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The Effect on Water-To-Binder Ratio (W/B) on the Properties of GGBS-based Geopolymer Mortar

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KEYWORDS

One-part geopolymer
Slag
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Compressive Strength

ABSTRACT

This work aims to expand the understanding of application on one-part geopolymer mortar made up of GGBS. The water absorption and compressive strength were utilized to determine the properties of geopolymer mortar. For mix designation, the water-to-binder ratio was changed from 0.35 to 0.50, with alkaline activator-to-slag ratios of 0.18 and alkali activator ratios of 4.0 constant. The lowest water absorption obtained was at the ratio of 0.35. The compressive strength of 40.88 N/mm^2 was obtained at the ratio of 0.45 due to the dense and complex structure. GGBS also proved that it can achieve earlier strength growth as the compressive strength obtained at 7 days is almost the same as at 28 days of curing.

1. INTRODUCTION

Ground granulated blast-furnace slag (GGBS) generated in the iron and steel industry is regarded as a secondary solid waste resource due to its exceptional sulfate erosion resistance and durability. The gradual pozzolanic activity of GGBS necessitates alkaline substances to initiate their pozzolanic properties and expedite the process (Zheng et al., 2023). GGBS is frequently utilized as a cementitious substance, enhancing strength and decreasing permeability by augmenting the interface with the aggregate (Ahmad et al., 2022).

Geopolymers and alkali-activated materials represent more environmentally friendly alternatives to conventional cement-based materials, typically generated by activating aluminosilicate industrial byproducts with alkali metal hydroxides and silicates (Ozcelikci et al., 2023). Geopolymers provide superior high-temperature resilience compared to cement binders since they demonstrate less thermal cracking, spalling, and diminished loss of compressive strength (Deng et al., 2023).

The one-part geopolymer is a solid combination of aluminosilicate precursors and alkali activators combined with water. In contrast, the two-part technique uses a liquid alkaline solution to activate the solid precursor (Yao et al., 2024). Conventional geopolymers have the issue of transporting, storing, and managing these potent alkaline solutions, necessitating stringent protective measures, thereby impeding mass production and increasing costs (Srinivasa et al., 2023). Compared to conventional geopolymer, the one-part geopolymer markedly streamlines the mixing procedure, enhancing speed and efficiency and diminishing the danger of alkaline skin burns (Zhang et al., 2023). In contrast to traditional two-part geopolymers, one-part geopolymers demonstrate diminished compressive strengths due to the inability of solid alkaline activators to dissolve completely and react fully with aluminosilicate within a brief period (Zhao et al., 2023).

2. EXPERIMENTAL PROCEDURE

2.1 Materials and Mix Design

Ground granulated blast furnace slag (GGBS) provided by Macro Dimension Concrete (MDC) at the Chuping Plant was employed as a solid precursor to produce alkali-activated materials in this study and will be designated as slag. Sodium hydroxide in pellet form supplied by HmBG Chemicals and the anhydrous Na_2SiO_3 was supplied by R&M Chemicals were used as alkaline activators in this study.

For alkaline activator, a fixed ratio of 4.0 for sodium silicate (Na_2SiO_3)-to-sodium hydroxide (NaOH) was used. The alkaline activator-to-slag ratio was set at 0.18. Various water-to-binder ratio, 0.35, 0.40, 0.45 and 0.50 was used. Alkali-activated slag (AAS) was synthesized by mixing slag with solid alkaline activator with water at a specific mixing time (within three minutes) for each of the ratios used. After mixing, the fresh geopolymer mixture was immediately casted in 50mm mold and allowed to cure for 24 h at room temperature. After demolding, the samples were cured for 7 and 28 days.

2.2 Determination Properties of Geopolymer Mortar

The water absorption of geopolymer mortar was determined based on ASTM C140.The strength of geopolymer mortar was determined by using Universal

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Testing Machine (UTM) as compliance with BS 1881-116 (1983).

3. RESULTS AND DISCUSSION

3.1 Water Absorption

As being illustrated in Figure 1, all the water absorption had been improved after 28 days of curing.

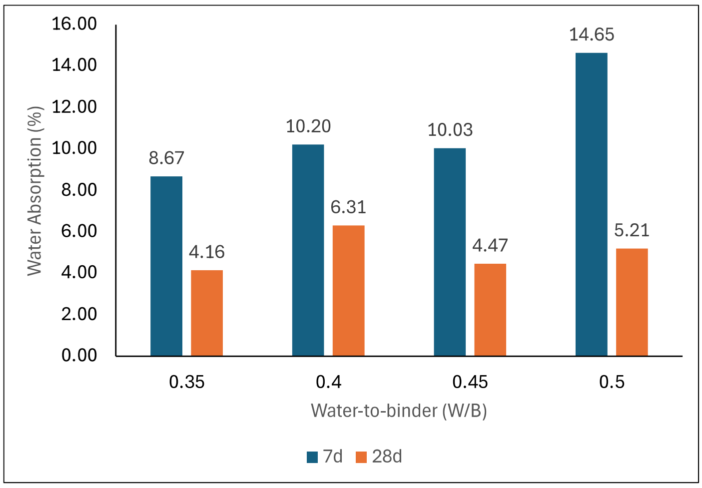

Figure 1. Water absorption for different water-to-binder ratio.

The greater water absorption of geopolymer mortars with different w/b ratios at 7 days may result from the gradually geopolymerization process and the chemical inactivation of those components. After 28 days of curing, the water absorption for each w/b ratio improved. This can be due to the formation and accumulation of hydration products comprising ettringite and C-S-H gel, which occupy pores in the matrix to get a compact body (Zhang et al., 2022). In addition, the w/b ratio of 0.35 had the lowest water absorption because reducing the water-to-binder ratio is a common strategy for decreasing the permeability of the composites (Pantić et al., 2023). The slightly increased water absorption at ratios of 0.4 and 0.5 can be due to the incomplete geopolymerization reaction.

3.2 Compressive Strength

The compressive strength was tested at 7-day and 28-day ages to study the strength growth, and the results are shown in Figure 2. The highest compressive strength was obtained at a ratio of 0.45. In general, the higher strength of geopolymer mortar can be due to its denser and more complex structure. The chemical composition and reactivity of the source material used to synthesize the geopolymer mortar determine the degree of development of hydration products and the type of hydration products, which in turn greatly impact the strength of the material (Sasui et al., 2021).

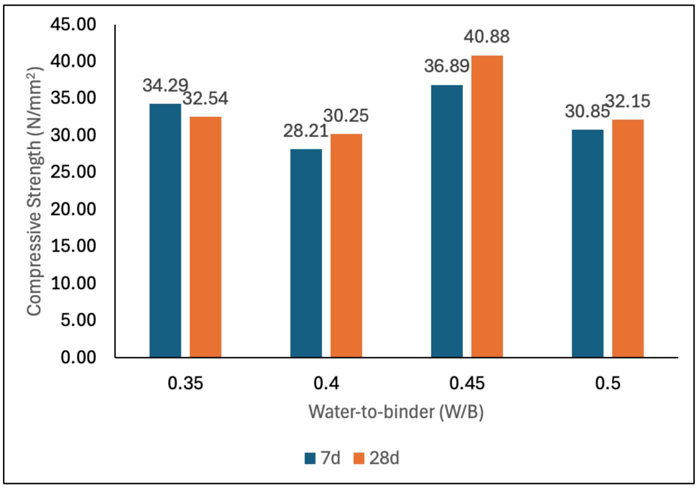

Figure 2. Compressive strength for different water-to-binder ratio.

The compressive strength for each w/b ratio increases slightly after 28 days of curing. The geopolymer mortar, which is made up of GGBS, gains early strength at 7 days of curing (Mishra et al., 2024). Furthermore, the compressive strength of geopolymer mortar at the ratio of 0.35 was reduced slightly. The unreacted GGBS particles, which act as filler, help reduce the mortar's porosity but do not contribute to strength development (Zhang et al., 2022).

4. CONCLUSION

In summary, the optimum water-to-binder ratio for geopolymer mortar that made up of GGBS with ratio of 4.0 as the compressive strength can be achieve up to 40.88 N/mm^2 and water absorption of 4.47% after 28 days of curing. Meanwhile, as evidenced by compressive strength, GGBS can gains early strength which development of denser and complex structure.

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