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Experimental study on geopolymer mortar prepared with fly ash and Silica

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ABTRACT

This dissertation presents an experimental investigation into the effects of the binder-to-sand ratio on the mechanical strength of fly ash-based geopolymer mortar, tested across different alkaline solution ratios (1, 2, 2.5, and 3). It also examines the impact of adding silica fume on both the mechanical strength and durability of the mortar.The geopolymer binder mix comprises fly ash, sodium hydroxide, and sodium silicate solution by mass. Mechanical strength was evaluated through compressive and transverse strength tests, while durability was assessed using an acid resistance test. The study maintained a constant alkaline solution-to-fly ash ratio by mass (0.35) and a sodium hydroxide concentration of 14 molarity, based on previous research findings. Silica fume was added to the geopolymer mortar in incremental percentages from 1% to 8% by binder mass to observe its effects on strength and durability.For acid resistance test, sample specimen exposed to 5% solution of H_2SO_4 for four week under normal room temperature was taken. Freshly prepared geopolymer mortar was casted into mould size of 70.6×70.6×70.6 mm for mortar cube and 160×40×40 mm for mortar beam temperature cured at 80°C for 24 hours into hot air dry oven. From the test results it has been observed that binder to sand ratio optimizes at 0.75 for all alkaline ratios of 1, 2, 2.5 and 3 and gives highest compressive strength for combination of alkaline solution and binder to sand ratio of 2 and 0.75, respectively.

Keywords: - Silica fume, Portland cement, flyash, geopolymer mortar, strength and durability.

1. 1 INTRODUCTION

Geopolymer concrete (GPC) is a type of concrete that uses geopolymer binder instead of traditional Portland cement. It is made by combining industrial byproducts, such as fly ash or slag, with alkali activators to create a sustainable and eco-friendly construction material.

Key Features of Geopolymer Concrete

1. **Cement-Free Binder**: Replaces cement with a geopolymer binder formed through the reaction of aluminosilicate materials with alkali activators.
2. **Environmentally Friendly**: Utilizes waste materials like fly ash, ground granulated blast furnace slag (GGBS), and silica fume, significantly reducing carbon emissions.
3. **High Strength and Durability**:
   - Excellent compressive strength, comparable to or exceeding that of traditional concrete.
   - High resistance to chemical attacks, fire, and extreme temperatures.
4. **Rapid Strength Gain**: Gains strength faster under specific curing conditions, especially at elevated temperatures.

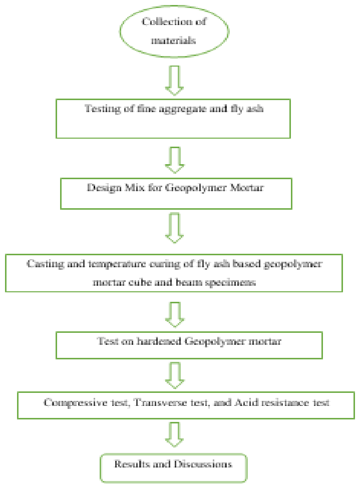
1. 2 LITERATURESURVEY &BACKGROUND

Jagan et al. (2023) conducted a comprehensive review of Engineered Geopolymer Composites (EGC), highlighting the effects of various factors—such as alkali activator additions, their chemistry, reaction mechanisms, precursors, admixtures, and hybrid fiber combinations—on the engineering properties of EGC. Notably, the alkali activator solution is pivotal in geopolymer formulation and binding capacity. Their review found that EGC exhibits a high strain-hardening capacity (4–7%) and enhanced mechanical properties due to improved geopolymerization and a robust interfacial bond between fibers and the matrix. The research identifies a gap in EGC studies related to the use of both low- and high-modulus fibers in hybrid combinations, as well as durability, carbonation, and corrosion analyses, suggesting these areas should be focal points for future research **Zhuang et al. (2017)** studied on acid resistance of geopolymer mortar (GM) with H_2SO_4 and NaCl attacks. The investigation was about the variation of mechanical strength and weight of GM after soaking in water, sulphuric acid and sodium chloride for different duration (30, 60, 90, 180, 270 and 360 days). For transverse strength and compressive strength of prism of GM with dimension of 160mm×40mm×40mm used

1.3 OBJECTIVESOFTHEWORK

To study the effect of binder to sand ratio (0.5, 0.75 & 1) on compressive strength of geo-polymer mortar for different alkaline ratio (1, 2, 2.5 &3) and to determine the optimum binder to sand and alkaline solution ratio. To study the effect of successive percentage of silica fume (1%, 2%, 3%, 4%...,up to 8% by mass of binder) on compressive strength and transverse strength of geopolymer mortar and to obtain the optimum dose of silica fume

1.4 FLOW CHART OF DISSERTATION WORK



1.5 RESULT AND DISCUSSION

To observe the effect of binder to sand ratio and alkaline ratio on the geopolymer mortar, thirty six numbers of mortar cube and twelve numbers of mortar beams were casted and tested for compressive strength and transverse strength properties.

The result obtained represented in graphical form in Fig: 1 for alkaline ratio 1, in Fig: 2 for alkaline ratio 2, in Fig:.3 for alkaline ratio 2.5 and in Fig: 4 for alkaline ratio 3

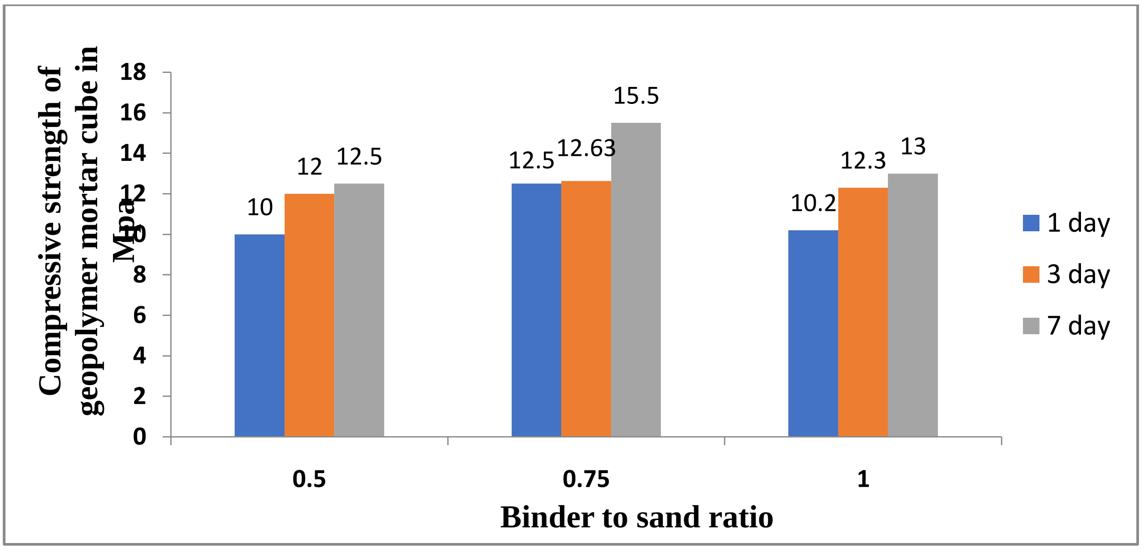


Figure 1 Compressive Strength of Flyash Based Geopolymer Mortar Cube for Alkaline Ratio 1

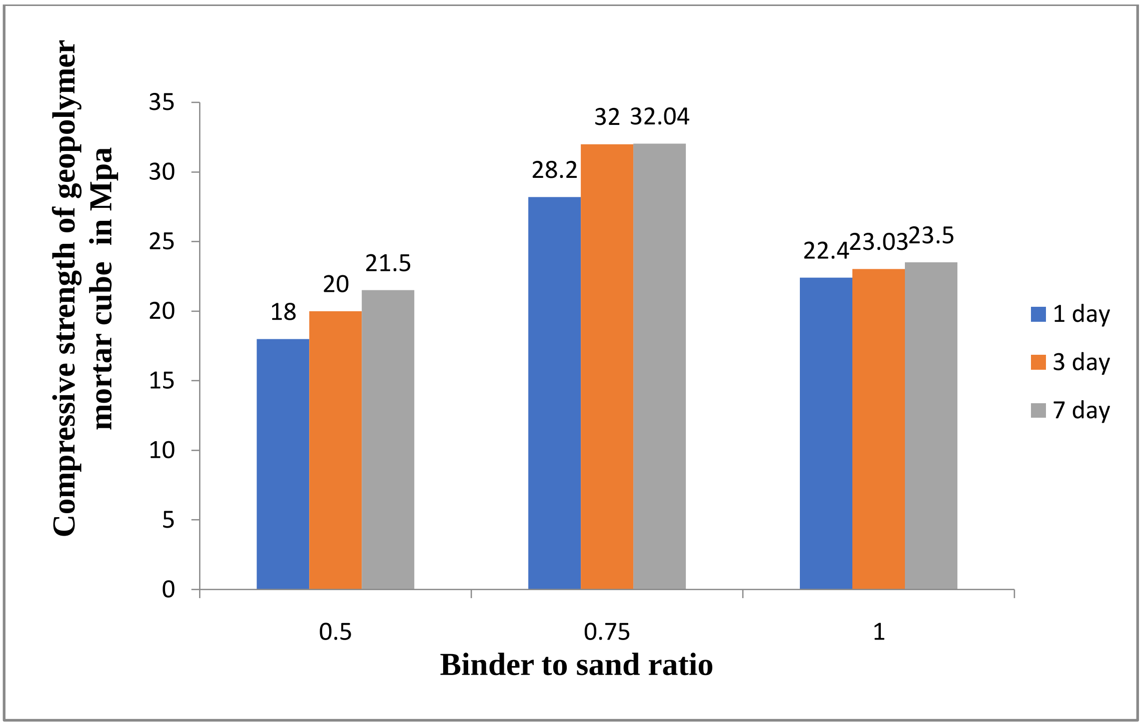


Figure 2 Compressive Strength of Flyash Based Geopolymer Mortar Cube for Alkaline Ratio 2

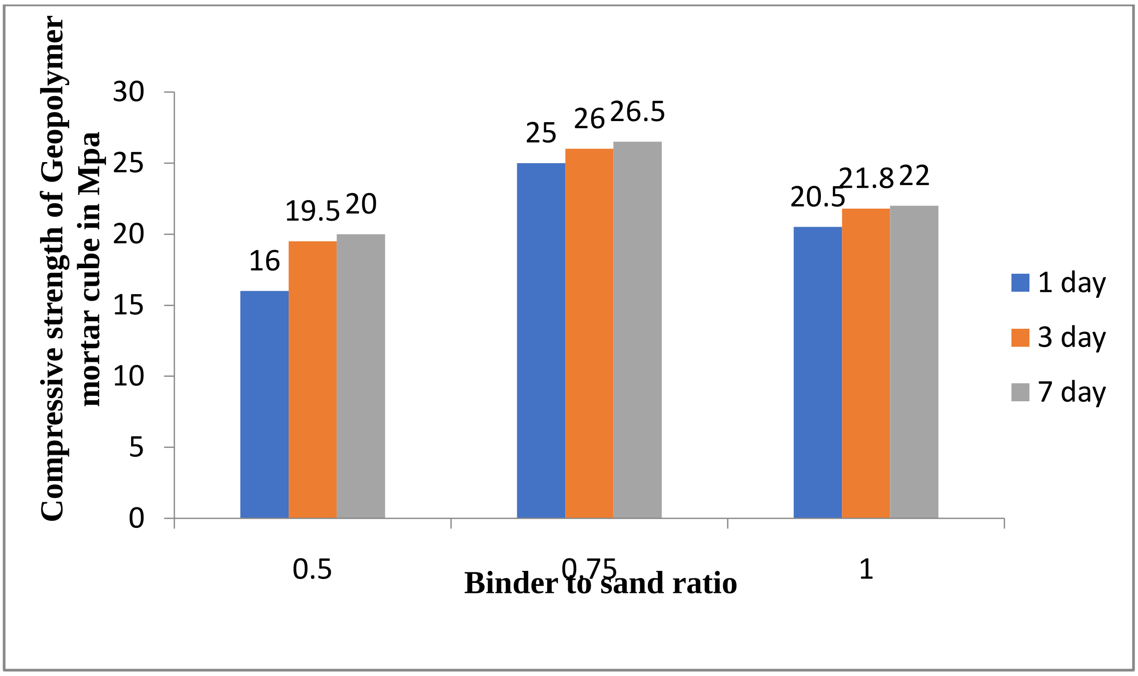


Figure 3 Compressive Strength of Fly Ash Based Geopolymer Mortar Cube for Alkaline Ratio 2.5

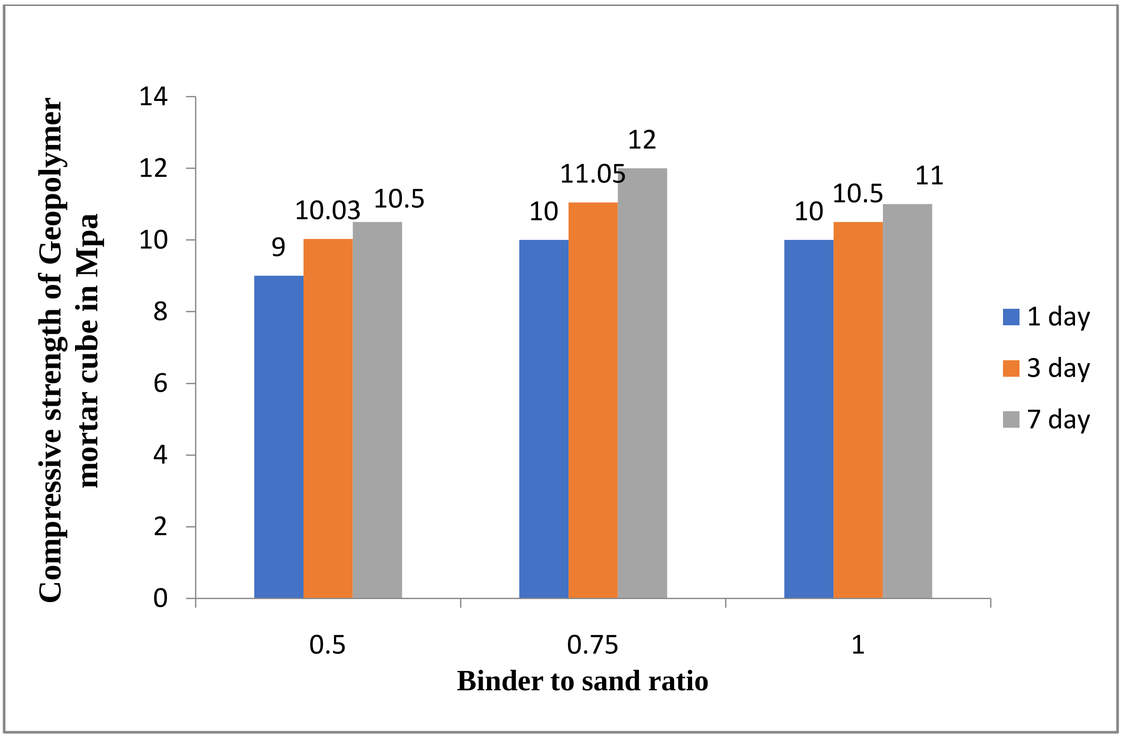


Figure 4 Compressive Strength of Flyash Based Geopolymer Mortar Cube for Alkaline Ratio 3

From the Fig 1, Fig 2, Fig 3 and Fig 4 it can be seen that binder to sand ratio optimizes at 0.75 to give comparatively higher compressive strength for all alkaline ratio (1, 2, 2.5 and 3). Binder to sand ratio of 0.5 provide mixture incorporating less amount of binder probably not allowing the proper bonding between binder and sand. In case of binder to sand ratio of 1, the binder is not properly reinforced with the fine aggregate resulting in low compressive strength as comparision to binder to sand ratio of 0.75

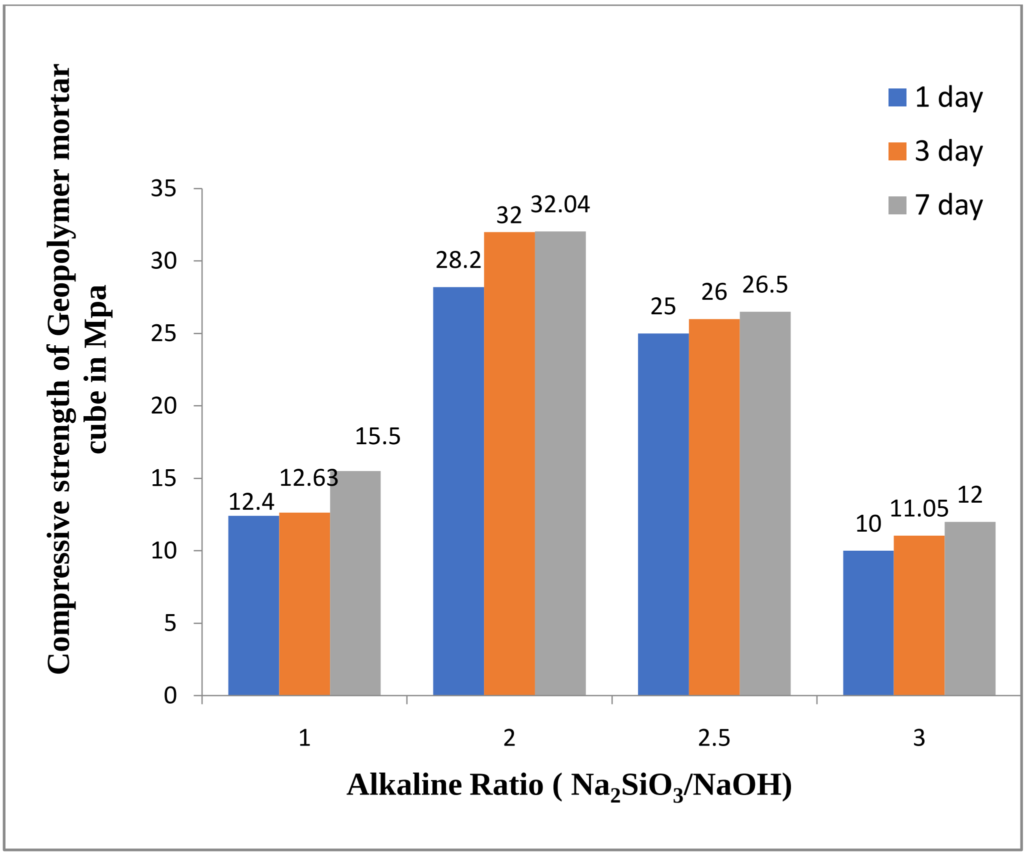


Figure 5 Compressive Strength of Geopolymer Mortar Cube for Various Alkaline Ratio and Constant Binder to Sand Ratio of 0.75

From Fig: 5 it can be seen that with binder to sand ratio of 0.75, the compressive strength of flyash based geopolymer mortar cube was achieved highest for alkaline ratio of 2. For alkaline ratio 1, 2.5 and 3 the compressive strength is low. The reason probably that for alkaline ratio 1.0 the sodium silicate and sodium hydroxide in equal amount do not induce Aland Siproperly from flyash. For alkaline ratio of 3 the sodium silicate being in larger amount in comparision to sodium hydroxide leaves some amount of unreacted silica from sodium silicate into the mortar mix.

1.6 CONCLUSION

Based on the test results of the study following conclusions are drawn.

1. Variation in binder to sand ratio affects mechanical properties of geopolymer mortar. With increase in binder to sand ratio the compressive strength also increases, at binder to sand ratio 0.75 the compressive Strength achieved highest for all alkaline ratios 1, 2, 2.5 and 3.
2. The effect of ratio of sodium silicate to sodium hydroxide to obtained better mechanical strength and durable Geopolymer mortar were studied.
3. It was found that the alkaline ratio is the important parameter for durable and better compressive strength of flyash based geopolymer mortar cube. As the alkaline ratio increases the mechanical strength of geopolymer mortar also increases.
4. For alkaline ratio of 2 Geopolymer mortar cube has better compressive strength and transverse strength.

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