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Evaluation of Strength In Fly Ash Based Geo polymer Concrete

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Abstract

Construction materials that are friendly to the environment are now being researched and developed all over the globe in an effort to limit the use of natural resources that are depleting at an alarming rate and to cut down on the production of greenhouse gases. In this respect, geopolymer plays an extremely important function, and a large number of researchers have investigated the numerous dimensions of its viability as a material for binding. In order to alter the geopolymerisation reaction of fly ash, ground granulated blast furnace slag (abbreviated as GGBS) has been used into fly ash-based geopolymer concrete (abbreviated as GPC). In this paper, the influence of various proportions of GGBS (0-100%) on Fly Ash based GPC, as well as the effect of the amount of Alkaline Activated Solution (AAS) in the mixture of GPC, is studied to determine how it affects the compressive strength of the GPC under conditions of ambient temperature. It was observed from the results of the experiments that the compressive strength of the GPC increases both with an increase in the percentage of GGBS and also with an increase in the amount of the sodium silicate solution in which the concentration of sodium hydroxide in the aqueous solution is fixed at a constant value of 10M. This was the case even though the amount of sodium hydroxide that was present in the solution remained the same.

Keywords: Alkaline Solution; GGBS; Geopolymer; Flyash

1. Introduction

It is generally agreed that climate change is one of the most significant environmental challenges now confronting mankind. The manufacturing of cement results in the release of carbon dioxide (CO_2) due to the decarbonization of limestone(Aleem, M.I.A and Arumairaj, 2012; Aleem, 2016). Cement is one of the construction materials that is used across the globe in the greatest quantity. The production of concrete and cement both produce significant amounts of carbon emissions. During the assessment of strategies to reduce carbon emissions, emissions and should be taken into consideration. It is accountable for something in the neighbourhood of 6% of the total CO_2 emissions(Bharti et al., 2020; Amran et al., 2021). The production of one tonne of Portland cement results in the emission of about one tonne of carbon dioxide into the environment.

Many people consider climate change to be one of the most significant environmental threats that civilization faces today. The calcination of limestone, which is a step in the production of cement, releases carbon dioxide into the atmosphere. Cement is one of the building materials that is utilised in construction the most all over the globe. The production of concrete and the cement industry both represent significant sources of carbon emissions and have to be taken into consideration when evaluating various solutions for the reduction of carbon emissions. It is responsible for around 6% of the world's total CO2 emissions. About one tonne of carbon dioxide is released into the atmosphere for every tonne of Portland cement that is produced. Concrete is by far the most popular building material on the whole world. This is due to the material's exceptional compressive strength, as well as its durability and accessibility. In order to produce ecologically friendly concrete, one of the strategies that is being used is to partially replace the quantity of OPC that is present in the concrete with by-product materials such as fly ash(Tempest et al., 2009; Shahmansouri et al.,

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2021). Fly ash is a byproduct of the burning of coal that is easily accessible in many parts of the globe and contributes to difficulties in waste management. Recent research found that it is feasible to utilise 100% fly ash as a mortar binder if the fly ash is activated with an alkali component, such as silicate salts or non-silicate salts of weak acids. This was discovered over the course of the investigation.

In geopolymer concrete made using fly ash, both silica and alumina may be found naturally occurring within the source. An inorganic aluminosilicate polymer is referred to by its more formal term, geopolymer(Vijai et al., 2010; Vora and Dave, 2013). According to one research, binders might be produced by a polymeric reaction of alkaline liquids with silicon and aluminium in geological source materials or by-product materials such as fly ash. This reaction would take place in geological source materials. These binders were given the term geopolymers by the scientific community. The two fundamental elements that make up geopolymers are the source materials and the alkaline liquids(Wasim et al., 2021). The alumino-silicate source materials that you use should have a high percentage of both silicon (Si) and aluminium (Al).

In the course of this research project, a comprehensive analysis of fly ash-based geopolymer concrete blocks has been carried out. The project's primary objective is to find a way to totally replace cement with fly ash as a binding element. In the first part of the investigation, it was investigated that the production process of low calcium fly ash based geopolymer concrete and its properties, which will include compressive strength, split tensile strength, and flexural strength, among others. In addition, geopolymer concrete specimens were subjected to chemical resistance testing. Studies on the properties of geopolymer concrete blocks and hollow blocks that were cast from the material were done.

2. Material and methods

2.1. Materials used

2.1.1. Mineral Admixture

One of the deposits that is created as a byproduct of burning coal is known as Class F low calcium fly ash. The Class F fly is used in this work. The ash from Tata Power Plant located at Jamshedpur was utilised, which was collected for the experiment. In general, fly ash classified as Class F offers a high level of pozzolanic activity, and it has less than 10% lime content (CaO). Granulated Ground Blast (GGB). The by-product of iron that was collected from JSW Steel Limited in Salem is known as Furnace Slag (GGBS). The characteristics of Flyash and GGBS are compared and contrasted (Table 1).

Table 1 Properties of Mineral Admixtures

Properties	**Flyash**	**GGBS**
Specific Gravity	2.200	2.900
Fineness Modulus	2.730	3.750

2.1.2. Alkaline Solution

Table 2 Properties of Alkaline Solution

NaOH		**Na_2SiO_3**	
Properties	**Values**	**Properties**	**Values**
Appearance	Flaky	Appearance	Colorless viscous
Chemical Composition	NaOH (99.51 % by mass)	Specific Gravity	1.35
	Na_2CO_3 (0.35% by mass)	Mg_2O	9%
	Cl^- (0.05% by mass)	SiO_2	28%
	SO_4^{2-} (0.005 % by mass)	Solids	35-40%
	Iron (8 ppm)		

The Alkaline Activated Solution (AAS) that was used in this scenario was a combination of sodium silicate (Na_2SiO_3) and sodium hydroxide (NaOH), the characteristics of which are detailed in Table II below. It was possible to get a solution of the desired molecular weight by dissolving flakes of sodium hydroxide in water that had been distilled. The combination of water and NaOH flakes resulted in the production of a greater quantity of heat. Because of this, the NaOH solution was made a day before the casting of Geopolymer Concrete, during which the material goes through some exothermic process that ultimately leads in a decrease in heat. After that, the solution of sodium silicate is combined with the solution of sodium hydroxide before batching. The properties of alkaline solutions are mentioned in Table 2.

2.1.3. Aggregates

We made use of local aggregates, which included coarse aggregates of crushed granite-type materials measuring 20 millimetres, 14 millimetres, and 10 millimetres in size, as well as fine aggregates (fine sand) in a saturated surface dry state. Table 3 outlines all of their characteristics for you.

Table 3 Physical Properties of Aggregates

Properties	**Coarse Aggregates (C.A)**	**Fine Aggregates (F.A)**
Specific Gravity	2.620	2.750
Fineness Modulus	2.720	2.970

Table 4 Properties of the Superplasticizers

Appearance	**Light Brown Liquid**
Relative Density	1.080 ± 0.010 at 25 °C
pH	≥ 6.0
Cl- content	< 0.20 %

2.1.4. Superplasticizers

Chemical admixture was added to geopolymer concrete so that issues with the material's poor workability and quick setting time could be mitigated. In the course of this research, Gelenium B233 was applied to concrete in an effort to make it more workable. After thoroughly combining the raw materials and aggregates, it was then added. Table 4 is a listing of their characteristics as provided by the manufacturers.

2.2. Methodology

2.2.1. Proportioning

Because GPCs are a novel building material, they do not yet have a standard approach for the design of their mixes. This is in contrast to Ordinary Portland Cement, or OPC. As a result, the mixes were developed using the technique for mix design that was followed for OPC in accordance with IS 10262 (2009) in order to achieve a characteristic compressive strength of 40 MPa after 28 days. The ratio of AAS to binder was changed with various proportions in order to get a good workability range (Slump of 100mm to 160mm). After doing so, it was determined that 0.55 was the optimal ratio, and this value was used for all of the mixes. There was some variation in the quantities and compositions of GPC and AAS, which are shown in Table V. The mixtures were created for a variable amount of flyash substitution with GGBS, with the ratio of AAS to binder set at 1.00 and 1.50, respectively. Both the rate of superplasticizer and the concentration of NaOH were maintained at a constant 2% across all of the different mixtures. The concentration of NaOH was maintained at 10M throughout. There has not been any more water added to any part of the mixture. As a result of the mixing, it has been observed that the workability of the concrete decreases as the amount of time spent mixing it increases.

2.2.2. Test Specimens

Compaction of the mixture was achieved with the use of table vibration, and the cube specimens measuring 150 millimetres on a side were cast in order to investigate the material's compressive strength. The specimens were allowed to remain in the mould for twenty-four hours before being removed, after which they were allowed to continue curing at room temperature. The mix proportion of 1:1.08:3.44 is used and the test results are shown in Table 5.

Table 5 Proportions of Design Mix

Mix.	NaOH Concentration	AAS Ratio	Replacement of Flyash with GGBS (%)
GC-01	10.0 M	1.0	0.00
GC-02			20.00
GC-03			40.00
GC-04			60.00
GC-05			80.00
GC-06			100.00
GC-07		1.5	0.00
GC-08			20.00
GC-09			40.00
GC-10			60.00
GC-11			80.00
GC-12			100.00

3. Results and discussion

The workability of the mixtures was evaluated using the slump cone test, and their respective compressive strengths were evaluated using a compression testing machine with a capacity of 3000 kN. The results of these evaluations are presented in Table 6.

Table 6 Test Results of Concrete

Mix	Slump Value (mm)	Compressive Strength (N/mm^2)	
		7 Days	28 Days
GC-01	100.00	11.220	17.570
GC-02	115.00	14.920	22.230
GC-03	120.00	30.170	37.610
GC-04	140.00	36.120	40.560
GC-05	150.00	37.100	41.230
GC-06	150.00	41.630	48.310
GC-07	110.00	12.640	21.350
GC-08	120.00	17.791	28.690
GC-09	140.00	30.700	39.460
GC-10	160.00	39.130	43.480
GC-11	160.00	40.920	46.44
GC-12	160.00	42.490	53.870

It has been determined, on the basis of the findings of the tests, that the value of the slump rises as the percentage of GGBS in the mixture rises. In order to assess the early age of the specimens and their typical strength after 28 days of curing, the compressive strength of the samples was evaluated after 7 and 28 days of curing. It has been observed that the strength at 7 days is around 70.00%, and that it increases with the rise in the GGBS concentration. However, it has also been discovered that the strength decreases when the slag component makes up 100% of the mixture. The addition of superplasticizer equal to 2.0% of the binder has not shown any influence on the strength of the concrete, but it has shown a significant improvement in the concrete's workability.

4. Conclusion

The following inferences may be made based on the results of the experimental investigations:

- The emission of carbon dioxide (CO_2) has been considerably decreased as a direct consequence of the removal of the use of portland cement, which has led to a reduction in the amount of environmental pollution.
- The workability of geopolymer concrete is dependent on the amount of time that is spent mixing the concrete, and this workability decreases as the amount of time spent mixing the concrete increases. In addition to this, it grows as the amount of slag in the mixture does as well.
- The impact of Geopolymer concrete's limited workability and short setting time has been mitigated by the use of the chemical additive known as Glenium B233. This addition does not seem to have any effect on the compressive strength of the concrete, but it does appear to significantly improve the concrete's workability.
- In order to determine whether or not Geopolymer concrete is suitable for use in cast-in-situ environments, the specimens were allowed to cure at room temperature rather than undergoing an expedited curing process.
- It was discovered that the strength after 7 days is 70% of the strength after 28 days; this percentage increases with the amount of slag in the mixture, but it was discovered that it decreases when the mixture is composed entirely of slag. When compared with OPC, the 28-day strength demonstrates significantly greater strength. This demonstrates that geopolymer concrete is a viable alternative to cement concrete and should be regarded as such.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that there is no conflict of interest.

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