GEOPOLYMER MORTAR, A SUSTAINABLE ALTERNATIVE

Abhinaya K[1], Akhila K[2], Bharath VJ[3], Rohith TP[4], Rohini P[5]

[1,2,3,4], *Student, Department of Civil engineering, Jawaharlal College of Engineering and Technology, Ottapalam, Kerala, India*

[5]Assistant professor, *Department of Civil Engineering, Jawaharlal College of Engineering and Technology, Ottapalam, Kerala, India*

---***---

Abstract *Geopolymer mortar is a type of mortar that is made using geopolymer binders instead of traditional cement-based binders. Geopolymer binders are typically derived from industrial by-products or natural materials and have lower environmental impact compared to cement. Geopolymer mortars offer high strength, durability, and chemical resistance properties, making them suitable for a variety of construction applications. Geopolymer Concrete has gained attention to the development of pavement repairs, Airport highways and other civil engineering structures. In this paper a comprehensive study was carried out for compressive strength of Geopolymer mortar using Fly Ash. The compressive strength of Geopolymer mortar prepared by replacing 100% cement with Fly Ash was checked. Alkali activators such as sodium hydroxide and sodium silicate were used as binders. Compressive strength were checked at 7 days and 14 days by performing compression test and it was observed that from the result of optimum molarity dosage of M ,the compressive strength of Geopolymer.*

Key Words: Fly Ash, sodium Hydroxide, Sodium Silicate, M Sand, Geopolymerization, Geopolymer mortar.

1.INTRODUCTION

In order to reduce environmental deterioration and address climate change concerns, the global construction industry has been under increasing pressure to embrace sustainable techniques and materials in recent years. The creation of substitute binders for Portland cement, which is notorious for its high carbon footprint and energy-intensive manufacturing process, is one area of great interest and innovation in the field of sustainable building materials. A viable option that provides a sustainable substitute for conventional cement-based materials is geopolymer technology.

The manufacture of Portland cement, a vital component of traditional mortars and concrete, accounts for a sizeable amount of the world's carbon dioxide (CO2) emissions. High-temperature kiln firing is a step in the process that releases CO2 as a byproduct and consumes a significant amount of energy. In addition, habitat devastation and environmental degradation are caused by the mining of raw minerals like limestone. There is a pressing need to lessen the environmental impact of cement production as urbanization and infrastructure development drive up demand for building materials.

The building sector also faces a great deal of difficulty due to the loss of natural resources, including the supply of high-quality aggregates for the manufacturing of concrete. Conventional river sand mining has resulted in habitat destruction, bank erosion, and environmental damage. In addition, the lack of appropriate aggregates has led to increased expenses and logistical difficulties for building projects.

Examining sustainable aggregates and alternative binder systems that provide performance on par with or better than traditional materials while reducing their environmental impact is imperative in light of these difficulties. By using locally accessible minerals and industrial by-products, geopolymer technology offers a creative solution to these problems by producing high-performance mortars and concrete with a lower carbon footprint and resource usage.

With potential advantages in terms of performance, economy, and the environment over traditional Portland cement-based mortar, geopolymer mortar has become a viable substitute. Through a process known as geopolymerization, inorganic polymers known as geopolymers are created from aluminosilicate precursors, such as fly ash, slag, or other industrial by-products. Geopolymerization can be accomplished at ambient temperature or mild heat, resulting in reduced energy consumption and CO2 emissions than Portland cement, which requires high-temperature calcination and releases considerable volumes of CO2.

2. THE METHODOLOGY FOLLOWED IN THIS PROJECT

- Collection of materials like Fly ash, M sand, sodium silicate and sodium hydroxide.
- Selecting dimension of cube.
- Preparation of mix proportions.
- Casting cubes for compression test.
- Test on specimen
- Arriving at conclusion

3. MATERIAL PROPERTIES

3.1 Fly Ash

A fine, powdery substance known as fly ash is produced when thermal power plants burn pulverized coal. It is removed from coal-fired power stations' chimneys and collected in the flue gases. Fly ash can be used to concrete as an additional cementitious ingredient because it is high in iron, silica, and alumina. "The finely divided residue that results from the combustion of ground or powdered coal and that is transported by fuel gases from the combustion zone to the particle removal system" is the definition of fly ash given by ACI 116 R. In thermal power plants, fly ash is a byproduct of burning pulverized coal. Table 1 lists the different constituents and fly ash's chemical composition.

Table -1: Chemical composition of flyash.

SI. No.	Chemical Composition	Percentage
1	SiO_2	82.04
2	Al_2O_3	3.70
3	Fe_2O_3	1.80
4	CaO	3.75
5	MgO	0.01
6	SO_3	0.08
7	LOI	3.50
8	IR	78.97

3.2 Alkali activator

3.2.1 Sodium silicate

Water glass, or sodium silicate, is a crucial component in geopolymer concrete. It functions as an activator, forming the geopolymer binder through reactions with aluminum silicate and other substances. Sodium silicate aids in the creation of a strong and long-lasting geopolymer matrix and supplies alkalinity. The Prowess Company provides the necessary quantity of sodium silicate for collection. In figure 1, sodium silicate is displayed.

Fig 1: Sodium silicate

3.2.2 Sodium hydroxide

Caustic soda, or sodium hydroxide, is an alkaline activator that is utilized in geopolymer mortar compositions. Sodium hydroxide starts the chemical reaction required for geopolymerization when combined with fly ash and sodium silicate (water glass), two more activators.as depicted in Figure 2, sodium hydroxide

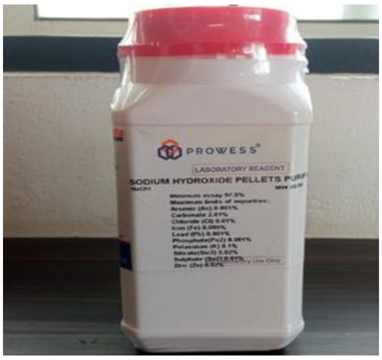

Fig 2: Sodium hydroxide

The product is obtained as pellets with a purity of 98% sodium hydroxide. To get the molarity, these pellets are combined with distilled water in the appropriate ratio. To ensure that the alkali liquid undergoes no additional chemical reaction, distilled water is used. Once sodium hydroxide has been added to the water, thoroughly agitate the mixture until all of the pellets have dissolved. As the pellets dissolve and the water temperature rises, take good care of your skin. The water's temperature has reached the point when it boils. After that, the solution is allowed to thoroughly cool. The solution cools down over the course of four to five hours.

A 1M sodium silicate solution is made. After that, the mixture was let to stand for roughly a full day in order to create a uniform mixture. In this case, four distinct molarity types—8M, 10M, 12M, and 14M—have been examined. provides the amount of sodium hydroxide that must be mixed with water to produce 1000 grams of NaOH solution, while Table 1 displays the density and molecular weight of various molar solutions.

3.3 M sand

Manufactured sand, or M sand, is a kind of sand made from crushed hard granite rocks. It serves as a natural sand substitute in construction projects and is an alternative to river sand. Typically, M sand particles range in size from 150 microns to 4.75 mm. Since it is finer than sand from a natural river, it can be used for a variety of construction projects.

4 MANUFACTURING PROCESS OF MORTAR

4.1 Mould preparation

Moulds of size 70.6x70.6x70.6mm are prepared with multiwood sheets with sufficient thickness as shown in the figure 3.

Fig 3 : mortar mould

4.2 Preparation

The basic difference between ordinary cement mortar and geopolymer mortar is the binder. The silica and aluminum oxide present in Fly ash and reacts with alkali liquid to form a geopolymer paste which on heating goes through a geopolymerization process.

1. In the study work, low calcium, class F dry fly ash are obtained from Malabar cements is used as base material to make the geopolymers.

2. Sodium silicate (Na_2SiO_3) mixed with sodium hydroxide (NaOH) as an alkaline activator has been used in this study, NaOH in pellet form with 98% purity & Na_2SiO_3 is in powdered form consist of Na_2O=9.4% and SiO_2=30.1%

3. The ratio of Na_2SiO_3 & NaOH is kept as 1.

4. Oven dry curing temperature i.e., 60ºC for time in 48 hours is kept constant.

5. The ratio of alkali activator to fly ash is considered 0.8.

4.3 Hand mixing and casting of mortar

The process of making geopolymer mortar involves the use of regular Portland cement. Both regular Portland cement mortar and geopolymer mortar are made using the same technique. The three primary ingredients used to make mortar are fly ash, M sand, and alkali activator solution. The sand is cleaned in accordance with IS 2116-1980 by passing it through a 4.75mm sieve. A fly ash to sand ratio of 1:3 is assumed. After thoroughly combining the sand and fly ash with a trowel or by hand, a very slow addition of alkali liquid is made. For two to three minutes, mix. The cementitious material and alkali liquid binder are thoroughly combined. Following the mixing of the combination and cube formation (as per IS 2250(1981), the mixture is baked for 48 hours at 60 degrees Celsius to cure it. After 48 hours in the oven, the compressive strength test for each molarity's cube will be conducted. Likewise, after 7, 14, and 28 days, the mortar cube of each molarity will undergo a compressive strength test. For curing, geopolymer mortar blocks are stored outside. Shown in figure 4 and 5.

Fig 4 : casting of mortar cubes

Fig 5 : mortar cubes

5.RESULT AND DISCUSSION

5.1 Density test

Results obtained from density tests are given below

(i) The density of mortar cubes of 8M,10M,12M,14 and 16M after 48 hours of oven drying is shown below.

Table -2: Density after oven drying

MOLARITY	MASS (kg)	DENSITY (kg/m^3)
8M	0.620	1761.9
10M	0.621	1767.5
12M	0.637	1810.2
14M	0.644	1832.9
16M	0.652	1852.8

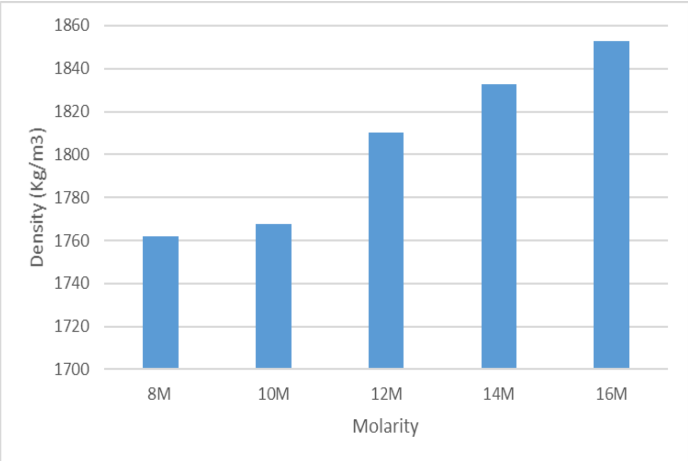

Fig 6: Density after oven drying

After measuring the density of mortar cubes of different molarities after 48 hours of oven drying, the highest density was obtained in mortar cubes with 16M NaOH. And the lower density is obtained in mortar cubes of 8M.

(ii) The density of mortar cubes of 8M,10M,12M,14 and 16M at 7th and 14th day is shown in table 3.

Table -3: Density after ambient curing

MOLARITY	7th DAY		14th DAY	
	MASS (kg)	DENSITY (kg/m^3)	MASS (kg)	DENSITY (kg/m^3)
8M	0.645	1832.9	0.639	1815.9
10M	0.651	1850.0	0.644	1830.1
12M	0.666	1892.6	0.661	1878.4
14M	0.670	1904.0	0.662	1881.2
16M	0.681	1935.2	0.673	1912.5

After measuring the density of mortar cubes of different molarities that are subjected to ambient curing, the highest density was obtained in mortar cubes with 16M NaOH. And the lower density is obtained in mortar cubes with 8M NaoH as shown in fig 7.

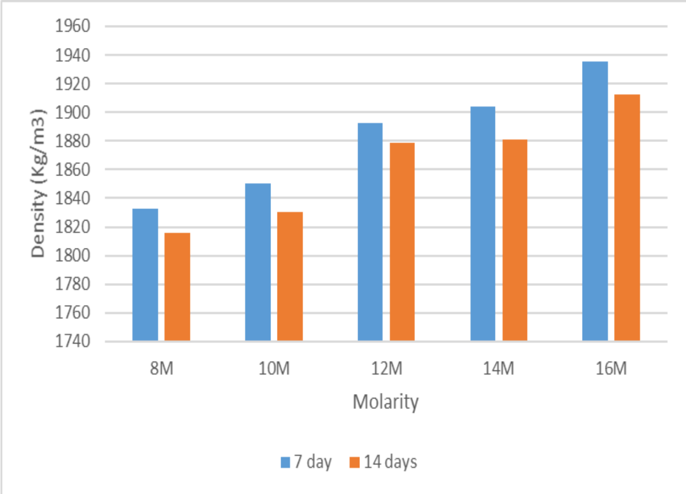

Fig 7: Density after ambient curing

5.2 Compressive strength test

Results obtained from compressive strength tests are given below.

(i) compressive strength of oven dried mortar cubes.

The compressive strength of mortar cubes after 48 hours of oven curing is shown in table 4.

Table – 4: Compressive strength after oven curing

MOLARITY	AREA (mm^2)	FAILURE LOAD KN	COMPRESSIVE STRENGTH (N/mm^2)
8M	70.6x70.6	27.5	5.51
10M	70.6x70.6	30	6.01
12M	70.6x70.6	30	6.01
14M	70.6x70.6	47.5	9.52
16M	70.6x70.6	42.5	8.52

Here after 48hours of oven curing of mortar cubes at a temperature of 60 degrees Celsius, the highest value compressive strength is obtained from the geopolymer mortar made from 14M NaOH and least value compressive strength is obtained from mortar made from 8M NaOH. The Following Chart Shows the Compressive strength of Mortar with Different Molarities as shown in figure8.

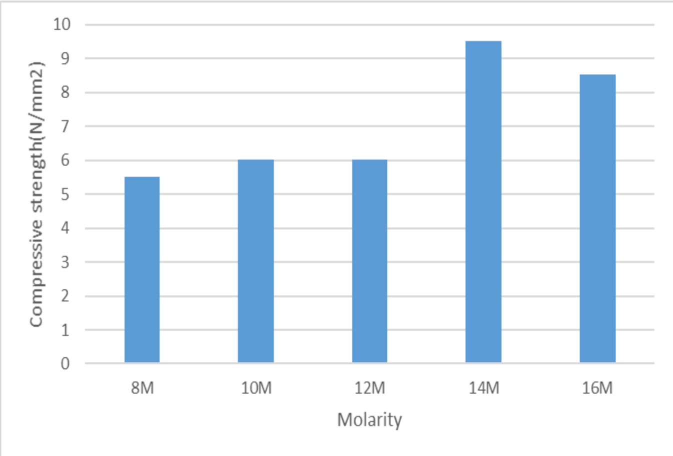

Fig 8: Compressive strength after oven curing

(i) compressive strength of mortar cubes after ambient curing.

The compressive strength of mortar cubes after 7 and 14 days of ambient curing are shown in table 5.

Table – 5: Compressive strength after ambient curing

MOLARITY	COMPRESSIVE STRENGTH (N/ mm^2)	
	7 days	14 days
8M	1.2	4.01
10M	2	3.51
12M	2	3.51
14M	2	5.51
16M	2	3

The following chart shows the comparison of compressive strength of different molarities of geopolymer mortar cubes after 7 and 14 days of ambient curing. From this chart it is observed that, the compressive strength of mortar cube is increasing by increasing the molarity of NaOH.

Here after comparing the results, the maximum compressive strength is obtained from mortar with 14M NaOH is shown in figure 9.

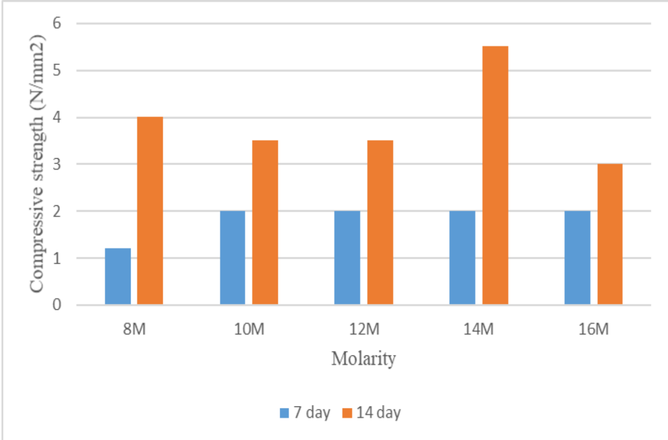

Fig 9: Compressive strength after ambient curing

5.3 Water absorption test

Results obtained from water absorption tests are given below;

Table – 5: water absorption test of oven dried samples

MOLARITY	WEIGHT BEFORE ABSORPTION OF WATER	WEIGHT AFTER ABSORPTIO N OF WATER	% OF ABSORPTIO N OF WATER
8M	0.620	0.639	3.06
10M	0.621	0.636	2.41
12M	0.637	0.645	1.25
14M	0.644	0.651	1.08
16M	0.652	0.661	1.38

The following chart shows the percentage of water absorption of mortar cubes made using different molarities of sodium hydroxide. Here the percentage of water absorption is reducing with an increase in molarity except in 16M. in cube made with 16M NaOH, the percentage of water absorption increases slightly compared to 14 M.

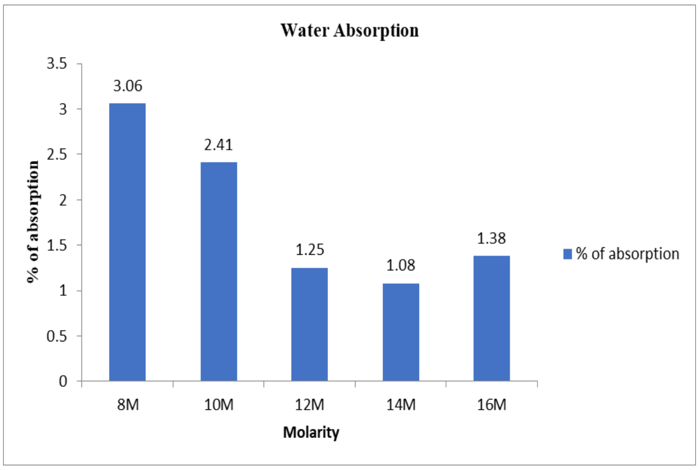

Fig 10: water absorption test of oven dried samples

5.4 Consistency test

Results obtained from consistency tests are as shown,

Weight of fly ash taken = 400g

Table – 6: consistency of fly ash

% of water	Amount of water	Depth of oenetration of plunger (from bottom)
26	104	32 mm
29	116	24 mm
32	128	15 mm
35	140	7 mm

Water required for making standard consistency of fly ash is 140 ml for 400 gm.

Standard consistency (%) = (140/400) x100

= 35 %

6. CONCLUSIONS

The conclusion that can be drawn based on the results of research on the effects Na2SiO3 and NaOH on the properties of geopolymer mortar are as follows;

- Geopolymer mortar offers a sustainable alternative to traditional cement mortar, with benefits including reduced environmental impact and good performance.
- Geopolymer technology reduces the carbon footprint associated with cement production, as it relies on industrial waste materials, contributing to sustainability goals.
- Maximum compressive strength after 48 hours of oven drying is obtained on geopolymer mortar 14 M with a value of 9.42 MPa and the minimum value is obtained on geopolymer mortar with 8 M which is equal to 5.51 MPa. Based on this result, it can be concluded that the optimum mixture to get the maximum strength is used NaOH 14 M. Based on the results, it can be concluded that the optimum molarity to get maximum compressive strength is NaOH 14M.
- The result of compressive strength of geopolymer mortar is lower than cement mortar type S according to ASTM C 1329-03.
- The greater the molarity of NaOH, the greater the density of geopolymer mortar obtained
- The percentage of water absorption reduces with increase in molarity of NaOH except 16M. in 16 M the percentage of water absorption increases slightly.

REFERENCES

[1] Atabey, İsmail İsa, Okan Karahan, Cahit Bilim, and Cengiz DuranAtiş,"Very high strength Na2SiO3 and NaOH activated fly ash based geopolymer mortar" (2020).

[2] D. R. Fitriani, "Pengaruh Modulus Alkali Dan Kadar Aktivator Terhadap Kuat Tekan Fly Ash-Based Geopolymer Mortar," p. 58, 2010.

[3] Kandoria, Vikrant & Kaur, Loveleen & Sharma, Dr. (2022). Development of Geopolymer Mortar Using Fly Ash. International Journal for Research in Applied Science and Engineering Technology. 10. 2375-2377. 10.22214/ijraset.2022.41139

[4] Tenepalli, J.S. and Neeraja, D, "Properties of class F fly ash based geopolymer mortar produced with alkaline water", Journal of Building Engineering, *19* (2018).

[5] Thokchom, S., Ghosh, P., and Ghosh, S. (2011). "Durability of Fly Ash Geopolymer Mortars in Nitric Acid–effect of Alkali (Na2O) Content." Journal of Civil Engineering and Management, 17(3), 393–399