pozzolan ash geopolymer concrete offers a number of economic advantages over Portland cement mortar as fly ash and clay costs are lower than that of Portland cement.

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