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THE METHOD FOR DETERMINING THE EFFECT OF BINDER RATIO AND DIFFERENT CURING METHODS ON STRENGTH PARAMETERS OF GEOPOLYMER CONCRETE

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ABSTRACT

It is being investigated in this study how different source materials and NaOH concentrations affect the strength of geopolymer concrete to determine how different source materials and NaOH concentrations affect the strength of the concrete. For two other binders, 360 and 400 kg/m3 (replacing flyash with GGBS with 70-30, 60-40, and 50-50) with different A/B ratios (0.45 and 0.5), the compressive strength of specimens is investigated for 7, and 28 days (outdoor curing and oven curing at 60 °C for 24 hours) following an alkaline solution made of NaOH and Na2Sio2, under an alkaline solution made of even though higher GGBS concentrations have a detrimental influence on workability, the combination of fly ash and GGBS during the outdoor curing process can result in increased strength and suitability for particular applications, according to the manufacturer. Therefore, it is feasible to cure specimens in real-time applications, despite oven curing providing the most substantial potential result.

Index terms: Alkaline activator, binder content, compressive strength, flyash, sodium hydroxide, sodium silicate, workability

INTRODUCTION

This study shows how novel CO_2 capture and utilization techniques can yield amazing outcomes. Cement demand is expected to climb as infrastructure construction intensifies. Cement production makes up roughly 3% of overall cement production. It demands a significant quantity of resources, as well as sedimentary rock. The cement sector accounts for approximately 8% of global carbon emissions, a greenhouse gas contributing to global warming]. New technology is required to mitigate the harmful consequences of the cement trade [1], [2], [3], [4]. Because of their superior properties, alkali-activated binders can assist with this. Concrete binders include inorganic binders (such as gypsum, lime, and cement), organic binders (such as emulsions and epoxy resins), and mineral binders (such as rice husk ash, red mud, silicon dioxide fume, metakaolin, GGBS, and fly ash). This study uses ground granular blast furnace slag (GGBS) and flyash as binding materials and an alkaline activator (combined hydroxide and silicate solution). Ceramic powder is made from high calcium content tiles and has superior structural capabilities to concrete [5]. Concrete has a stronger compression zone than a lesser tension zone. Although concrete is reinforced with a range of fibers [6], [7], aggregate texture significantly impacts its strength. The concrete's fire resistance should be tested at various temperatures [8]. The most common industrial byproducts of GPC are GGBS and ash. In 1978, a Frenchman used "geopolymer" to describe minerals with chemical compositions similar to mineral binders. Geopolymers rely heavily on alkali

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activators and source activators. GPC power gels are created by alkali-resolving silicon dioxide and alumina in alumina. This process contributes to the environmental friendliness of geopolymer concrete. As sources, flyash, metakaolin, GGBS, and other minerals can be employed. He also makes use of garbage from numerous enterprises. The construction industry, for example, is seeking to reduce cement production by utilizing industrial byproducts that emit fewer emissions. As a result, geopolymer is an excellent binder for concrete preparation that can be used instead of cement. GPC is created by combining an alkaline activator with silica (Si) and alumina (Al) rich source materials. A literature review led to the conclusion that fly ash might be utilized successfully as a GPC base material. To obtain initial strength, geopolymer concrete requires 24 hours of curing at 60°C. The cement manufacturing process is a major source of greenhouse gas emissions in massive construction projects worldwide that rely on cement for concrete. According to [9] the same amount of carbon is released into the atmosphere during cement manufacturing for one ton of cement. This is related to the decarbonization of limestone in kilns and fossil fuels in cement production. [10] 0.53 tons of CO_2 are released throughout the cement-making process. When carbon fuel is used to create cement, 0.98 tons of CO_2 are released into the atmosphere, contributing to global warming and emissions. Thus, replacing cement in a construction project with geopolymer material reduces pollution by lowering CO_2 emissions into the air and utilizing fly ash, a waste product from thermal power plants. Waste must be eliminated and repurposed as a viable cement alternative by cement-producing enterprises [11]. Processing fly ash reduces greenhouse gas emissions by 80 to 90 percent [12]. The materials used are influenced by cost, availability, and application. Geopolymer concrete employs sustainable building materials as binders. Instead of cement, the area's industrial wastes are used as a binder. Because of its waste management and low greenhouse gas emissions, GPC is both cost-effective and environmentally friendly [13]. This research aims to determine how different source materials and NaOH concentrations affect the strength characteristics of GPC Alkaline activators in fly ash-based geopolymers cause the silica and alumina in the source material to gel improving bonding between aggregates and unreacted components. According to [14] geopolymer concrete requires thermal curing at 40-70 degrees Celsius to accelerate the hydration process. As a result, the samples are baked for 24 and 48 hours, respectively. [15] Investigated the qualities of geopolymer concrete with various GGBS-to-flyash ratios and discovered that raising the GGBS concentration increased strength while lowering workability. Several scholars have conducted a limited study on geopolymer concrete to investigate mechanical properties with various GGBS substitutions and molarities. This discovery will serve as a model for future geopolymer researchers. When a geopolymer concrete hardened outside demonstrated good compressive strength, it paved the way for further study into this material. According to [16], aggregate content, sodium silicate to sodium hydroxide ratio, oven curing temperature for 24 hours, and alkaline solution to fly ash ratio all impact the performance of flyash-based geopolymer concrete. A mixture with a total aggregate concentration of 70%, a sodium silicate to sodium hydroxide ratio of 2.5, and a sodium hydroxide molarity of 10 M had the highest modulus of elasticity. [17] The strength properties of geopolymer concrete produced with fly ash were investigated. This study

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also looked at fine aggregates, sandstone, and the sodium hydroxide/sodium silicate 1:2.5 ratio. After 90 days, the strength was nearly 60% higher than after 28 days, when the binder content was 410 kg/m3. For GGBS replacement ratios of 0, 10, and 20%, the SS/SH ratio was computed. (1.5-2.5). [18] investigated how GGBS content affected the behavior of fly ash and GGBS-based geopolymer concrete. The mechanical characteristics of GPC improved as the GGBS concentration grew, while its workability declined when the alkaline/binder ratios fell. According to [19], increased GGBS concentration in geopolymer concrete improves mechanical properties when exposed to the environment. GGBS can be used to reduce oven curing in fly ash-based systems. In this study, geopolymer concrete was made and baked in an oven and outside. According to [20], the molar ratio of Na_2SiO_3/NaOH influences the properties of geopolymers. Several tests have been conducted to find the maximum compressive strength value with constant binder content. According to [21], heat at room temperature for an extended time considerably increased the strength of fly ash-based GPC. The effects of changing the sodium silicate to sodium hydroxide ratio (1-1.5) and alkaline content while keeping a sodium hydroxide concentration of 10M were studied. The compressive strength of geopolymer concrete has increased with GGBS, as has the alkaline content. According to published research, geopolymer is an effective concrete binder with high strength, durability, cost-effectiveness, and environmental friendliness. This study aims to discover how concrete behaves in terms of strength. For preparing geopolymer concrete, NaOH and Na_2Sio_2 outperform any other alkaline solution. Flyash dissolves faster and has a higher compressive strength because it contains silicon and aluminum. Alkaline solutions can activate GGBS particles. [22] pointed out that the polymerization rate and strength are enhanced by replacing GGBS with fly ash in varying quantities. The significance of this research effort in terms of research is discussed in this publication. Geopolymer concrete, unlike normal concrete, does not use a mixed design process. Many researchers have proposed a GPC based on GGBS. However, more research on GGBS under various curing conditions is required [23]. Geopolymer concrete material quantification is necessary for practical GPC applications.

METHODOLOGY

In this study, fly ash and GGBS were used as raw materials. These materials were obtained from several local sources. GGBS and fly ash had specific gravities of 2.17 and 2.90, respectively. Table 1 details the chemical composition of the raw components. The morphology of the fly ash and GGBS was examined using a scanning electron microscope (SEM). According to our observations, fly ash particles are spherical and composed mainly of silica and alumina, whereas GGBS grains are crystalline and angular in shape.

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TABLE 1: Chemical Composition of Flyash and GGBS (percentage by mass)

Chemical Composition	Fly ash	GGBS
SiO_2	60.11	34.06
Al_2O_3	26.53	20
Fe_2O_3	4.25	0.8
SO_3	0.35	0.9
Cao	4.00	32.6
MgO	1.25	7.89
Na_2O	0.22	NIL

Super Plasticizer

To improve workability, a sulfated naphthalene formaldehyde-based superplasticizer is utilized.

Fine aggregate

We utilized Zone-2 compatible fine aggregate. On the spot, the fine aggregate was obtained. To make Zone-2 sand, the required proportions of each size fraction must be blended.

Coarse aggregate

As a coarse aggregate, crushed granite was used. It is obtained from a local crushing plant with a nominal size of 20mm. The dimensions of the sieves used to sieve the coarse aggregate from the quarry are used to calculate the amount of each size fraction that must be blended.

Preparation of an Alkaline Solution

The concentration of NaOH in the GPC solution determines its strength. For GGBS and fly ash blends, the nominal molarity range is 2 to 10 M. High strength, on the other hand, leads to a higher sodium hydroxide concentration [24]. All combinations' compressive strength increased from 8M to 16M [25]. The qualities of geopolymer concrete were examined by mixing it with 8M sodium hydroxide. The solution comprises 320 grams of NaOH pellets dissolved in drinkable water per liter. Before casting, the sodium silicate solution must be mixed 2.5 times with sodium hydroxide solution and held for 24 hours at 25°C with a relative humidity of 65 percent. Then, a suitable amount of sodium silicate solution (2.5 times the weight of sodium hydroxide solution) is added to produce an alkaline activator [26], [27], [28]. Because NaOH generates a significant amount of heat when it reacts with water, it must be cooled to room temperature before concrete can be poured.

Casting and Curing of GPC.

Individually, the dry components are weighed and blended in a 100 kg revolving drum pan mixer. After the dry ingredients have been well combined, the alkaline liquid and superplasticizer are added. As a result, Figure 2 depicts a few instances of geopolymer

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concrete cubes. Continuous mixing, on the other hand, should provide homogeneous mixing for 5 to 7 minutes to ensure the workability of GPC. After inserting newly mixed concrete into concrete moulds (150mm x 150mm x 150mm), the table vibration process was used for 45 seconds, followed by 24 hours of settling. After 24 hours, the cast specimens were demolded and thoroughly cured. Cured specimens are placed out in the open (at a temperature of 25 degrees Celsius and relative humidity of 65 percent) until the testing age (7 and 28 days). The demolded specimens are kept at 60ºC for 24 hours as part of the oven curing phase. Then they are removed from the oven and let to cool for the appropriate amount of time (7 or 28 days).

The Workability of Geopolymer Concrete

Geopolymer concrete is challenging to compact due to its rigid consistency when new. The only way to make geopolymer concrete workable is to utilize high-range admixtures that reduce water content, particularly naphthalene-based superplasticizers. A binder dosage of 4 percent by mass was required to complete this trial. The slump values of geopolymer concrete were determined using a slump test, as indicated in Table 2. The slump is visible at high alkaline-binder ratios, binder concentrations, and fly ash levels based on slump values. With the same binder content, an increase in the alkaline-binder ratio resulted in a decrease in slump values. Due to the lower alkaline concentration, an additional superplasticizer is necessary to achieve optimum workability. Because GGBS particles are angular and react quickly, substituting GGBS for fly ash reduced slump values.

TABLE 2: Workability of Geopolymer Concrete

Fly ash: GGBS	Alkali-Binder ratio	Binder Quantity (kg/m^3)	
		360	400
70:30	0.45	95	102
	0.5	102	125
60:40	0.45	84	100
	0.5	100	110
50:50	0.45	78	92
	0.5	92	101

DISCUSSIONS AND OUTCOMES

As a result, the compression strength is determined and given in Table 3. In addition, however, alternative binder content, various GGBS to flyash substitutes, alkaline binder ratios, and curing regimens were chosen from the above-developed mix, and a detailed discussion on the effect of healing and the impact of age is shown.

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TABLE 3: Compressive Strength of Geopolymer Concrete of 360 and 400 kg/^{3}

Binder content (Kg/m3)	Source material (Flyash: GGBS)	A/B ratio	Type of curing and Strength (Mpa)			
			Ambient curing		Oven curing	
			Seven days	28 days	Seven days	28 days
360	70:30	0.45	17	32	18	35
		0.5	18	33	19	37
	60:40	0.45	19	34	20	38
		0.5	19	34.5	21	39
	50:50	0.45	21	35	23	39
		0.5	21	36	23	40
400	70:30	0.45	27	39	28	41
		0.5	28	40	29	42
	60:40	0.45	29	41	30	42
		0.5	29	42	31	43
	50:50	0.45	31	44	33	45
		0.5	31	45	33	47

The effect of curing on the compressive strength of concrete

This study looks into outdoor and oven curing impacts on compressive strength. Geopolymer has a higher compressive strength in the range than it does outdoors. The polymerization process is sped up at a higher temperature than the ambient temperature, increasing the strength. Therefore, concrete should be cured at room temperature in many practical applications. When the molarity of sodium hydroxide is considered to be 8M, the GPC specimens cured at outdoor temperatures reached a maximum strength of roughly 45MPa for 400 kg/m^3, whereas 47MPa at oven temperature. Outdoor curing fly ash and GGBS-based geopolymer concrete are possible even with a low NaOH molarity. As a result, where oven curing is difficult in the field. As a result, GPC formed from GGBS, which replaces fly ash, can be manufactured without an oven. The compressive strength values obtained from the experimental work are shown in Table 3 for both 7 and 28 days. As the proportion of GGBS in the mix was altered with increasing alkaline content, the compressive strength increased after seven days and lasted for 28 days. After 28 days, GGBS-based mixtures with 50% GGBS content outperformed GGBS-based geopolymer concrete. The enhanced calcium concentration of GGBS contributed to the combination's increased strength. The inclusion of soluble calcium increases compressive strength and speeds up the hardening process [29].

The Strength of Concrete as a Function of Age

Even though concrete strengthens after 28 days, it is frequently referred to as 28-day concrete strength. GPC's seven-day and 28-day strength have a significant correlation. The strength of geopolymer concrete after seven and twenty-eight days is being studied. The molarity of an alkaline activator in geopolymer concrete is proportional to the binder concentration and curing regime. Strength develops faster at a young age than at an older age. For both types of curing, the strength gain was more prominent for oven-cured GPCs than for outdoor-cured GPCs. After seven days of curing, the compressive strength of the oven-cured specimen is greater than that of the outdoor-cured sample. The initial rate of strength gain is considerable, but it does not last as long as regular concrete. The ratio of 28-day compressive strength to 7-day compressive strength demonstrates this.

CONCLUSION

1. It is demonstrated that GGBS, an industrial waste product, can be used to manufacture geopolymer concrete.
2. The compressive strength of fly ash and GGBS increases as the concentration of sodium hydroxide solution rises.
3. Geopolymer mortar is more durable when the GGBS component is more significant.
4. GGBS mixed with fly ash can aid in the creation of geopolymer mortar in outdoor curing conditions.
5. The curing process is crucial for polymerization.
6. Extensive testing on fly ash and GGBS-based geopolymer concrete reveals that substituting GGBS for fly ash enhances concrete compressive strength independent of curing. The advantage is more fantastic for outdoor curing.
7. The critical temperature for geopolymer concrete based on fly ash and GGBS has been determined to be 60°C.
8. The effect of GGBS on workability is inversely proportional.
9. The compressive strength of the GGBS increased when 50% of the GGBS was replaced with fly ash for a binder content of 360 kg/m3.
10. A similar tendency was discovered at binder amounts of 400 kg/m^3.
11. The proposed methodology was used to conduct workability and compressive strength tests on intermediate mixes, yielding reliable workability and compressive strength results.
12. Under outdoor curing circumstances, combining fly ash and GGBS could be a viable solution for making geopolymer concrete.
13. When GGBS is added, geopolymer concrete sets much faster and gives greater strength without heat curing.

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