The Properties of Geo-polymer Concrete by Partial Replacement of Cement with GGBS & Fly ash

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Abstract. The production of Portland cement contributes to significant environmental pollution, with around 7% of global carbon dioxide emissions attributed to this industry. To address this issue, the construction sector seeks eco-friendly alternatives to conventional concrete. This project focuses on geopolymer concrete, which utilizes Fly ash and ground granulated blast-furnace slag (GGBS) can be utilized as a partial substitute for cement. The study investigates the effects of incorporating different percentages of fly ash (5%, 10%, 15%, 20%, and 25% as cement replacement) and GGBS (10%, 15%, 20%, 25%, and 30% as sand replacement) in geopolymer concrete. Compressive strength tests are conducted on cube specimens (150mm x 150mm x 150mm) at various ages (7 days, 14 days, and 28 days).

1 Introduction

The construction sector is progressively adopting sustainable measures to minimize its ecological footprint. One area of focus is the reduction of carbon dioxide emissions associated with traditional cement-based concrete production. The utilization of industrial by-products as partial replacements for cement and sand in concrete mixtures has gained significant attention.Two frequently used materials for partial replacement in concrete are fly ash, a by-product of coal combustion in power plants, and ground granulated blast furnace slag (GGBS), a by-product of the iron and steel industry. Fly ash & GGBS are simultaneously replaced with cement, in what is known as geo polymer concrete. This innovative approach not only reduces the consumption of traditional materials but also improves the environmental performance of the concrete. The utilization of fly ash and GGBS as cement replacements in concrete offers multiple advantages. It significantly reduces carbon dioxide emissions and promotes environmental sustainability. These supplementary cementitious materials enhance the durability of concrete by improving resistance to chemical attacks. They also contribute to increased strength and performance, improving the long-term structural integrity of the concrete. Furthermore, the use of fly ash and GGBS reduces the heat of hydration, minimizing the risk of thermal cracking. Overall, incorporating fly ash and

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GGBS as cement replacements promotes sustainable construction practices while maintaining or even enhancing the performance of concrete structures.

2 Literature Review

Anand Kumar B.G. (2012) In this work, the experiment is carried out by substituting ground granulated blast furnace slag (GGBS) and fly ash for the cement. He used fly ash to replace 10% of the cement and GGBS to replace the remaining 50%. The trials he performed on the blocks led to the following conclusions, which were mixed with at least 50% fly ash. We can create high volume fly ash concrete utilising GGBS by employing the 70% fly ash as a binder. It is possible to attain a 15Mpa compressive strength by employing 70% fly ash and 10% GGBS. The cost of higher concrete can be decreased by up to 20% by substituting these components for cement and sand, and the cost of lower cement can be reduced by up to 45%

Kumar, Anant & Deep, Krishna. (2022) This experimental inquiry is focused on the substitution of GGBS and fly ash for cement. In this study, we generated samples with varying ratios of Fly-ash and GGBS to replace the binding material. The specimen underwent testing with both fresh and hardened ordinary concrete. This study found that when fly ash and GGBS are partially substituted for cement in concrete, it exhibits superior compressive strength, tensile strength, and flexural strength when compared to ordinary concrete. It also gives better workability. In order to create a sustainable, eco-friendly, and cost-effective environment, this study also offers superior byproduct options.

3 Objectives

- To perform various tests to determine the strength and capacity of blocks that have been cast in the laboratory using GGBS and Fly Ash that have been partially replaced in the appropriate proportions.
- To conduct experiment on modified Cement blocks by replacing with materials such as GGBS & Fly Ash in different ratios to check the efficiency and compressive strength.
- To make productive use of GGBS & Fly Ash.
- To decrease the heat emitted by the concrete.

4 Materials and Methodology

4.1 Materials

4.1.1 Cement

53-grade for the construction of blocks, ordinary Portland cement (OPC) from a manufacturer is needed. Due to quality fluctuations between different batches of cement, cement supplied by plants is not advised. Tables 1 and 2 display the chemical compositions and physical characteristics of OPC.

Table 1. Chemical Compositions (%) of OPC

Constituents	Percentage
Al2O3	6.19
Fe2O3	2.45
MgO	3.55
CaO	60.29
SiO2	18.24
SO3	2.38

Table 2. Physical properties of OPC

Fineness (Sp. Surface)	303 m2/Kg
Specific Gravity	3.1
Soundness	10mm
Comp. Strength -7 days	51.6 MPa
Comp. Strength -28 days	71.3 MPa
Initial Setting Time	50 min
Final setting Time	275 min

4.1.2 Fine Aggregate

The river sand used in the investigation is free from organic impurities. It has a particle size that passes through a 4.75mm sieve and is retained on an IS sieve with 150µ size. Clean sieves should be used, and the physical properties of the fine aggregate are detailed in Table 3.

4.1.3 Coarse Aggregate

The coarse aggregate used in the investigation has a maximum size of 20mm. The proportion of the coarse aggregate mix is determined using IS 383:1970, with 60% of the aggregate being 10mm in size and 40% being 20mm in size. The physical properties of the coarse aggregate can be found in Table 4.

4.1.4 Fly Ash

Fly ash is a byproduct of the burning of coal in boilers. It is also known as flue ash, coal ash, or pulverised fuel ash. Particulates, or the tiny fragments of fuel that remain after combustion, are released during this process along with flue gases. The accumulation of residue at the base of the combustion chamber in a boiler is commonly known as bottom ash. Fly ash is often collected in contemporary coal-fired power plants using electrostatic precipitators or other particle filtration devices prior to the emission of flue gases via the chimneys.

Table 5. Chemical composition of Fly Ash

Oxides	**Percentage**
Sio2	52.0
Al2O3	33.9
Fe2O3	4.0
CaO	1.2

K_2O	0.83
Na_2O	0.27
MgO	0.81
SO_3	0.28
LOI	6.23
SiO_2/Al_2O_3	1.5

4.1.5 Ground Granulated blast furnace Slag (GGBS)

The production of blast furnace iron results in a byproduct known as blast furnace slag. This slag is formed when molten slag, which has been heated to temperatures ranging from 1300 to 1600 °C, is rapidly cooled to prevent crystallization. To create ground-granulated blast furnace slag (GGBS), the liquid iron slag from the blast furnace is quenched using water or steam. This process yields a granular product that is subsequently dried and processed into a fine powder. GGBS possesses a glassy, disordered, crystalline structure, which contributes to its cementitious properties. The specific GGBS used in this study was obtained from JINDAL STEEL WORKS in the Bellary region of Karnataka. It is available for purchase at a price of 200 rupees per ton.

Table 6. Chemical composition of GGBS

Chemical constitution	**Cement (%)**	**GGBS (%)**
Calcium oxide (CaO)	65	40
Silicon di-oxide (SiO_2)	20	35
Aluminum oxide (Al_2o_3)	5	10
Magnesium oxide (MgO)	2	8

4.1.6 Water

In the investigation, concrete is mixed and dried using only clean, potable water. It is devoid of any dangerous elements that can harm the concrete, including oils, acids, alkalis, salts, sugar, organic materials, and other noxious things.

4.2 Methodology

Materials: Gather all the necessary materials for the experiment, including cement, fine aggregate (sand), coarse aggregate, fly ash, GGBS, and water. Ensure that the aggregates are clean and free from any impurities.

Table 7. Percentages of materials used

Case	**Cement (Kgs)**	**GGBS (grams)**	**Fly Ash (grams)**
1	85%	10%	5%
2	75%	15%	10%
3	65%	20%	15%
4	55%	25%	20%
5	45%	30%	25%

Proportions: Determine the proportions of the materials based on the desired M20 grade concrete. use the following percentages of materials for cubes:

Fine Aggregate = 2.873 kgs
Coarse Aggregate = 3.76 kgs
Water = 0.6 to 0.65 of cement
Mixing: In a clean and sturdy mixing container, combine the cement, fine aggregate, coarse aggregate, GGBS, and fly ash. Gradually add the predetermined amount of water while continuously mixing the ingredients. Mix thoroughly until a uniform consistency is achieved. Ensure that the fly ash and GGBS are evenly distributed throughout the mixture.

Casting:

- Prepare the casting molds of 150mm x 150mm x 150mm and apply a thin layer of oil or release agent to prevent the concrete from sticking. Carefully pour the mixed concrete into the molds, ensuring that they are filled evenly and compacted to remove any air voids.
- Prepare the casting moulds of cylinders of 150 mm diameter and 300 mm length for casting the cylinders

Curing: After casting, cover the molds with plastic sheets or damp burlap to create a moist curing environment. Allow the concrete to cure for a specified period according to standard curing practices.

5 Results

5.1 Compressive strength

After completing the curing of cubes for 7 days, 14 days, 28 days the cubes need to be tested for compressive strength.

Table 8. CS results for Conventional concrete

Stages of testing	Load KN	Compressive strength Mpa
7 days	410	17.4
14 days	520	22.8
28 days	700	31.1

Table 9. Case – 1 CS results for Composition of Fly Ash 5% & GGBS 10%

Stages of testing	Load KN	Compressive strength Mpa
7 days	520	23.03
14 days	600	26.8
28 days	705	31.45

Table 10. Case – 2 CS results for Composition of Fly Ash 10% & GGBS 15%

Stages of testing	Load KN	Compressive strength Mpa
7 days	540	24.12
14 days	615	27.3
28 days	730	32.32

Table 11. Case – 3 CS results for Composition of Fly Ash 15% & GGBS 20%

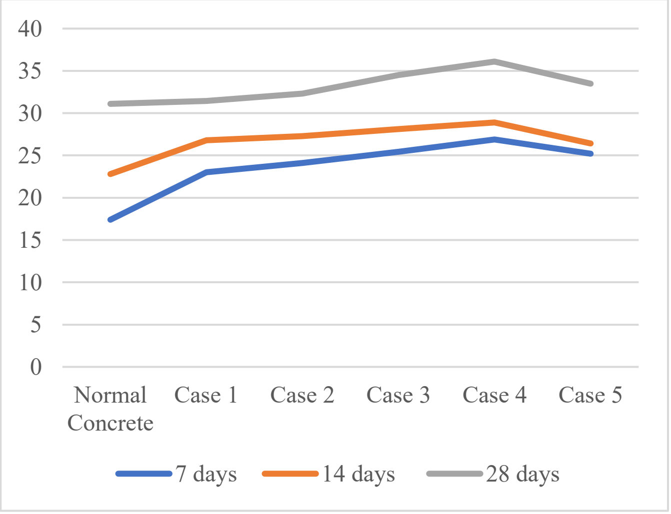
Stages of testing	Load KN	Compressive strength Mpa
7 days	570	25.45
14 days	630	28.1
28 days	780	34.5

Table 12. Case – 4 CS results for Composition of Fly Ash 20% & GGBS 25%

Stages of testing	Load KN	Compressive strength Mpa
7 days	605	26.89
14 days	650	28.9
28 days	810	36.1

Table 13. Case – 5 CS results for Composition of Fly Ash 25% & GGBS 30%

Stages of testing	Load KN	Compressive strength Mpa
7 days	565	25.2
14 days	595	26.4
28 days	750	33.5



Graph 1. Compressive strength variation in different cases

Table 14. Compressive strength variation in different cases

	7 days	**14 days**	**28 days**
Normal concrete	17.4	22.8	31.1
Case 1	23.03	26.8	31.45
Case 2	24.12	27.3	32.32
Case 3	25.45	28.1	34.5
Case 4	26.89	28.9	36.1
Case 5	25.2	26.4	33.5

5.2 Split tensile strength (STS)

The cylinders should be tested for split tensile after having been properly cured for 7, 14, and 28 days.

Table 14. STS results for Normal Concrete

Stages of testing	**Load KN**	**STS Mpa**
7 days	150	2.12
14 days	190	2.68
28 days	220	3.11

Table 15. Case – 1 STS results for Composition of Fly Ash 5% & GGBS 10%

Stages of testing	**Load KN**	**STS Mpa**
7 days	195	2.76
14 days	225	3.21
28 days	260	3.7

Table 16. Case – 2 STS results for Composition of Fly Ash 10% & GGBS 15%

Stages of testing	**Load KN**	**STS Mpa**
7 days	200	2.8
14 days	225	3.2
28 days	270	3.8

Table 17. Case – 3 STS results for Composition of Fly Ash 15% & GGBS 20%

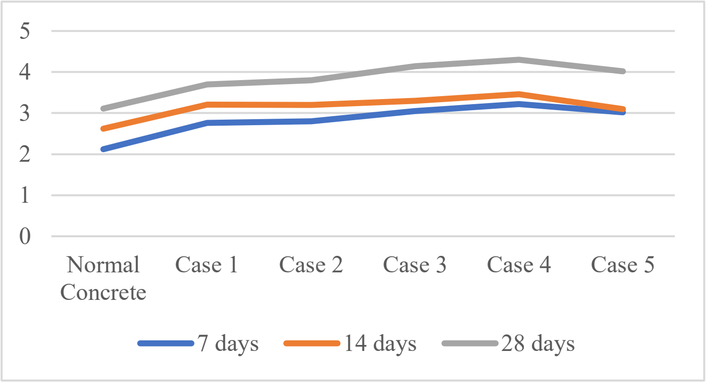
Stages of testing	**Load KN**	**STS Mpa**
7 days	215	3.05
14 days	235	3.3
28 days	295	4.14

Table 18. Case – 4 STS results for Composition of Fly Ash 20% & GGBS 25%

Stages of testing	**Load KN**	**STS Mpa**
7 days	230	3.22
14 days	250	3.46
28 days	300	4.3

Table 19. Case – 5 STS results for Composition of Fly Ash 25% & GGBS 30%

Stages of testing	Load KN	STS Mpa
7 days	215	3.02
14 days	220	3.1
28 days	285	4.02



Graph 2. Split tensile strength variation in different cases

Table 20. Split tensile strength variation in different cases

	7 days	14 days	28 days
Normal concrete	2.12	2.62	3.11
Case 1	2.76	3.21	3.7
Case 2	2.8	3.2	3.8
Case 3	3.05	3.3	4.14
Case 4	3.22	3.46	4.3
Case 5	3.02	3.1	4.02

6 Conclusion

1. With a higher ratio of fly ash and GGBS, geo-polymer concrete's compressive strength has increased.
2. When we raise the percentage of GGBS to 30%, the compressive strength decreases.
3. As we utilize more fly ash, there won't be any adverse impacts on the concrete.
4. With increasing usage of Fly ash & GGBS, the Geo-polymer concrete's split tensile strength has risen.

References

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