

Effect of Alkaline Activator Concentration on Early Strength of Geopolymer Mortar

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Abstract: *This study takes a closer look at how the concentration of alkaline activators affects the early strength of geopolymer mortar. Instead of traditional cement, we used fly ash and GGBS as binder materials to create the geopolymer mortar. We incorporated fine aggregate along with an alkaline activator solution made from sodium hydroxide and sodium silicate. In our mix design, we experimented with different binder proportions of 60%, 70%, and 80% fly ash. To see how they impacted strength development, we tested sodium hydroxide solutions with varying molarity. The mortar specimens were cast and cured in normal conditions, and we conducted compressive strength tests at 7, 14, and 28 days. The results indicated that strength improves with curing time and is affected by both the molarity of the solution and the GGBS content. In conclusion, this study highlights that geopolymer mortar is a promising sustainable alternative, offering impressive strength while minimizing environmental impact.*

Keywords: effect of alkaline activator concentration on early strength of geopolymer mortar

I. INTRODUCTION

The amount of glass waste is skyrocketing as more people use it, and even though it can be fully recycled, a large portion still finds its way to landfills. Glass, made from high-quality silica, is incredibly durable and can be repurposed in concrete production. This project focuses on utilizing crushed glass waste as a substitute for some traditional materials in the creation of paver blocks, promoting the development of more eco-friendly construction options. By reusing glass, we can reduce pollution and lessen the demand for natural sand and stones. This approach not only offers impressive durability and aesthetic appeal but also presents a greener alternative to conventional materials. Our goal is to create strong, cost-effective, and environmentally friendly paver blocks made entirely from recycled glass.

II. OBJECTIVE

- To create geopolymer mortar using fly ash and GGBS as binding agents.
- To investigate how different binder ratios (fly ash-GGBS) affect strength.
- To examine the impact of alkaline activator concentration (NaOH molarity) on early strength
- To measure the compressive strength of geopolymer mortar at 7, 14, and 28 days.
- To find the ideal mix ratio for achieving maximum strength.
- To assess the viability of geopolymer mortar as a sustainable alternative to traditional mortar.

III. SCOPE

- Investigation on the behavior of geopolymer mortar incorporating fly ash and GGBS as binder constituents.
- Investigation on the influence of alkaline activator concentration (NaOH concentration) on early strength development.
- Study on the effect of varying the binder composition (ratio of FA to GGBS) on compressive strength.
- Conducting compressive strength tests on specimens cured for 7, 14, and 28 days.



I. NEED FOR GEOPOLYMER MORTAR

- To minimize the use of traditional cement, which is known to cause emission of CO₂ gas.
- To incorporate industrial waste products such as fly ash and GGBS in construction.
- To produce a new type of mortar using environmentally friendly materials.
- To determine the importance of concentration of alkaline activators in geopolymerization reactions.
- To examine the effect of molar concentration of NaOH on the early strength gain of geopolymer mortar.
- To attain high early strength so that work can be done rapidly.
- To find the best activator concentration and mix proportion.

II. IMPORTANCE OF GEOPOLYMER MORTAR

- Helps to understand the role of concentration of alkaline activators on the geopolymerization process.
- Helps to optimize NaOH concentration for higher early strength.
- Leads to enhanced early strength formation that becomes beneficial for rapid construction works.
- Enhances mechanical properties of geopolymer mortar
- Encourages use of fly ash and GGBS that helps reduce waste from industries.
- Assists in developing environment-friendly materials for construction using minimum cement content.

IV. MATERIALS

4.1 DESCRIPTION OF FLY ASH

Fly ash is a fine powder produced as a byproduct from the burning of coal in thermal power stations and is recovered from flue gas using electrostatic precipitators. The main constituents of fly ash include silica (SiO₂), alumina (Al₂O₃), and ferric oxide (Fe₂O₃) and thus can be used in geopolymer mortar. Fly ash is considered as one of the binders and reacts with sodium hydroxide solution to produce alumino-silicate gel in geopolymer mortar. Fly ash is generally divided into two categories namely, Class F and Class C depending upon the presence of calcium and Class F fly ash is usually chosen for geopolymer mortar preparation due to its properties.



4.2 DESCRIPTION OF FINE AGGREGATE

Fine aggregates are small particles of material used to fill the gaps existing between the bigger coarse aggregates in order to enhance workability of the concrete. They consist of mainly crushed stone particles or naturally occurring sand that can be able to pass through a 4.75 mm sieve. They improve workability and cohesion and consistency of concrete mix. In your research project, the fine aggregates will play the role of binding cement particles to the glass particles and therefore ensuring that you end up with durable paver blocks. They increase surface texture and reduce presence of entrapped air in the concrete while increasing compaction. Quality of fine aggregate used in terms of cleanliness, particle size and moisture content plays an integral part in determining the final durability of the produced glass paver blocks.





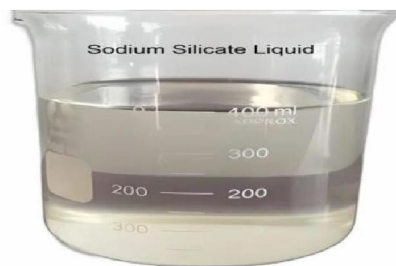
4.3 DESCRIPTION OF GGBS

Ground granulated blast furnace slag (GGBS) is a fine powder that is produced from the rapid cooling of molten iron slag that comes out of blast furnaces through water or steam, and then drying and grinding it. It has high amounts of calcium, silica, and alumina. Thus, it is highly appropriate for application in geopolymer mortars as a supplementary binder material. In this research, GGBS is added alongside fly ash, helping increase the effectiveness of geopolymerization especially the early strength of geopolymer mortar because of its high calcium content. GGBS enhances bonding, decreases setting times, and increases durability of the mortar



4.4 DESCRIPTION OF SODIUM SILICATE

Sodium silicate, also referred to as water glass, is a thick, alkaline solution made primarily from silica (SiO_2) and sodium oxide (Na_2O). Sodium silicate is commonly used as an alkaline activator for geopolymer mortar where it functions in synergy with sodium hydroxide to facilitate the process of geopolymerization. Sodium silicate in this study adds more soluble silica to the reaction mix, facilitating the production of more aluminosilicate gel that leads to more strength and durability. Besides adding more silica to the reaction mix, sodium silicate aids in the manipulation of workability and setting time.



4.5 DESCRIPTION OF SODIUM HYDROXIDE

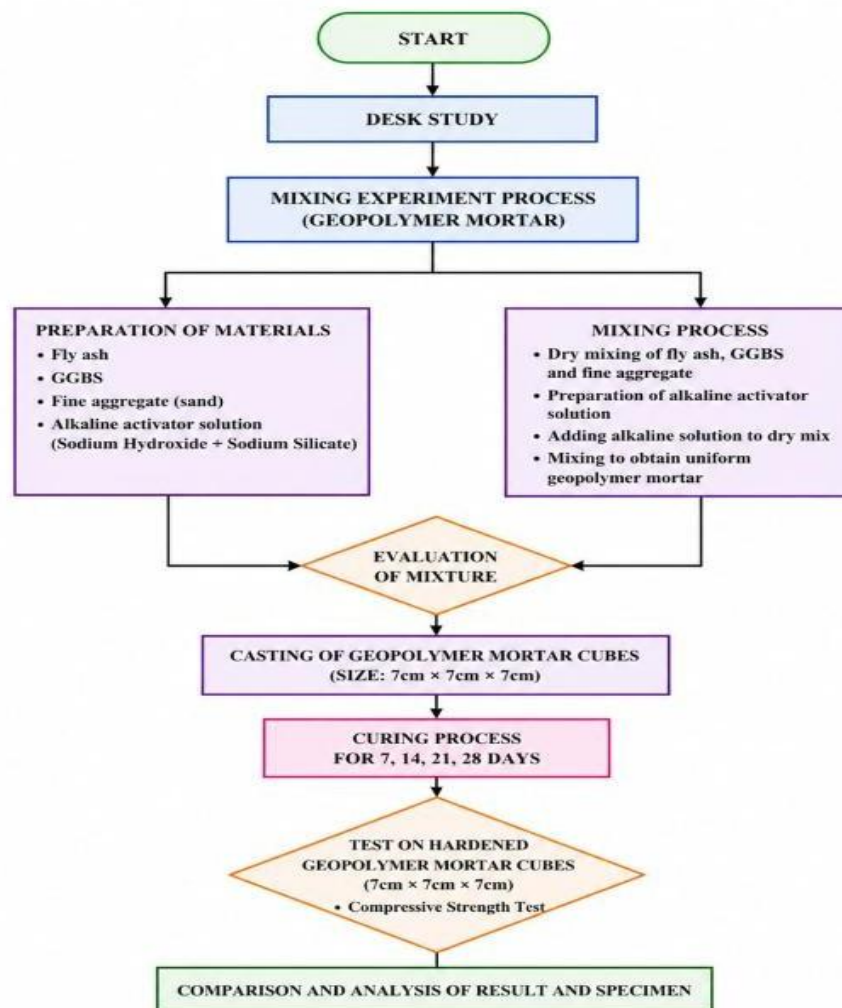
Sodium hydroxide (NaOH) is a strongly basic compound available in pellet or flake form and highly soluble in water. Once dissolved in water, a highly alkaline solution is obtained which is necessary for the initiation of the geopolymerization reaction in geopolymer mortar. Sodium hydroxide, in combination with sodium silicate, serves as an alkaline activator responsible for dissolving silica and alumina contained in fly ash and GGBS, resulting in the creation



of a strong gel binder. The molarity of the NaOH solution, measured in molar concentrations (for instance, 8M, 12M, and 16M), is a critical factor for influencing the reaction kinetics and early strength gains.



4.6 SUMMARY OF THE METHODOGY FOR THE STUDY



V. MIX PROPORTION FOR GEOPOLYMER MORTAR

WCG-PB	Fly Ash	GGBS	FA	Na ₂ SiO ₃	NaOH
Experimental setup A- 5%	0.188Kg	0.126Kg	0.786Kg	0.101Kg	0.040Kg
Experimental setup B – 10%	0.220Kg	0.094Kg	0.786Kg	0.101Kg	0.040Kg
Experimental setup C – 20%	0.251Kg	0.063Kg	0.786Kg	0.101Kg	0.040Kg

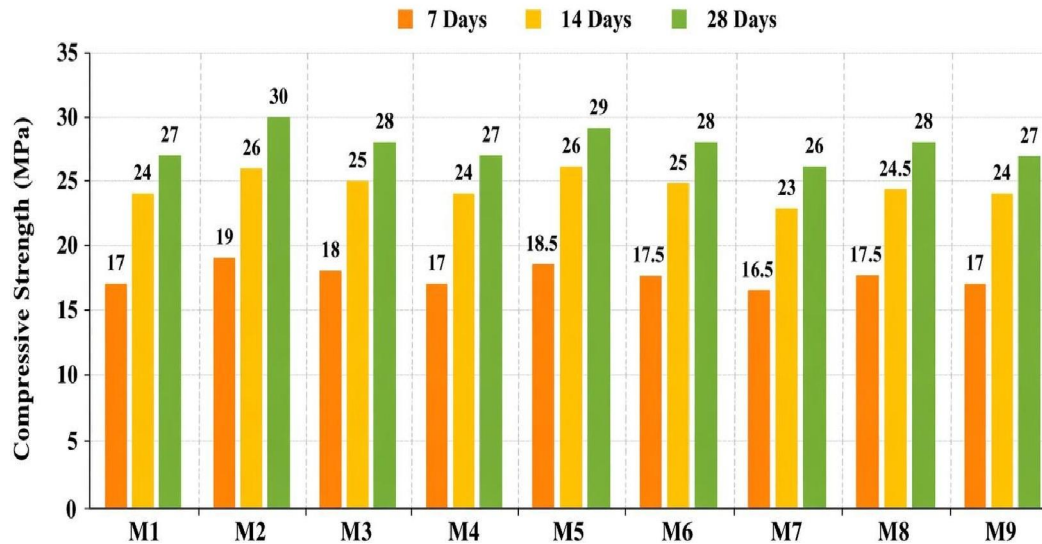
VI. COMPRESSIVE STRENGTH TEST:

This compression test was performed to measure the strength of the geopolymer mortar cube specimens made with various amounts of binders and alkaline activators. This compression test was done using a Compression Testing Machine (CTM).

MIX	FLY ASH	GGBS	MOLARITY	3 DAYS-Mpa	7 DAYS-Mpa
M1	80	20	8M	14	20
M2	80	20	12M	18	22
M3	80	20	16M	20	26
M4	70	30	8M	16	22
M5	70	30	12M	20	27
M6	70	30	16M	23	30
M7	60	40	8M	18	25
M8	60	40	12M	24	32
M9	60	40	16M	27	35



COMPRESSIVE STRENGTH OF GEOPOLYMER MORTAR



The compressive strength test was carried out on geopolymer mortar cubes using various proportions and molarities of the binder and alkaline activator respectively. The findings from the experiment at 7, 14, and 28 days indicated a steady growth in strength with an increase in the period. At 7 days, the test cubes had good initial strengths because the geopolymerization process was ongoing. This reaction involved the binding of fly ash and GGBS by the alkaline activator. At 14 days, a major increase in the compressive strength was noted because the geopolymerization was continuing, and more alumino-silicate gel had been produced. By 28 days, the cubes attained their maximum strengths. Among the various proportions tested, the mix ratio of 70% fly ash and 30% GGBS recorded the highest strength. The finding shows that there was an optimal proportion of calcium and reactivity of the materials. Mixture with more GGBS exhibited good initial strengths compared to those with high fly ash content since the reaction was slower in the latter than the former. The test results also show the importance of alkaline activator in terms of its molarity in producing good compressive strength.

VII. RESULT AND DISCUSSION

- The experimental results indicate that as the molarity of solution increases, the compressive strength also increases (from 8M to 12M to 16M).
- The mixes having higher GGBS (40%) had greater early strength than other mixes.
- The mixes were observed with following results:
- Mixes M2, M5, and M8 (having 12M solution) gave balanced strength.
- Mix M9 (60% FA + 40% GGBS + 16M) had maximum strength.
- The strength after 28 days is high from that of 7 days, which indicates successful geopolymerization.
- Low GGBS content mixes (i.e., 80% FA) had relatively low early strength.

VIII. CONCLUSION

This research work is focused on the impact of concentration of alkaline activator on early strength of geopolymer mortar prepared from fly ash and GGBS. The analysis has shown that the compressive strength of geopolymer mortar increases with the increase in curing age for all mixes. Moreover, the inclusion of GGBS helps in improving early



strength owing to the higher availability of calcium and faster reaction of GGBS. The importance of the alkaline activator concentration has been revealed as an important parameter in this analysis. It is evident that an increase in the molarity of NaOH leads to a corresponding increase in compressive strength until it reaches the optimum value. In terms of mixes, mix 4 with 70% fly ash and 30% GGBS performed better than other mixes. The mixes with relatively more fly ash showed lower values of compressive strength owing to the slow rate of reaction of fly ash.

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