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An Experimental Investigation Report of Chloride and Sulphate effects on geo polymer mortar

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Abstract: *This paper presents the progress of the research on making Geo polymer mortar using the Thermal Power Plant fly ash. The project aims at making and studying the different properties of Geo polymer mortar using this fly ash and the other ingredients locally available. Sodium met silicate and sodium Hydroxide solution were used as alkali activators in different mix proportions. The actual compressive strength of the mortar depends on various parameters such as the ratio of the activator solution to fly ash, morality of the alkaline solution, ratio of the activator chemicals, curing temperature etc. In recent years, Mortar usage around the world is second only to water. Ordinary Portland cement (OPC) is conventionally used as the primary binder to produce mortar. The amount of the carbon dioxide released during the manufacture of OPC due to the calcinations 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 aluminium. Attempts to reduce the use of Portland cement in mortar are receiving much attention due to environment-related. Fly ash-based Geo polymer concrete is a 'new' material that does not need the presence of Portland cement as a binder. The role of Portland cement is replaced by low calcium fly ash. Geo polymer is an inorganic alumina-Hydroxide polymer synthesized from predominantly silicon (Si) and aluminium (Al) materials of geological origin or by-product materials such as fly ash. The term Geo polymer was introduced to represent the mineral polymers resulting from geochemistry..*

I. INTRODUCTION

As the demand for concrete as construction material increases, the demand for Portland cement is also on the demand. Presently in India the power sector depends on coal based thermal power stations which produces a huge amount of fly ash and estimated to be around 110 million tons annually. The utilization of fly ash is about 30% in construction of landfills, embankments, pavement base, and sub base course; and in producing blended cement. The pioneering work by Prof. Joseph Davidovits (1988) in the field of geo polymer technology showed considerable promise for application in the concrete industry as an alternate binder for Portland cement. Extensive studies in the recent past had shown that fly ash based geo polymer has emerged as a promising new cement alternative in the field of construction materials. Geo polymers were obtained from fly ash (residue from coal burning thermal power station) as a result of geo polymerization reaction (Davidovits, 1989). This involves the chemical reaction of sodium metasilicate with alkali polysilicates yielding polymeric Si - O - Al bonds. Concrete obtained from geo polymer known to exhibit many excellent properties such as high compressive strength, low creep, good acid resistance and low shrinkage. The most potential source of geo polymers among the industrial waste or by-product materials, are fly ash and blast furnace slag. Several studies have reported the beneficial utilization of these materials in concrete (Hardjito and Rangan, 2005). The setting properties of fly ash-based geo polymer in which a combination of sodium hydroxide with sodium silicate and potassium hydroxide with potassium silicate as alkaline liquids was investigated in various research studies. The calcium content in fly ash played a significant role in rate of strength development as well as ultimate compressive strength. It is understood that the strength was higher with increasing calcium content and resulted in faster strength development and higher compressive strength due to the formation of calcium-aluminates-hydrate and other calcium compounds.

The main reasons for replacing cement are

1.During the production of cement large amount of carbon dioxide released into the atmosphere, which affects living beings.

2.The cost of the cement very high when compared to fly ash.

So, it is very important to replace the cement with another materials mainly fly ash because during manufacturing of cement approximately 20 to 30% of is used and also the chemical composition of cement and fly ash is also approximately same materials.

II. LITERATURE REVIEW

Experimental results indicate that the compressive strength of GPC increased over controlled concrete by 1.5Bhosale et al (2012) have conducted an experimental investigation in the processing of geo polymer using fly ash and alkaline activator with the geopolymerization process. The factors that influence the early age compressive strength such as molarities of sodium hydroxide (NaOH) have been studied. Sodium hydroxide and sodium silicate solution were used as an alkaline activator. The study comprises the comparison of the ratios of Na2Sio3 and NaOH at the values of 0.39 and 2.51.The geo polymer paste samples were 18 cured at 60oC. The compressive strength was done at 7 and 28 days. The result showed that the geo polymer paste with NaOH concentration, compressive strength increases with increase in molarities.

According to T.F. Yen geo polymers can be classified into two major groups: pure inorganic geopolymers and organic containing geopolymers, synthetic analogues of naturally occurring macromolecules. In the following presentation, a geopolymer is essentially a mineral chemical compound or mixture of compounds consisting of repeating units, for example silico-oxide (-Si-O-Si-O-), silico - aluminate (-Si-O-Al-O-), ferro-silico-aluminate (-Fe-O-Si-O-Al-O-) or alumino - phosphate (-Al-O-P-O-), created through a process of geopolymerization. This mineral synthesis (geosynthesis) was first presented at an IUPAC symposium in 1976. The geo polymers which are used in this investigation are NaoH ,Na2Sio3.

As per recent researches conducted GPM reduces the cost of binding material as compared to standard cement. The compressive strength test was performed and an empirical formula was derived from the results. Vijaysankar et al (2013) have investigated the behaviour of fly ash based geopolymer mortor solid blocks and its durability. The cubes were cast with fly ash to river sand with the ratio of 1:3. by weight. Mortor cubes of size 70.6 x 70.6 x 70.6 mm were prepared and cured under oven curing for 24 hours. The compressive strength was found out at 7 days and 28 days. The results are compared. The optimum mix is Fly ash: Fine aggregate (1:3) with a solution (NaOH and Na2SiO3 combined together) to fly ash ratio of 0.35. The results conclude that high and early strength was obtained in the geopolymer concrete mix and geopolymer concrete was a workable mix

III. MIX DESIGN

Fly ash mortor 1:3 with Geopolymers

$$\text{Volume of Cube} = 7.06 \times 7.06 \times 7.06 = 351.89\text{cm}^3 = 0.000352\text{m}^3$$

$$\text{Density of Fly Ash} = 2370\ {}^{\text{kg}}/_{\text{m}^3}$$

For 1 cube:

$$\text{Amount of fly Ash} = \frac{2370 \times 0.000352}{(1+3)} = 0.208\text{kg}$$

$$\text{Amount of Sand} = 3 \times 0.208 = 0.624\text{kg}$$

$$\text{Amount of NaOH} = 9.6\% \text{ of Fly ash}$$

$$\text{Amount of Na2SiO3} = 24\% \text{ of Fly ash}$$

Amount of Na2sio3 = 24% of Fly ash

Molarity used in the mortor is 12 moler in which 361 grams of NaoH solids dissolved in 639 grams of water. From the references of D.Hardjito and B.V. Rangan (2005).

$$\text{Amount of NaOH solution} = 0.02\text{kg}$$

$$\text{Amount of Na2SiO3} = 0.05\text{kg}$$

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$$\text{Water}/_{\text{Fly ash}}\ \text{Ratio} = \frac{\text{H2O} + \text{NaOH} + \text{Na2SiO3}}{\text{Fly ash}}$$

$$= 0.40$$

$$\text{Amount of Water} = \frac{0.40}{0.208} - 0.02 - 0.05$$

$$= 0.013\text{Litres}$$

Mix Proportions

Table 1: Quantities of Mix Proportions

Mix	Total Volume m^3	Fly ash kg	Sand kg	NaOH kg	Na2SiO 3 kg	Water litres
FM (1:3)	0.000352	0.208	0.624	0.02	0.05	0.013

Table 2: Proportions of Slightly Acidic Substances

Substances	Proportions
CaCl2	40gms/litre
	50gms/litre
MgCl2	40gms/litre
	50gms/litre
MgSO4	40gms/litre
	50gms/litre

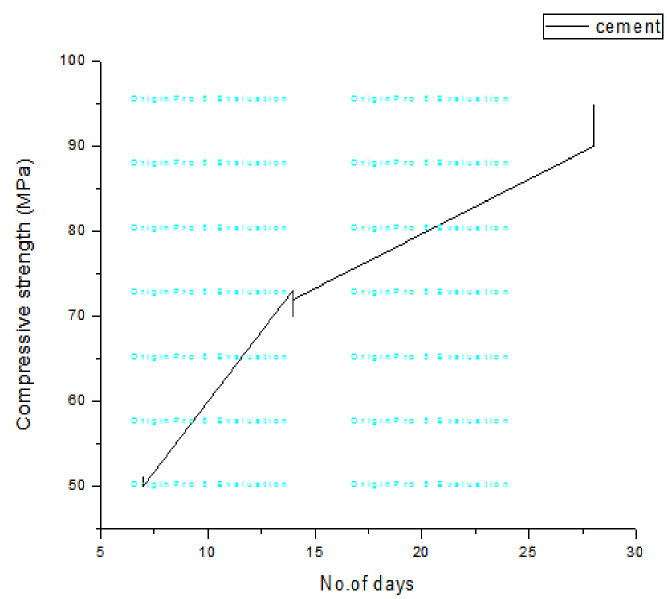
IV. TEST RESULTS

Compressive Strength Test

$$\text{Compressive Strength } (N/mm^2) = \frac{\text{Ultimate Compression Load (N)}}{\text{Area of cross section of specimen } (mm^2)}$$

Table 3: Cube Compressive strength of 1:3 Cement mortar

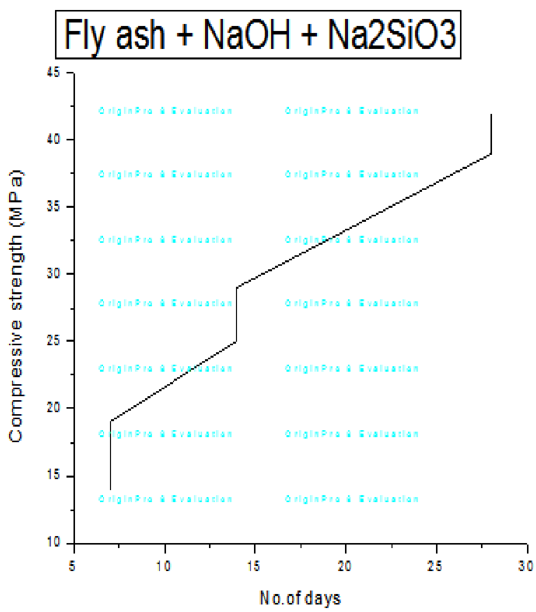
S.No.	Specimen Identification	Area in (mm^2)	Curing period in days	Load at failure in KN	Compressive Strength in N/mm2	Average Compressive in N/mm2
1	CM 1	4984.36	7	38	7.62	7.95
2	CM 2	4984.36	7	39	7.82	
3	CM 3	4984.36	7	42	8.42	
4	CM 4	4984.36	14	49	9.83	9.96
5	CM 5	4984.36	14	51	10.23	
6	CM 6	4984.36	14	49	9.83	
7	CM 7	4984.36	28	75	15.04	15.44
8	CM 8	4984.36	28	78	15.64	
9	CM 9	4984.36	28	78	15.64	



Graph 1: A Graph Representing Compressive Strength of Cement mortar

Table 4: Cube Compressive strength of 1:3 Geopolymer mortar

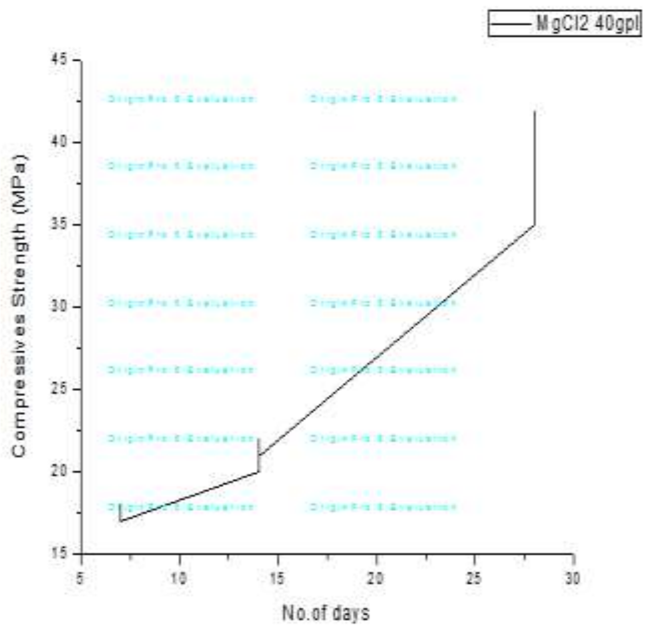
S.No.	Specimen Identification	Area in (mm^2)	Curing period in days	Load at failure in KN	Compressive Strength in N/mm2	Average Compressive in N/mm2
1	G.M 1	4984.36	7	14	2.80	
2	G.M 2	4984.36	7	16	3.21	3.14
3	G.M 3	4984.36	7	17	3.41	
4	G.M 4	4984.36	14	25	5.01	
5	G.M 5	4984.36	14	23	4.61	4.81
6	G.M 6	4984.36	14	24	4.81	
7	G.M 7	4984.36	28	30	6.01	
8	G.M 8	4984.36	28	33	6.62	6.35
9	G.M 9	4984.36	28	32	6.42	



Graph 2: A Graph Representing Compressing strength of Geo polymer mortar

Table 5: Cube Compressive Strength of Geopolymer mortar with MgCl2 40 gm/l

S. No.	Specimen Identification	Area in (mm^2)	Curing period in days	Load at failure in KN	Compressive Strength in N/mm2	Average Compressive in N/mm2
1	Mg1	4984.36	7	17	3.41	
2	Mg2	4984.36	7	18	3.61	3.41
3	Mg3	4984.36	7	16	3.21	
4	Mg4	4984.36	14	23	4.61	
5	Mg5	4984.36	14	25	5.01	4.68
6	Mg6	4984.36	14	22	4.41	
7	Mg7	4984.36	28	27	5.41	
8	Mg8	4984.36	28	25	5.01	5.48
9	Mg9	4984.36	28	30	6.01	



Graph 3: A Graph Representing Compressive strength of Geo polymer mortar with MgCl2 40 gm/L

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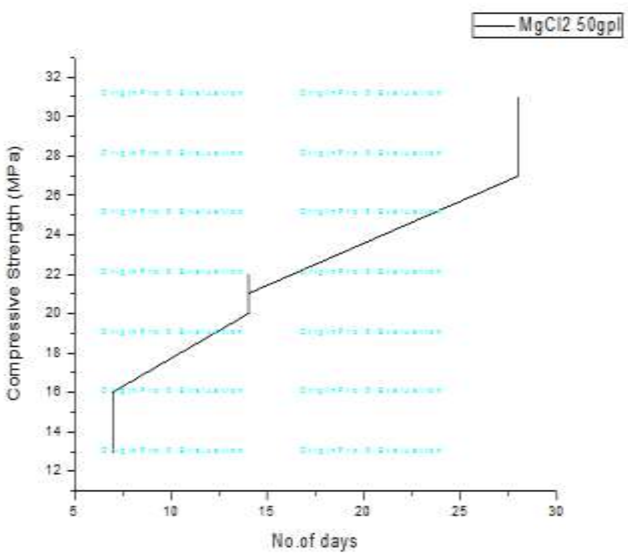
Table 6: Cube Compressive strength of Geo polymer mortar with MgCl2 50 gm/l

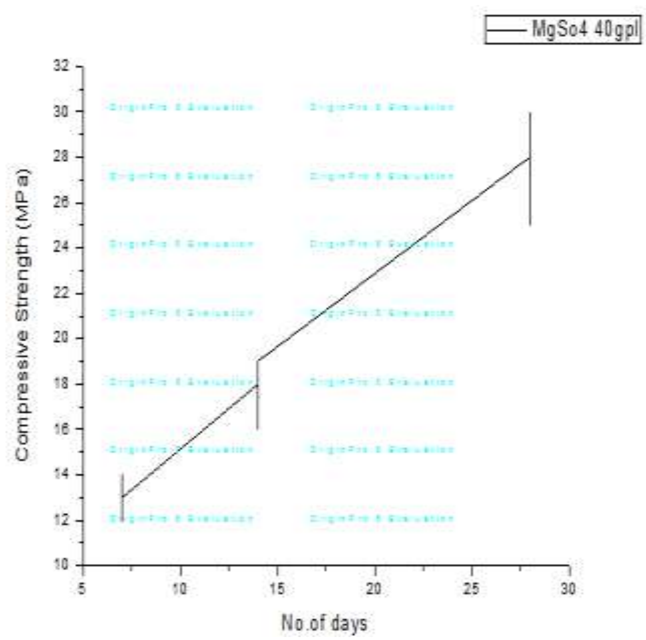
S.No.	Specimen Identification	Area in (mm^2)	Curing period in days	Load at failure in KN	Compressive Strength in N/mm2	Average Compressive in N/mm2
1	Mc1	4984.36	7	20	4.01	
2	Mc 2	4984.36	7	22	4.41	4.21
3	Mc 3	4984.36	7	21	4.21	
4	Mc 4	4984.36	14	25	5.01	
5	Mc 5	4984.36	14	26	5.21	5.07
6	Mc 6	4984.36	14	25	5.01	
7	Mc 7	4984.36	28	27	5.41	
8	Mc 8	4984.36	28	29	5.81	5.81
9	Mc 9	4984.36	28	31	6.21	



Graph 4: A Graph Representing Compressive strength of Geo polymer mortar with MgCl2 50 gm/L

Table 7: Cube Compressive strength of Geopolymer mortar with MgSO4 40 gm/l

S.No.	Specimen Identification	Area in (mm^2)	Curing period in days	Load at failure in KN	Compressive Strength in N/mm2	Average Compressive in N/mm2
1	MS 1	4984.36	7	18	3.61	
2	MS 2	4984.36	7	16	3.21	3.41
3	MS 3	4984.36	7	17	3.41	
4	MS 4	4984.36	14	20	4.01	
5	MS 5	4984.36	14	22	4.41	4.21
6	MS 6	4984.36	14	21	4.21	
7	MS 7	4984.36	28	28	5.61	
8	MS 8	4984.36	28	25	5.01	5.54
9	MS 9	4984.36	28	30	6.01	



Graph 5: A Graph Representing Compressive strength of Geo polymer mortar with MgSO4 40 gm/L

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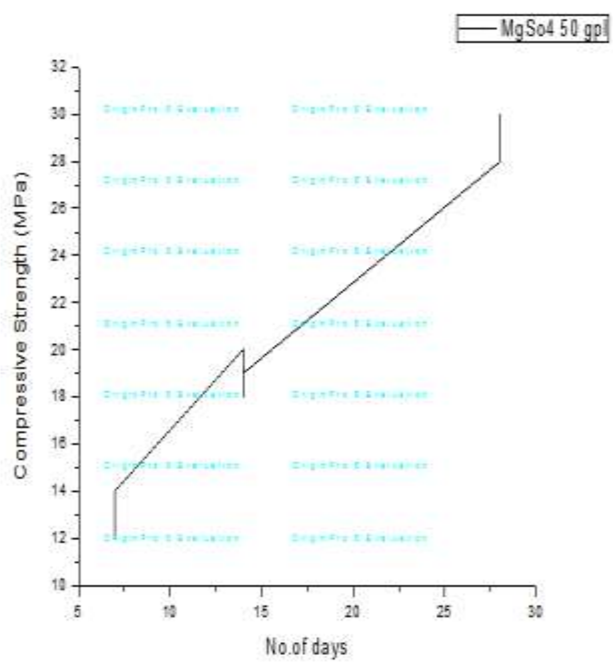
Table 8: Cube Compressive strength of Geopolymer mortar with MgSO4 50 gm/l

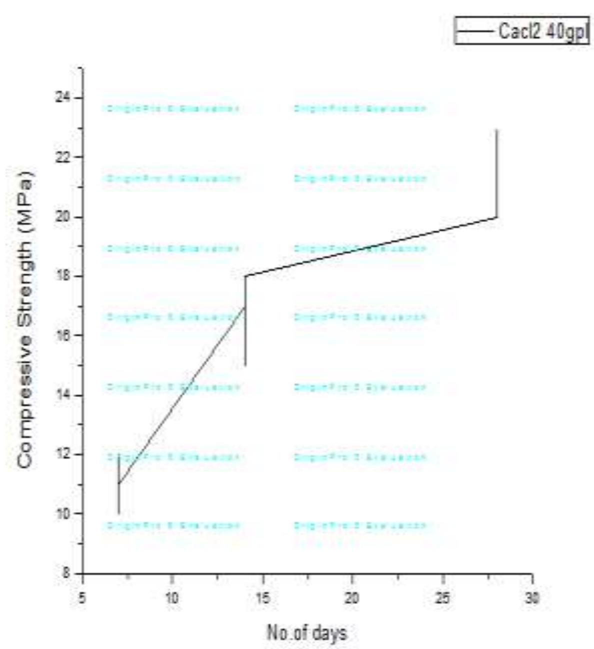
S.no	Specimen Identification	Area in (mm^2)	Curing period in days	Load at failure in KN	Compressive Strength in N/mm2	Average Compressive in N/mm2
1	MM 1	4984.36	7	16	3.21	3.41
2	MM 2	4984.36	7	18	3.61	
3	MM 3	4984.36	7	17	3.41	
4	MM 4	4984.36	14	22	4.41	4.61
5	MM 5	4984.36	14	24	4.81	
6	MM 6	4984.36	14	23	4.61	
7	MM 7	4984.36	28	28	5.61	5.81
8	MM 8	4984.36	28	30	6.01	
9	MM 9	4984.36	28	29	5.81	



Graph 6: A Graph Representing Compressive strength of Geo polymer mortar with MgSO4 50 gm/L

Table 9: Cube Compressive strength of Geopolymer mortar with CaCl2 40 gm/l

S.No.	Specimen Identification	Area in (mm^2)	Curing period in days	Load at failure in KN	Compressive Strength in N/mm2	Average Compressive in N/mm2
1	Ca 1	4984.36	7	10	2.0	2.27
2	Ca 2	4984.36	7	12	2.40	
3	Ca 3	4984.36	7	12	2.40	
4	Ca 4	4984.36	14	17	3.41	3.34
5	Ca 5	4984.36	14	15	3.00	
6	Ca 6	4984.36	14	18	3.61	
7	Ca 7	4984.36	28	21	4.21	4.14
8	Ca 8	4984.36	28	22	4.41	
9	Ca 9	4984.36	28	19	3.81	



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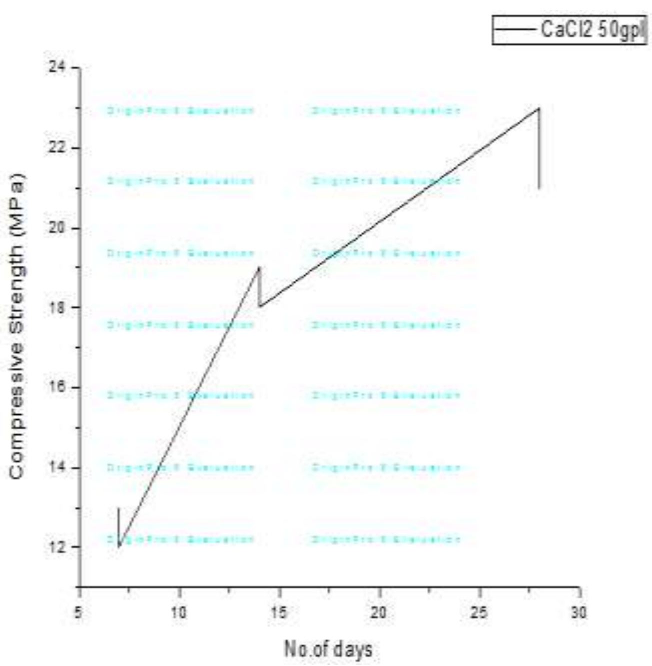
Graph 7: A Graph Representing Compressive strength of Geo polymer mortar with CaCl2 40 gm/L

Table 10: Cube Compressive strength of Geopolymer mortar with CaCl2 50 gm/l

S.No.	Specimen Identification	Area in (mm^2)	Curing period in days	Load at failure in KN	Compressive Strength in N/mm2	Average Compressive in N/mm2
1	CC 1	4984.36	7	13	2.60	2.60
2	CC 2	4984.36	7	12	2.40	
3	CC 3	4984.36	7	14	2.80	
4	CC 4	4984.36	14	19	3.81	4.21
5	CC 5	4984.36	14	23	4.61	
6	CC 6	4984.36	14	21	4.21	
7	CC 7	4984.36	28	24	4.81	5.01
8	CC 8	4984.36	28	26	5.21	
9	CC 9	4984.36	28	25	5.01	



Graph 8: : A Graph Representing Compressive strength of Geo polymer mortar with CaCl2 50 gm/L

V. CONCLUSION

Based on these extensive investigations, the following set of conclusions is drawn:

- This research has paved the way for the incorporation of promising Geo polymer mortar in structural applications and has led to the total elimination of cement from concrete which ultimately becomes “Green Concrete”.
- Heat cured Geo polymer concrete utilizes the ASTM Class F Indian fly ash efficiently and enormously and thereby nullify the issue of disposal of fly ash, an environmental concern.
- The fly ash, once considered as waste material, has found usefulness through Geo polymer concrete in construction industries and become a valuable material.
- It is evident from the test results that higher the concentration of NaOH, higher is the compressive strength of Geo polymer concrete.
- The utilization of geo polymer as cementious material provides additional environmental as well as technical benefits.
- The geo polymer technology reduces the cost of making mortar and increases its strength and durability characteristics.
- The initial setting time of fly ash based geo polymer binding material is higher upto 75% when compared with OPC, however the final setting time is almost similar.
- All the mortar cubes with different chlorides and sulphtes, the Compressive strength is increased gradually.
- The setting time is achieved only through elevated atmospheric temperature of around 65°C, hence it was concluded that heat curing is the possible way of curing geo polymer mortar.
- The strength of mortar cubes increases the maximum of 60% on third day when compared to OPC specimens. The increase in strength reduces as the age increases, hence it is concluded that the maximum strength of geo polymer mortar cube was achieved in its early ages.

SCOPE FOR FUTURE WORKS

From the available literatures on Geo polymer mortar and based on the findings in this research, following works are suggested for further research.

- Development of Geo polymer mortar manufactured with silicates and hydroxides of sodium and the effects on Compressive Strength of Geo polymer mortar.
- Investigations on the effect of varying percentage of Slightly acidic substances on Compressive strength of Geo polymer mortar.
- Achieving ultra high strength Geo polymer mortar by increasing the Concentration of silicates and hydroxides of sodium.
- Study on the addition of various slightly acidic substances in Geo polymer mortar and their effect on enhancement of strengths.
- All the works executed by hydrothermal mode of curing shall be experimented with dry-heat curing mode.

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