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A Review on Compressive Strength of Optimized Geopolymer Mortar Utilizing Various Materials

Krunali Jaymin Savalia[1], Vimalkumar N. Patel[2]
[1]Research Scholar, Gujarat Technological University, Ahmedabad, India, kjsavalia@gecrajkot.ac.in
[2]Professor & Principal, B.H. Gardi college of Engineering and Technology, Rajkot, India

Abstract-*Geopolymer mortar functions today as a sustainable mortar solution compared to conventional cement-based mortar because it produces reduced emissions while delivering greater durability. This paper examines the strength optimization of geopolymer mortars through investigations with industrial waste products (fly ash, slag, silica fume), natural pozzolanic materials and alkali activators and reinforcing fibers. The evaluation analyzes the impact of mix design variables that comprise activator formats and concentrations together with curing environments and additive usage. The review presents crucial research outcomes which support critical understanding of the most effective composition methods for developing high-performance geopolymer mortar.*
Keywords-*Alkaline Activators, Compressive Strength, Geopolymer Mortar, Industrial By-Products, Sustainable Construction.*

INTRODUCTION

Industrial construction activities constitute one of the world's biggest carbon dioxide (CO_2) emission sources because of widespread Portland cement utilization. The production process of cement responsible for releasing 8% of human-made CO_2 emissions creates sustainability issues regarding environmental impact. Investigators and engineers continuously survey replacement materials for cement purposes to establish alternatives which keep or boost mechanical structural performance [1]. Geopolymer mortar stands as an excellent replacement material since it combines environmentally-benign properties with superior durability as well as impressive mechanical characteristics [2].A synthesis of geopolymers occurs through the activation of fly ash and met kaolin and slag with alkaline solutions. Geopolymerization conducts a chemical process to create a durable three-dimensional arrangement with properties identical to or superior than the strength of regular cementitious materials [3]. The strength development mechanism in geopolymers occurs through Si-O-Al polymeric linkages instead of traditional cement-based C-S-H gel formation which provides superior chemical resistance as well as high-temperature durability and lower material shrinkage effects [4].The structural utilization of geopolymer mortar predominantly depends on its compressive strength among all its properties [5]. The optimization of geopolymer mortar compressive strength requires examination of various raw materials together with their mix proportions and alkaline activators and curing conditions. The incorporation of industrial by-products consisting of fly ash together with ground granulated blast furnace slag (GGBFS) boosts mechanical strength and creates opportunities to reuse waste in line with sustainable building methods. Researchers have explored silica fume along with rice husk ash and nano-silica as supplementary materials to improve both microstructural properties and compressive strength of geopolymer mortar [6].The optimization of geopolymer mortar material requires consideration of four key elements that include alkaline activator chemical types and concentrations, SiO_2/Al_2O_3 molar ratio and temperature-based curing practices and optional fiber or nano-material additions [4]. Experts have shown that raising the ratio of sodium silicate in relation to sodium hydroxide combined with proper curing methods leads to substantial strength improvements in geopolymer mortar [7]. Large-scale implementation of geopolymer mortar faces difficulties because of its extended setting times as well as workability problems and unpredictable raw material quality [8].This research document performs a full review of studies dealing with the optimization of geopolymer mortar compressive strength through multiple material investigations. The research evaluates multiple precursor substances and activators with additives along with their specific results and patterns for study. The paper reviews recent developments to identify successful combinations for geopolymer mortar compressive strength enhancement while promoting sustainability features and economical solutions.

1. Novelty and Contribution

The main value of this study emerges from its structured methodology to evaluate solution to binder ratios which boost geopolymer mortar compressive strength. Previous research examined individual elements of raw materials and curing techniques and specific activator ratios for compressive strength individually until this paper merged diverse study findings into a coherent system of influence factors. The key contribution of this review involves finding the best possible mix design parameters which deliver maximum compressive strength while maintaining sustainability levels. This paper collects data from multiple studies to help researchers and engineers design high-performance geopolymer mortar which suits particular applications. The review points out additional work required in existing studies for extended durability examinations and large-scale field deploymentSection 2 provides a review of relevant literature, while Section 3 details the methodology proposed in this study. Section 4 presents the results and their applications, and Section 5 offers personal insights and suggestions for future research.

2. Related Works

Geopolymer mortar stands out as a sustainable mortar option to conventional cement because researchers have focused on it heavily throughout recent years. Multiple investigations examine the variables affecting compressive strength alongside durability along with overall performance outcomes of geopolymer mortar. Research studies have mainly studied the effects of precursor materials combined with alkaline activators and curing conditions while adding supplementary additives to enhance mechanical properties. Researchers have thoroughly studied the selection of raw materials for geopolymer synthesis. The wide utilization of industrial by-products such as fly ash and ground granulated blast furnace slag (GGBFS) happens because these materials contain high amounts of aluminosilicate that aids geopolymerization. The research on mortar strengthening has included testing various precursor mixtures to boost overall mortar composition properties. Research shows that GGBFS addition strengthens the materials in the beginning stage and fly ash enhances their long-term durability properties.Multiple investigations have focused on understanding the effects of alkaline activators especially as they relate to the ratio of sodium silicate to sodium hydroxide. A higher proportion of sodium silicate in the mix improves compressive strength because it enhances aluminosilicate particle dissolution while promoting polymerization. An increased activator dosage results in degradation of workability characteristics as well as reduced setting duration times. Various researchers studied various activator combinations to strike a balance between mechanical strength and mortar workability properties.The optimization process of geopolymer mortars heavily relies on effective curing techniques. The geopolymerization response becomes faster when heat curing occurs at intermediate temperatures which improves early strength but normal curing is better suited for field applications. Researchers have extensively studied how different curing times and temperatures affect geopolymer mortar durability thus it is essential to develop cure methods suited to particular mix compositions.The improvement of geopolymer mortar compressive strength has successfully progressed but researchers still need to overcome performance inconsistencies when using various material sources combined with outdoor environmental factors. Geopolymer material researchers now concentrate on major field implementation and measurements of durability against real-world impacts and environmental consequences of these materials.

3. Proposed Methodology

A systematic research methodology evaluates how geopolymer mortar compressive strength optimizes through the analysis of several precursor materials and activator ratios and curing conditions and supplementary additives. Experimental testing assessments will lead to a perfect mix design for geopolymer mortar featuring greater compressive strength.

4.1. Selection of Materials

For this research project the fundamental raw elements combine fly ash along with ground granulated blast furnace slag (GGBFS)shown in figure 1. The precursors will become activated through their combination with sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3). The workability of the mix will benefit from river sand addition while maintaining its structural integrity. The W/S ratio between water and solid content will receive exact control priorities to achieve mix consistency across every mixture.Raw materials for geopolymerization will undergo XRF and SEM analysis for determining their compatibility with geopolymerization processes. A molar ratio optimization process of SiO_2/Al_2O_3 will generate mixes with exceptional mechanical properties.

Fig 1: Raw materials for specimen

4.2. Mix Design and Optimization

The experimental design tests mix proportions by varying these parameters: activator concentration and sodium silicate-to-sodium hydroxide ratio as well as cure conditions and assistant binder contents.

- Activator concentration of molarity of NaOH 16 M.
- Solution to binder ratio:0.5 and 0.6.
- Sodium silicate-to-sodium hydroxide ratio: 1.5, 2.0, 2.5 and 3.
- Sample covered with plastic after demoulding and applied ambient curing for 24 hours.

4.3. Specimen Preparation and Testing

Cube (70.6 mm*70.6 mm *70.6 mm) types of specimens will be cast (figure:2) while being cured under distinct conditions. Testing methods will determine fresh and hardened characteristics of geopolymer mortar through the following assessments:

- Testing the setting time requires the use of Vicat apparatus.
- The flow table test measures workability as one of the properties.
- The testing device used for compressive strength measurements is the universal testing machine.

Fig-2: Casting of specimens

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4.4. Flowchart of Methodology

The following flowchart summarizes the experimental procedure:

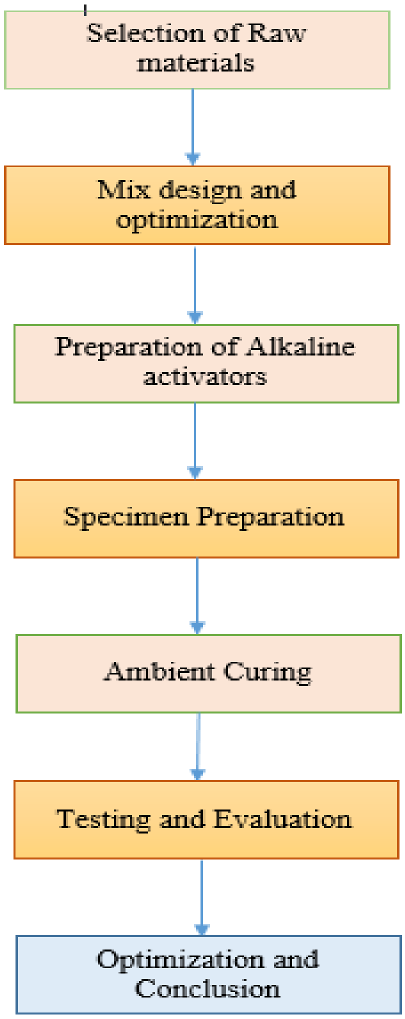

Fig 3: Methodology for Optimizing Geopolymer Mortar Compressive strength

4. RESULTS AND DISCUSSIONS

Experimental work conducted during this study yielded important information about geopolymer mortar compressive strength development through modification of mix design methods. The mechanical strength of mortar strength changed extensively based on the distinct precursor materials and the proportions of activators. The measurement of compressive strength through testing found that it steadily grew across the analysis period according to 7 and 28 days. The trend of compressive strength growth appears in Figure 2 across different mix. Geopolymer mortar possesses enhanced early-age strength when activated with elevated sodium silicate-to sodium hydroxide ratio values. The fast geopolymerization occurs because the enhanced dissolution rate of alum inosilicate precursors plays a role in this process. The workability decreased while micro cracking increased because of excessive activator concentration which went above the optimum threshold. The mix formulation of 1.5 sodium silicate to sodium hydroxide showed the best results for combining both strength and workability characteristics.

The compressive strength of ambient cured samples at room temperature for 24 hours achieved better early performance. The data presented in table-1 demonstrates samples achieved good results at the 7-day and 28-day strength with room temperature curing.

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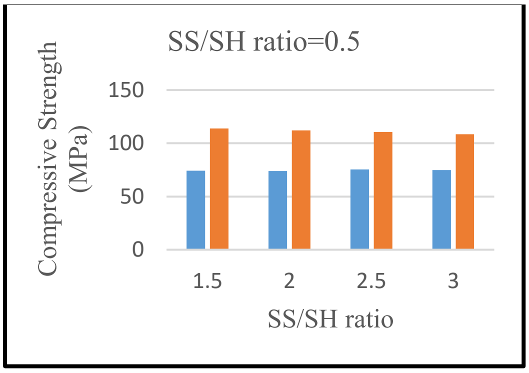
Test results showed that geopolymer mortars made from 50 % fly ash and 50% GGBFS produced with 16 M solution evolved strength quickly in the first days. The 28-day compressive strength data for various precursor relations exists in Table 1.

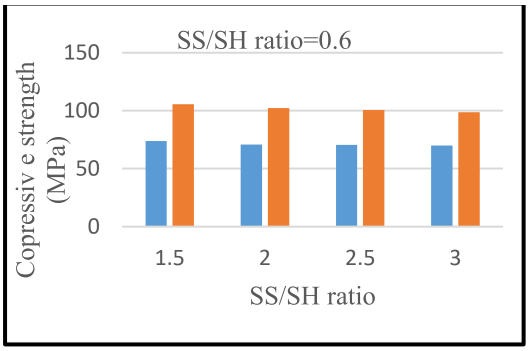
Table 1: Compressive Strength Comparison of Different Precursor Combinations at 28 Days

Solution to binder ratio	SS to SH ratios	Compressive Strength	
		7days	28 days
0.5	1.5	74	113.5
0.5	2	74	112
0.5	2.5	75.3	110.5
0.5	3	74.8	108.4
0.6	1.5	73.9	105.5
0.6	2	70.7	102.4
0.6	2.5	70.4	100.6
0.6	3	70.1	98.8

The data in Table 1 presents the results from activator ratio comparisons. Experimental results established that the sodium silicate-to-sodium hydroxide ratio directly affected compressive strength values when set at 1.5 to 3.Results indicate that proper selection of activator ratios plus solution to binder ratios leads to optimal mechanical abilities in geopolymer mortar. This research enhances knowledge about selecting materials and mix design techniques which strengthen geopolymer mortars sustainably at reasonable costs.



(a)



(b)

Fig 4: Compressive strength variation of geopolymer mortar over time with SS/SH reaito=0.5 and SS/SH ratio = 0.6

5. CONCLUSION

Geopolymer mortar represents an innovative option to cement mortar because optimized compositions produce strong materials. Curing methods together with activator selection and aluminosilicate resources act as fundamental determinants for strength development. Research needs to concentrate on implementing large-scale geopolymer applications alongside studies of construction durability performance and evaluation of affordable manufacturing processes to advance complete industry acceptance.

6. FURTHER RESEARCH

Further research shall have focused on different proportion of ingredients for required strength of geopolymer mortar. Also work on some other wastes like rice husk, iron fibers, metakolin, neno materials etc. Researcher shall work on strength with respect to time and curing conditions.

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