International Journal of Research in Engineering, Science and Management
Volume 4, Issue 4, April 2021
https://www.ijresm.com | ISSN (Online): 2581-5792

Parametric Study On Geo Polymer Concrete in Sustainable Development

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***Abstract*: In present day scenario, global warming is its peak due to emission of greenhouse gasses. In the concrete industry, cement plays a vital role in production of CO_2. Due to increased cement production, cement manufacturing industries have become the largest contributors of CO_2 emission, which severely affects the environment. Hence it is necessary to find an alternative and sustainable replacement for cement in concrete. Geopolymer is one of the replacement for cement in concrete. So, we have taken Fly ash, Metakaolin, and Silica fume. We also used sodium silicate and sodium hydroxide solution as alkaline activator. It was used to make cube and morter cube. In which the cube and morter cubes are tested. In this paper we will discuss about compressive strength of the concrete. In which we will discuss about the different tests we conducted and discuss about workability of concrete.**

***Keywords*: Fly ash, Metakaolin, Pozzolana Portland Cement, Silica fume.**

1. Introduction

In recent times as global warming is rising steadily due to raise in production of greenhouse gases. In the process of production of cement carbon-dioxide is produced. As the production of cement is huge the production of carbon-dioxide is also huge. So we have replaced cement with geo polymers like fly ash, metakaolin, silicafume with the help of alkaline activators. The alkaline activator we have used is sodium silicate and sodium hydroxide.

2. Materials and Method

A. Materials

1) Metakaolin

Metakaolin is a highly reactive pozzolana formed by the calcinations of kaolinite. Metakaolin is a dehydroxylated form of the clay mineral kaolinite. Metakaolin reacts very rapidly with the calcium hydroxide produced during hydration converting it to a variety of insoluble, stable cementitious products. In India metakaolin can be produced in large quantities, as it is a processed product of kaolin mineral which has wide spread proven reserves available in the country. MK as it has been found to possess both pozzolanic and microfiller characteristics. At present the market price of metakaolin in the country is about 3–4 times that of cement.

2) Silica fume

Silica fume is a byproduct of producing silicon metal or ferrosilicon alloys. One of the most beneficial uses for silica fume is in concrete. Because of its chemical and physical properties, it is a very reactive pozzolan. Concrete containing silica fume can have very high strength and can be very durable. Silica fume is available from suppliers of concrete admixtures and, when specified, is simply added during concrete production. Placing, finishing, and curing silica-fume concrete require special attention on the part of the concrete contractor. Silica fume concrete has a much finer paste phase and the bond to substrates, old concrete, reinforcement, fibres and aggregates will be improved. In terms of consumption, the market is estimated to reach 1,622.58 thousand tons by 2020, at a CAGR of 3.12% between 2015 and 2020. The increasing demand in the building construction and marine structure construction applications will be the key factor influencing the growth of the global silica fume market. The building construction sector contributed a share of 41.50% to the market in 2014.

3) Fly ash

Fly ash is the residue that results from the combustion of pulverized coal. It is transported from the combustion chamber by exhaust gases. Fly ash is produced by coal-fired electric and steam generating plants. Typically, coal is pulverized and blown with air into the boiler's combustion chamber where it immediately ignites, generating heat and producing a molten mineral residue. Currently, over 22 million tons of fly ash are used annually in a variety of engineering applications. Typical highway engineering applications include: portland cement concrete, soil and road base stabilization, flowable fills, grouts, structural fill and asphalt filler.

3. Objectives

- To evaluate the utility of geopolymer concrete in replacement of cement.
- To study the compressive strength of geopolymer concrete.
- To derive the proportion of geopolymer. Which is partially replaced in concrete.

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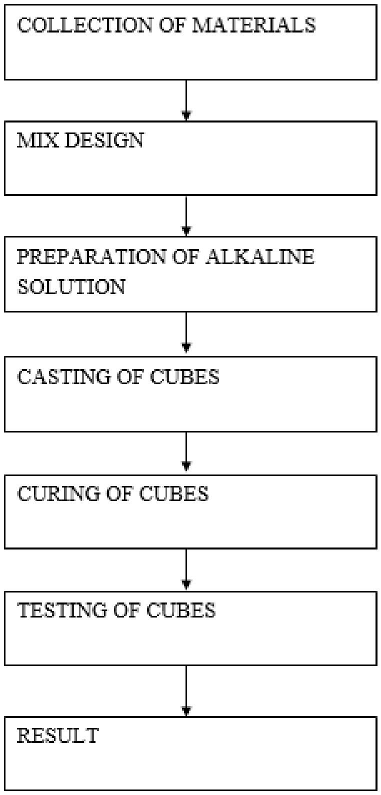

Fig. 1. Methodology

4. Working Procedure

The experimental investigation is to study the properties of metakaolin, fly ash and silica fume in increase in compressive strength of concrete by replacing cement. Strength characteristics of concrete with replacement of fly ash, metakaolin and silica fume are done in three ways.

1. The cement is fully replaced with geopolymer (Fly ash and Metakaolin). The replacement is done in two proportions they are Fa=60% M=40% and Fa=50% M=50%. Cubes are made and curing in two ways which is oven curing and ambient curing. The results are discussed below. Oven curing is done at 80 ºc.
2. The cement is fully replaced with geopolymer (Fly ash, Metakaolin & Silica fume). The replacement is done in three proportions they are Fa=60% M=20% S=20%, Fa=50% M=30% S=20% & Fa=40% M=30% S=30%. Cubes are made and curing is done in two ways which is oven curing and ambient curing. The results are discussed below. Oven curing is done at 80 ºc.
3. The cement is partially replaced with geopolymer (Metakaolin & Silica fume). The partial replacement is done with PPC cement (Pozzolana Portland Cement). The partial replacement is done in three proportions they are PPC 60% + Metakaoline 20% + silica, PPC 50% + Metakaoline 20 % + silica fumes 30% & PPC 40% + Metakaoline 20% + silica fumes 40%. Cubes are made and curing is done in two ways which is oven curing and ambient curing. The results are discussed below. Oven curing is done at 80 ºc.

5. Tests Conducted

1. Sieve analysis
2. Specific gravity
3. Compressive strength

A. Sieve Analysis

A sieve analysis is used to assess the particle size distribution of a granular material by allowing the material to pass through a series of sieves of progressively smaller mesh size and weighing the amount of material that is stopped by each sieve as a fraction of the whole mass.

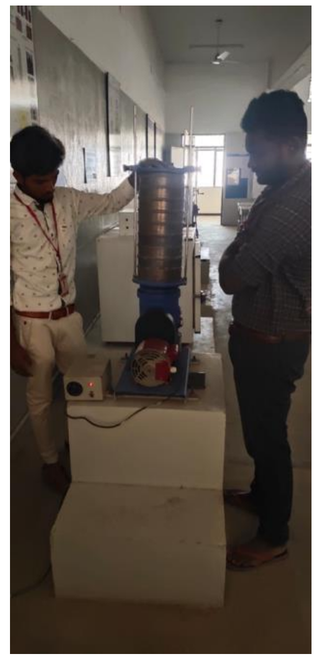

Fig. 2. Sieve analysis

Table 1
Result of sieve analysis

SI No.	Sieve opening size (mm)	Weight of fine aggregate retained (g)	Percentage retained %	Cumulative percentage retained %
1	4.75	0	0	**0**
2	2.36	60	6	**6**
3	1.18	220	22	**28**
4	0.6	150	15	**43**
5	0.425	160	16	**59**
6	0.3	130	13	**72**
7	0.15	210	21	**93**
8	0.075	50	5	**98**
9	**Pan**	**20**	**2**	**100**

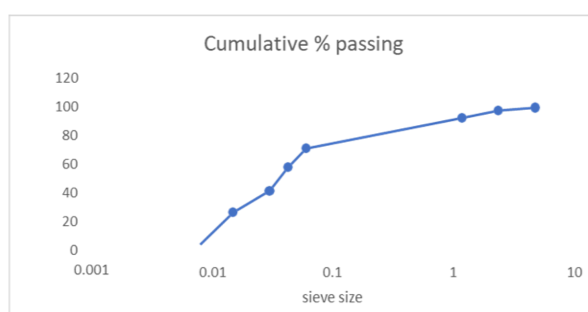

Fig. 3. Graphical result of Sieve analysis

Table 2
Result of specific gravity test

Weight of pyconometer (W1) kg	Weight of Pyconometer+Weight of M-sand (W2) kg	Weight of pyconometer +M –sand + water (W3) kg	Weight of pyconometer +water (W4) kg	Specific gravity G
0.628	0.83	1.656	1.53	2.525

B. Specific Gravity Test

The Specific Gravity is computed as the ratio of the weight in air of a given volume of soil particles at a stated temperature to the weight in air of an equal volume of distilled water at the same temperature. The procedure that is followed towards that goal is the following:

1. Weigh the empty and clean volumetric flask (W_1).
2. Fill the flask with distilled water up to the graduation mark.
3. Clean and dry the inside (above the water level) and the outer part of the flask and weigh it (W_4).
4. Empty and dry the Flask.
5. Weigh around 50 grams of soil material.
6. Use the funnel to carefully place the soil into the flask and weigh it (W_2).
7. Fill around 2/3 of the flask with distilled water.
8. Clean and dry the flask and add distilled water up to the mark.
9. Weigh the flask (W_3)

Fig. 4. Specific gravity test

Specific gravity of m-sand = 2.525

C. Compressive Strength

Fig. 5. Compressive strength

Compression strength is the capacity of a material or structure to withstand loads tending to reduce size, as opposed to which withstands loads tending to elongate. compressive strength is one of the most important engineering properties of concrete. It is a standard industrial practice that the concrete is classified based on grades. This grade is nothing but the Compressive Strength of the concrete cube or cylinder. Cube or Cylinder samples are usually tested under a compression testing machine to obtain the compressive strength of concrete.

6. Test Results for Compressive Test

Mix design = M20
Fa= Fly ash
M = Metakaolin
S = Silica fume

Table 3
Compressive test on cube for 7 days' oven curing

Control mix	Compressive strength in N/mm^2 7 days oven curing	
	Various % of geo polymer	
	Fa=60% M=40%	Fa=50% M=50%
M20	4	6

Table 4
Compressive test on cube for 14 days' oven curing

Control mix	Compressive strength in N/mm^2 14 days oven curing	
	Various % of geo polymer	
	Fa=60% M=40%	Fa=50% M=50%
M20	8	10

Table 5
Compressive test on cube for 28 days' oven curing

Control mix	Compressive strength in N/mm^2 28 days oven curing	
	Various % of geo polymer	
	Fa=60% M=40%	Fa=50% M=50%
M20	13	15

Table 6
Compressive test on cube for 7 days ambient curing

Control mix	Compressive strength in N/mm^2 7 days ambient curing	
	Various % of geo polymer	
	Fa=60% M=40%	Fa=50% M=50%
M20	2.3	4

Table 7
Compressive test on cube for 14 days ambient curing

Control mix	Compressive strength in N/mm^2 14 days ambient curing	
	Various % of geo polymer	
	Fa=60% M=40%	Fa=50% M=50%
M20	6.2	8.4

Table 8
Compressive test on cube for 28 days ambient curing

Control mix	Compressive strength in N/mm^2 28 days ambient curing	
	Various % of geo polymer	
	Fa=60% M=40%	Fa=50% M=50%
M20	12.4	14.3

Table 9
Compressive test on cube for 7 days' oven curing

Control mix	Compressive strength in N/mm^2 7 days oven curing		
	Various % of geo polymer		
	Fa=60% M=20% S=20%	Fa=50% M=30% S=20%	Fa=40% M=30% S=30%
M20	5.2	5.4	8

Table 10
Compressive test on cube for 14 days' oven curing

Control mix	Compressive strength in N/mm^2 14 days oven curing		
	Various % of geo polymer		
	Fa=60% M=20% S=20%	Fa=50% M=30% S=20%	Fa=40% M=30% S=30%
M20	10.4	12	15

Table 11
Compressive test on cube for 28 days' oven curing

Control mix	Compressive strength in N/mm^2 28 days oven curing		
	Various % of geo polymer		
	Fa=60% M=20% S=20%	Fa=50% M=30% S=20%	Fa=40% M=30% S=30%
M20	16.2	18	19.3

Table 12
Compressive test on cube for 7 days ambient curing

Control mix	Compressive strength in N/mm^2 7 days ambient curing		
	Various % of geo polymer		
	Fa=60% M=20% S=20%	Fa=50% M=30% S=20%	Fa=40% M=30% S=30%
M20	4.3	4.5	7

Table 13
Compressive test on cube for 14 days ambient curing

Control mix	Compressive strength in N/mm^2 14 days ambient curing		
	Various % of geo polymer		
	Fa=60% M=20% S=20%	Fa=50% M=30% S=20%	Fa=40% M=30% S=30%
M20	8.4	9.2	11.1

Table 14
Compressive test on cube for 28 days ambient curing

Control mix	Compressive strength in N/mm^2 28 days ambient curing		
	Various % of geo polymer		
	Fa=60% M=20% S=20%	Fa=50% M=30% S=20%	Fa=40% M=30% S=30%
M20	15.3	16.4	18

Table 15
Compressive test on cube for 7 days' oven curing

Control mix	Compressive strength in N/mm^2 7 days oven curing		
	Various % of geo polymer		
	PPC 60% + Metakaoline 20% + silica fume 20%	PPC 50% + Metakaoline 20 % + silica fumes 30%	PPC 40% + Metakaoline 20% + silica fumes 40%
M20	14.2	13.4	13

Table 16
Compressive test on cube for 14 days' oven curing

Control mix	Compressive strength in N/mm^2 14 days oven curing		
	Various % of geo polymer		
	PPC 60% + Metakaoline 20% + silica fume 20%	PPC 50% + Metakaoline 20 % + silica fumes 30%	PPC 40% + Metakaoline 20% + silica fumes 40%
M20	18.4	17.3	17

Table 17
Compressive test on cube for 28 days' oven curing

Control mix	Compressive strength in N/mm^2 28 days oven curing		
	Various % of geo polymer		
	PPC 60% + Metakaoline 20% + silica fume 20%	PPC 50% + Metakaoline 20 % + silica fumes 30%	PPC 40% + Metakaoline 20% + silica fumes 40%
M20	23.2	22	21.4

Table 18
Compressive test on cube for 7 days ambient curing

Control mix	Compressive strength in N/mm^2 7 days ambient curing		
	Various % of geo polymer		
	PPC 60% + Metakaoline 20% + silica fume 20%	PPC 50% + Metakaoline 20 % + silica fumes 30%	PPC 40% + Metakaoline 20% + silica fumes 40%
M20	13.4	13	12.5

Table 19
Compressive test on cube for 14 days ambient curing

Control mix	Compressive strength in N/mm^2 14 days ambient curing		
	Various % of geo polymer		
	PPC 60% + Metakaoline 20% + silica fume 20%	PPC 50% + Metakaoline 20 % + silica fumes 30%	PPC 40% + Metakaoline 20% + silica fumes 40%
M20	18	17.4	17

Table 20
Compressive test on cube for 28 days ambient curing

Control mix	Compressive strength in N/mm^2 28 days ambient curing		
	Various % of geo polymer		
	PPC 60% + Metakaoline 20% + silica fume 20%	PPC 50% + Metakaoline 20 % + silica fumes 30%	PPC 40% + Metakaoline 20% + silica fumes 40%
M20	22.4	22	21.5

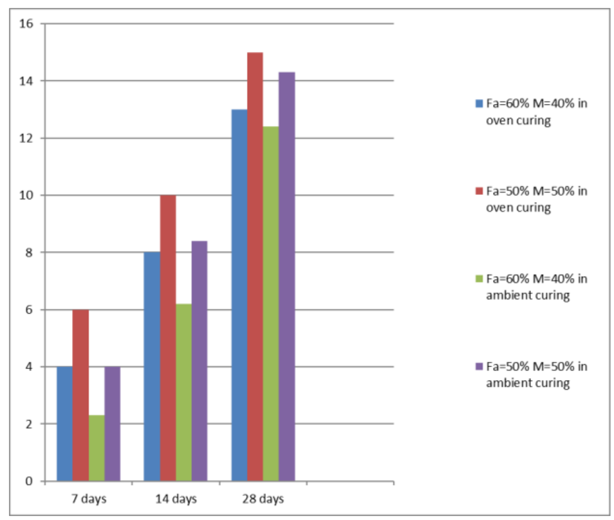

Fig. 6. Compressive test of cube in oven curing and ambient curing for F=60% M=40% & Fa=50% M=50%

The figure 6 represent the values of table 3 to table 8. The compressive strength exerted in 7, 14 & 28 days as shown in the above graph is not up to the standard i.e., M20. Thus new ratio is designed and tests are conducted which is discussed below.

The figure 7, represent the values of table 9 to table 14. The compressive strength exerted in 7, 14 & 28 days as shown in the above graph is not up to the standard i.e., M20. Thus new ratio is designed and tests are conducted which is discussed below.

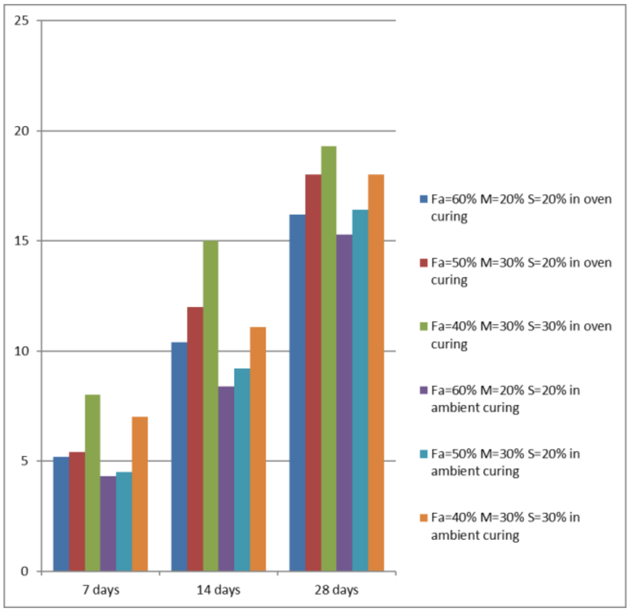

Fig. 7. Compressive test of cube in oven curing and ambient curing for Fa=60% M=20% S=20%, Fa=50% M=30% S=20% & Fa=40% M=30% S=30%

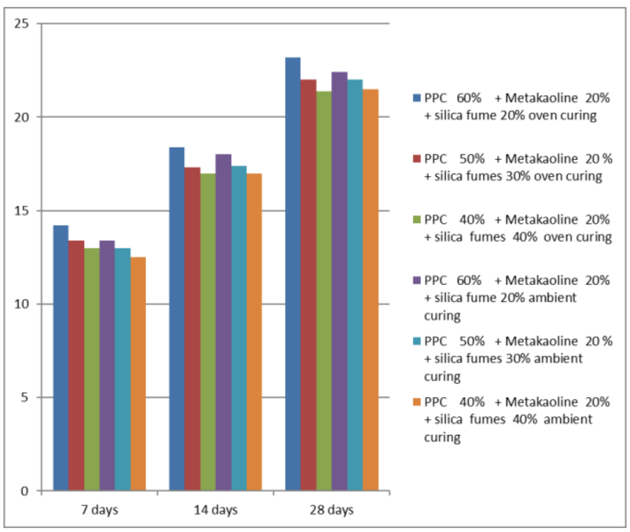

Fig. 8. Compressive test of cube in oven curing and ambient curing for PPC 60% + Metakaoline 20% + silica fume 20%, PPC 50 %+ Metakaoline 20 % + silica fumes 30% & PPC 40% + Metakaoline 20% + silica fumes 40%

The figure 8, represent the values of table 15 to table 20. The compressive strength exerted in 7, 14 & 28 days as shown in the above graph is up to the standard i.e., M20.

7. Conclusion

By using geopolymer in the ratio Fa=60% M=40% and Fa=50% M=50% is not upto the standard i.e., M20. From figure 6.

By using geopolymer in the ratio Fa=60% M=20% S=20%, Fa=50% M=30% S=20% & Fa=40% M=30% S=30% is not upto the standard i.e., M20. From figure 7.

By partially replacing cement with geopolymer the desired compressive strengthis obtained. From figure 8.

By partially replacing Pozzolana Portland Cement (PPC) with geopolymer the desired mix design can be obtained and the compressive strength is high when oven cured.

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