Properties and Applications of Geopolymer Mortar

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Classic cement mortar is often utilised as a standard binding and repairing material in various engineering structures. Many scholars have addressed GPM's viability and potential applications as a suitable replacement for regular cement mortar. Sathonsaowaphak was the first to investigate geopolymer mortar and studied the properties of bottom ash fineness, ash/liquid alkali ratio, $NaOH/Na_2SiO_3$ ratio, NaOH dosage, water to ash ratio, and superplasticiser on the behaviour in terms of workability and compressive strength of GPM. Geopolymer mortar has a mechanical strength of 24–58 MPa, and adding NaOH solution improves the workability performance of GPM without reducing strength. According to the results of Detphan and Chindaprasirt, who prepared GPC using rice husk ash and fly ash and activated by NaOH and $NaSiO_3$ solution as a liquid for the mix, they found that the maximum strength of GPM is acquired by employing a Na_2SiO_3-to-NaOH mass ratio of four. Moreover, more discussion about geopolymer mortar properties is reported in the following Content.

Keywords: geopolymer composites ; clean technology ; flexural strength

1. Fresh Geopolymer Mortar Properties

1.1. Fresh Geopolymer Mortar Workability

The workability of fresh geopolymer mortar (GPM) is crucial in determining the hardened GPM quality. The concentration ratio of NaOH determines the geopolymer mortar's workability and the Na_2SiO_3 to NaOH. The flowability of modern mortars is typically controlled with the addition of water, which does not compromise the mortar's strength [1]. Flow, which a flow test may evaluate, is frequently used to determine whether mortar is workable. The term "flow" is widely used to describe how well new mortars work, and it is given as a percentage of the starting base diameter as per the ASTM C1437 standard [2]. Some testing instruments include a flow mould, measuring tape, tamper, flow table, and trowel. The flow test determines a material's consistency, filling ability, and workability. Sathonsaowaphak [3] studied the effect of bottom ash (BA) fineness on mortar workability and suggested that ground bottom ash might be employed as a raw material for the production of geopolymer. When the fineness of BA was increased, the workability of the mortar was improved, as well as the impact of various liquid ratios of alkaline/ash. The workability of the mixes improved as the liquid alkaline/ash ratio was raised.

Bhowmick and Ghosh [4] determine the impact of fly ash/sand ratios and the influence of SiO_2/Na_2O ratio inactivators on GPM workability. They found that the flow value percentage increases with the fly ash/sand ratio, and the fresh geopolymer mortar's flowability increases as the SiO_2/Na_2O ratio in the activator increases.

1.2. Fresh Geopolymer Mortar Setting Time

Fresh mortar setting time is critical for transporting, casting, and compacting the mortar within the time restriction. The Vicat needle device can be utilised to test the setting times per the BS EN 480-2 and ASTM C 807-13 standards [5][6]. The first and final setting times are calculated using the needle's depth as a reference point, which ranges between 2.5 and 4 mm [6][7]. In order to determine the influence of time after mixing on dielectric properties before heat curing, cast specimens were kept in a laboratory at 28 to 29 °C while being protected from moisture loss by a vinyl sheet geopolymer. The dielectric characteristics of GPM were then measured after being mixed for 24 h [7]. Jumrat et al. [7] investigated the setting time of the specimen's mixture with the addition of water to obtain the standard flow. The results demonstrate that the weight proportions of NS/NH and FA/AS do not affect the initial and final setup periods. The setting time reduces as NS/NH and FA/AS weight ratios increase [8]. By increasing the molarity of NaOH, the initial and final setting times of GPM can be greatly decreased [9].

The setting time reduction in GPM has been attributed to the increased use of PCs.

2. Geopolymer Mortar Mechanical Properties

2.1. Geopolymer Mortar Compressive Strength

Numerous types of source materials are employed as base materials for producing geopolymers. The raw materials used and the proportioning factors impact the strength of GPM. A. Erfanimanesh et al. [10] tried to compare the compressive strength of GPM at the ages of 7 and 28 days, using two different mixed materials (PC mortar, slag, and zeolite). The findings revealed that the compressive strength of GPM increased by up to 48% in the first 7 days compared to the cement mortar after 28 days.

Yusuf et al. [11] studied the effect of blending silica-rich (MK) and palm oil fuel ash (POFA) on the strength of GPM. They indicated that the Weibull distribution is suitable for analysing the blended GPM. Low calcium FA, GGBFS, and POFA can be combined to manufacture GPM under the standard condition that their percentage should be suitable. Ismail et al. [12] investigated the early strength characteristics of a GPM made from palm oil fuel and ash metakaolin with various degrees of NaOH and Na_2SiO_3 medium replacement. Ismail et al. [12] studied the compressive strengths of GPM with sisal fibre (SF), coconut fibre (CF), and glass fibre (GF).

Phoo et al. [13], who studied the compressive strength of GPM with different NaOH dosages (6, 10, and 14 mol/dm^3), found that high calcium FA GPM comprised of PC type I showed increasing PC replacement levels and NaOH concentrations as well as increasing mortar compressive strengths.

A. De Rossi [14] discovered that the strength of geopolymer mortars was affected by the use of construction and demolition waste (CDW) fine aggregates. GPM was formed by combining biomass FA waste and MK as a binder, sodium hydroxide as an activator, alkali sodium silicate solution, and CDW as fine aggregates. Except for the mortar created with particles of 1.0–2.0 mm, when the maximum strength was acquired with sand, CDW was used as aggregate. For CDW–geopolymer mortars, the values were 21 MPa (1.0–2.0 mm), 34 MPa (0.5–1.0 mm), and 40 MPa (0.5–2.0 mm). The mixed fraction had the highest strength values due to the maximum packing density.

2.2. Geopolymer Mortar Flexural Strength

In cement mortars, compressive and flexural strength are tightly linked. However, due to the incredible fragility of the geopolymer and its firm adherence to the aggregate particles, geopolymer mortars have high flexural strength but poor compressive strength [15]. With the addition of sand concentration to 77%, the flexural strength of GPM improves and reaches its maximal value, which slowly decreases because there is an insufficient binder to hold the grains together [16]. Thus, these findings indicate the formation of coarse pores and increased porosity. The alkali activator solution type and curing temperature impact GPM's flexural strength considerably [17]. According to the results of Huseien et al. [17], the GPM with a curing temperature of 28 °C has higher flexural strength than mortars with curing temperatures of 60 °C and 90 °C. Additionally, the activator solution of sodium aluminosilicate hydrate has lower flexural strength than the sodium hydroxide solution [18]. Li et al. [19] studied the influence of curing conditions on the strength of Class-C FA geopolymer at W/F0.35, where he concluded "For Class-C FA GPM with a water/ash ratio of 0.35 (CF35-C), the findings showed that before the age of 7 d, the non-standard curing shows much higher flexural strength than the standard curing. After steam curing for 24 h and 6 h, flexural strength increased sharply at the age of 1 d; then, strength developed slowly". Atis et al. [20] studied the flexural strength of GPM with various sodium concentrations and cured it for 24, 48, and 72 h at temperatures ranging from 45 °C to 116 °C. Atis et al. [20] showed the GPM containing 13% sodium after 24 h of heat curing at 116 °C had the maximum flexural strength, while the GPM incorporating 4.0% sodium after 24 h of heat curing at 106°C had the lowest flexural strength. Al-Majidi et al. [21] investigated the effect of Ground granulated blast-furnace slag (GGBFS) content on the ultimate flexural strength of GPM specimens cured at ambient temperature and variations in flexural strength with increasing GGBFS volume at curing ages of 7, 14, and 28 days; the results showed that at all ages, increasing the GGBFS content increased the ultimate flexural strength of GPM significantly. At 7 days, the flexural strength was improved by increasing the GGBFS content from 10 to 20, 30, and 40%, respectively. Flexural strength increased with longer curing durations, with flexural strength values for 10S, 20S, 30S, and 40S combinations rising at 14 and 28 days, respectively, compared to flexural strength values at 7 d.

According to Erfanimanesh et al. [10], flexural strength comparison between GPM and PC mortar (Na_2CO_3 concentration was about 10% by weight of powder mixes (zeolite and slag), and 100% Fine Aggregate). GPM's flexural strength was tested using two distinct mix designs that used slag and zeolite as base ingredients. The geopolymer and the PC mortars had nearly comparable flexural strengths.

Wongsa et al. [22] examined the properties of GPM comprising natural fibres and high levels of calcium fly ash. The primary materials in this investigation included coir or coconut fibre (CF), glass fibre (GF), and sisal fibre (SF). SF and CF were acquired from a plant farm in the Thai provinces of Prachuap Khiri Khan and Chon Buri, respectively. According to the results, utilising fibres enhanced GPM's flexural strength. In addition, the flexural strength of GPM tended to increase as the fibre content increased. Even though flexural strengths increased with fibre content, the mixtures with more than 1% volume fraction had poor workability and were challenging to compact and cast. The flexural strength of GPM reinforced with natural fibre (CF and SF) varied from 5.3 to 6.6 MPa compared to CGM (3.2 MPa) and GPM reinforced with synthetic fibre (GF) (3.1–3.7 MPa).

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