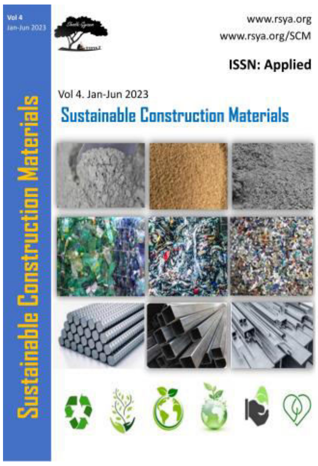

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Experimental Investigation of GGBS and Calcined Clay Based Geopolymer Mortar Fresh and Hardened Stage Properties

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Abstract: A long-term option for turning industrial waste into geopolymer composites is alkali activation of ground-granulated blast-furnace slag (GGBS) and calcined clay. The development of calcined clay-based geopolymer mortar and ground granulated blast furnace slag (GGBS) is the goal of this work. Alkaline activator is used to activate the aluminium silicates that make up GGBS and calcined clay. The alkaline activator is created using solutions of 8 M sodium hydroxide. Geopolymer consistency, setting time, and compressive strength were examined at ages 3, 7, and 28 days in relation to mixture proportioning and curing conditions. Process parameters such as the proportion of calcined clay, GGBS, fines content, and alkaline activator solution content were all studied. The experimental findings demonstrated that increasing the proportion of calcined clay in geopolymer mortar improved consistency and setting time. The highest compressive strength is reached when GGBS is employed 100 percent of the time in the mortar mix, and as the proportion of calcined clay replaced by GGBS in the mortar mix increased, the compressive strength decreased.

Keywords: Geopolymer mortar, alkaline activator, GGBS, Calcined clay, Compressive strength, consistency.

INTRODUCTION

For the construction of concrete road surface, building structures, dams, and residential buildings, cement is the most practical construction material in the world[1], [2]. With the advent of high performance concrete, concrete's strength and longevity have increased[3]. Cement manufacture uses a significant amount of energy and contributes to increased CO2 emissions[4]. About 5% of the world's carbon emissions are caused by cement production[5]. Additionally, only steel and aluminium require more energy to manufacture than OPC. On the other hand, the increased accessibility of fly ash presents an opportunity to partially replace OPC in the production of cement and concrete products with this coal combustion byproduct[6]. Geopolymer has the potential to replace OPC in the construction sector. In order to completely replace OPC in the manufacturing of geopolymer concrete, geopolymer is used as the binder[7]. On the other hand, geopolymer is a novel building material that may be made without the use of Portland cement through the chemical synthesis of inorganic molecules. The geopolymer, an aluminosilicate binder that is three dimensional and devoid of CaO, was discovered by Joseph Davidovits[8]. By alkali activating aluminosilicate raw materials and then geopolymerizing them in a high pH environment with a low curing temperature, geopolymer is a form of ceramic material[9]. Studies conducted in the past have shown that these novel materials are more environmentally friendly than Portland cement because to their low energy requirements, inflammability at high temperatures, and acid resistance. The chemical interaction between aluminosilicate materials, such as sodium hydroxide and calcined clay that are rich in SiO2 and Al2O3, and an alkaline solution can result in the formation of geopolymer binding[10]. GGBS is an environmentally beneficial substance created from a waste product of the production of iron. In comparison to Portland cement, calcined clay may be made in large quantities with homogenous qualities by heating kaolinite to temperatures between 650°C and 750°C[11][12]. The use of geopolymer as a protective covering for coastal concrete and transportation infrastructure has been one of the focus areas of geopolymer research over the past ten years[13]. In order to employ geopolymer as a repair material, there needs to be a strong bond between it and the substrate. Portland cement concrete and geopolymer concrete can coexist since their Poisson's ratios, elastic moduli, and tensile strengths are equivalent to those of ordinary concrete [14]. In addition, when soaked in an acidic solution, geopolymer concrete degrades significantly more slowly than Portland cement concrete. For the purpose of repairing failing infrastructures such manholes, chambers, and pipes, etc., geopolymer can be employed using the same tools and techniques as Portland cement concrete. Workability and strength are two essential characteristics shared by geopolymer, mortar, and concrete. Water can be used to significantly improve the workability of the geopolymer mortar with only a slight loss in strength. The GGBS mortar with calcined clay used in this investigation has been obtained. GGBS has cement-like characteristics. As a result, it has replaced conventional cement as the main binding component. This study concentrated on the fresh and hard characteristics of geopolymer mortar for various GGBS and calcined clay content levels.

MATERIALS

GGBS is a product that is favourable to the environment and is constructed of metal. It is both a high-quality and low-CO2 material. By extracting molten metal slag—a mixture of metal and metal—from a furnace in water or steam, the glassy, granular product GGBS is created. With a maximum particle size of 96.12 m, GGBS has a moisture content of 0.12%. GGBS has a specific gravity and bulk density of 2.85 and 1275 kg/m3, respectively. By raising the temperature of a kaolinite source to between 650°C and 750°C, calcined clay can be produced. It is a pozzolanic substance with particles that are smaller in size than Portland cement. Compared to other pozzolanas, it is considerably more effective. Calcined clay comes in the form of a white powder with a specific gravity of 2.45. Table 1 displays the chemical make-up of GGBS and calcined clay. Sand is a granular material made up of perfectly spaced-out rock and mineral particles. Although the sand is separated into layers, each layer is distinguished by its grain size. The size of sand particles is between that of gravel and silt. Sand can also be used to describe a class of soil or a specific type of soil, i.e., soil having particles that are more than 85% of their original size. Sand has a specific gravity of 2.74 and a fineness modulus of 2.25. Sodium hydroxide is also referred to as caustic soda. At room temperature, sodium hydroxide is a solid that is white and odourless. Liquid sodium hydroxide has no flavour or colour.

Strong acids and water trigger an immediate reaction. It is a brilliant base and alkali that, at standard temperatures, decomposes protein and can cause severe chemical burns. It readily dissolves in water and absorbs atmospheric moisture and carbon dioxide. For this study, sodium hydroxide in an 8 M solution is used.

METHODOLOGY

Alkali solution is typically a sodium hydroxide solution. Make this solution by dissolving 320 grammes of flakes in 1000 millilitres of water in a conical flask. As soon as the NaoH flakes are completely dissolved in water, slowly stir the solution in the flask. Three minutes are spent manually combining the dry ingredients (GGBS, calcined clay, and sand), after which a solution of NaoH is progressively included. To get consistent mortar mix, materials and solution must be mixed for five to ten minutes. Then, the mortar mix is filled into the cubes (70.7 mm X 70.7 mm X70.7mm). In order to allow for air curing, samples are kept at room temperature. At 3, 7, and 28 days, testing is conducted. Vicat apparatus is used to assess the consistency and initial and final setting times of GGBS and calcined clay paste. According to IS: 516-1959, the compressive and tensile strengths of mortar specimens were tested after 3, 7, and 28 days.

Figure 1: (a) calcined clay (b) GGBS (c) flakes of sodium hydroxide (d) fine aggregate

Table 1 Chemical composition of Calcined clay and GGBS

Compounds	Calcined clay	GGBS
CaO	0.49%	34.48%
SiO_2	70.42%	30.61%
MgO	0.16%	6.19%
Al_2O_3	22.34%	16.24%
Fe_2O_3	2.34%	0.584%
SO_3	0.02%	1.85%

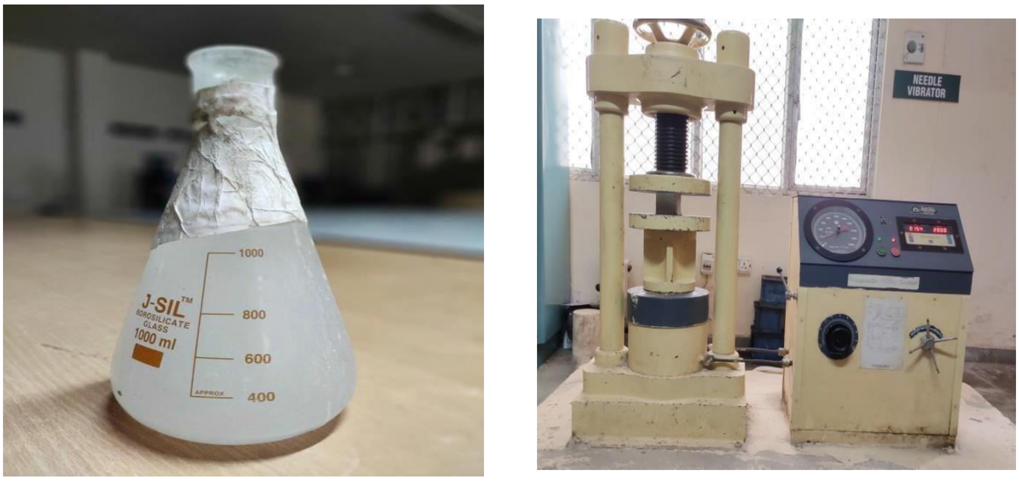

Figure 2: (a) Solution of sodium hydroxide (b) compression testing machine

RESULTS AND DISCUSSION

Normal consistency

When determining amount of water needs to be added to cement in order to obtain a standard or typical consistency, the consistency of cement test is utilised. According to figure 3, maximum consistency was reached at G70C30 (a). This consistency exceeds G100C0 as 37 by a significant margin. The consistency values and the vicat apparatus for measuring the consistency are shown in Figures 3(a) and 3(b).

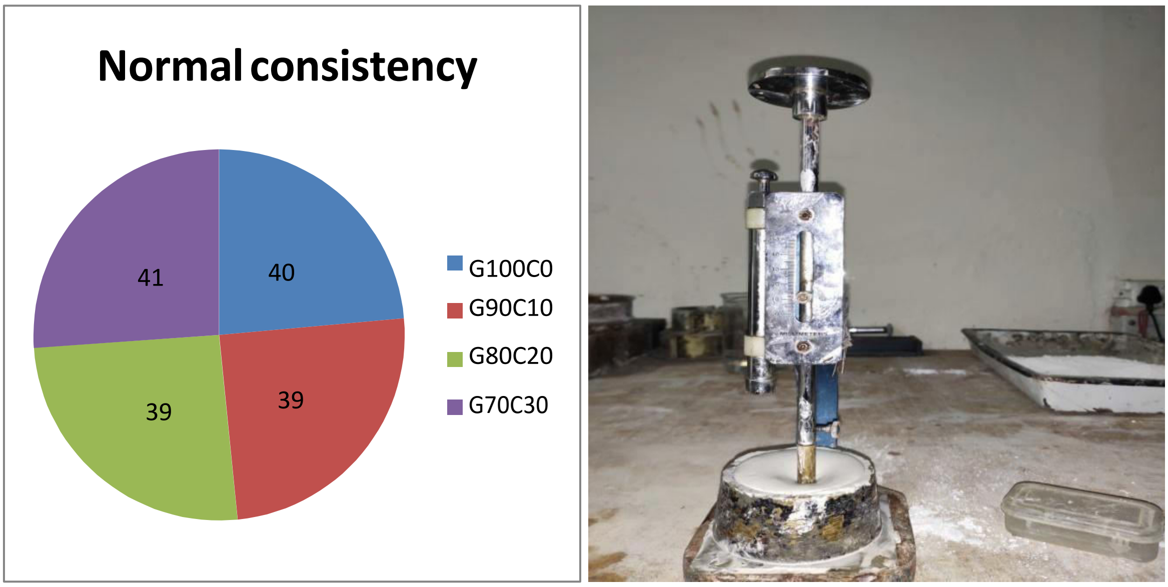

Figure 3: **(a)** Normal consistency of GGBS and Calcined clay paste **(b)** Consistency test by vicat apparatus

Initial and Final Setting Time

The paste's setting time was calculated in minutes. Setting time tests using different ratios of ggbs and calcined clay were carried out under the specified circumstances. At G70C30, the maximum beginning and final setting times were 43 minutes and 82 minutes, respectively. Given that 25 minutes and 59 minutes are referenced in figure 4, this setting time is significantly longer than that of G100C0. It is evident that as the percentage of calcined clay increased, so did the initial and ultimate setting times. Due to the existence of low calcium inputs from the source material, when the substitution of calcined clay increased from 0 to 30 percent, their reactivity decreased compared to GGBS [15].

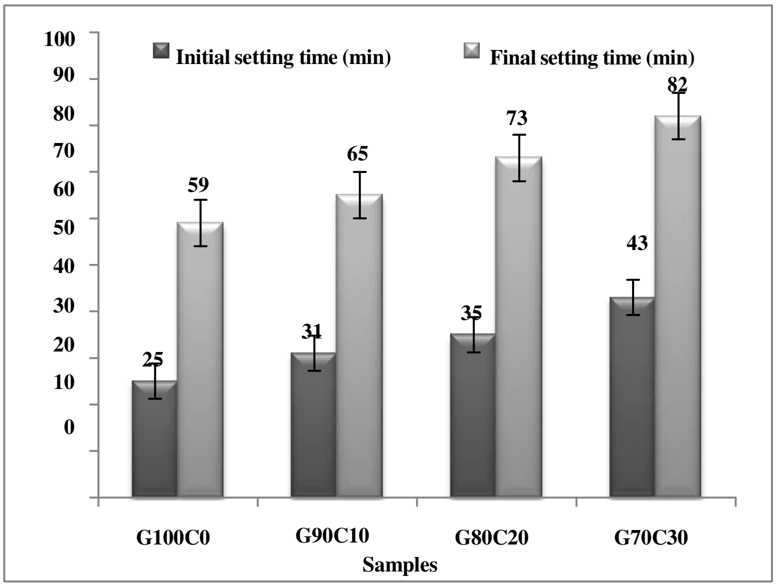

Figure 4: Setting time of GGBS and Calcined clay paste

Compressive strength

To determine the true strength of geopolymer concrete, a 70.6 mm X 70.6 mm X 70.6 mm cube is loaded at a 90 degree angle. The results of the compressive test conducted on various mixes are shown in Fig. 2The goal of the experimental study was to ascertain the effect of alkali activated activator solution on the GGBS and calcined clay based geopolymer mortar's strength. From this research, the following findings can be drawn:

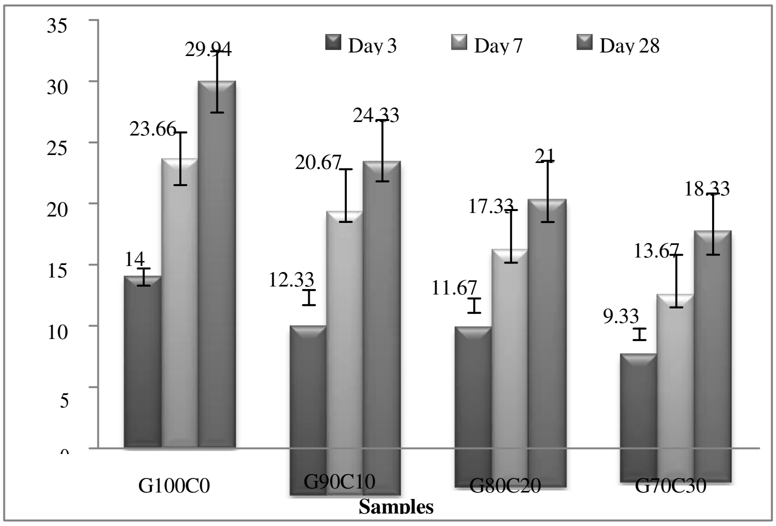

Figure 5: Compressive strength test of geopolymer mortar

According to Fig. 5, geopolymer specimens of G100C0 show the largest improvement in compressive strength, increasing by 18.73%, 29.85%, and 38.77% at 28 days compared to G90C10, G80C20, and G70C30. The idea that slag-based GPC has stronger early age strength is consistent with the improvement in compressive strength that was seen as the quantity of GGBS in the geopolymer mix was increased [15].

CONCLUSION

The objective of the experimental study was to ascertain the effect of alkali activated activator solution on the GGBS and calcined clay based geopolymer mortar's strength. From this research, the following findings can be drawn:

- At G70C30, maximum consistency was reached. This consistency exceeds G100C0 as 37 by a significant margin. It is obvious that as the percentage of calcined clay increased, so did the consistency of the samples.
- At G70C30, the maximum beginning and final setting times were 43 minutes and 82 minutes, respectively. This setting time is substantially longer than the G100C0 setting times of 25 minutes and 59 minutes.
- In comparison to G90C10, G80C20, and G70C30 at 28 days, geopolymer specimens of G100C0 show the largest gain in compressive strength, increasing by 18.73, 29.85, and 38.77 percent. As the percentage of GGBS in the geopolymer mixture was raised, strength was shown to increase.

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