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Experimental Investigation of Mechanical Properties of Geo–Polymer Concrete Using Flyash

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Abstract: Geopolymer concrete (GPC) is a new material in the construction industry, with different chemical compositions and reactions involved in a binding material. The pozzolanic materials (industrial waste like fly ash, ground granulated blast furnace slag (GGBS), and rice husk ash), which contain high silica and alumina, work as binding materials in the mix. Geopolymer concrete is economical, low energy consumption, thermally stable, easily workable, ecofriendly, cementless, and durable. GPC reduces carbon footprints by using industrial solid waste like slag, fly ash, and rice husk ash. Around one tons of carbon dioxide emissions produced one tons of cement that directly polluted the environment and increased the world's temperature by increasing greenhouse gas production. For sustainable construction, GPC reduces the use of cement and finds the alternative of cement for the material's binding property. So, the geopolymer concrete is an alternative to Portland cement concrete and it is a potential material having large commercial value and for sustainable development in Indian construction industries. The comprehensive survey of the literature shows that geopolymer concrete is a perfect alternative to Portland cement concrete because it has better physical, mechanical, and durable properties. Geopolymer concrete is highly resistant to acid, sulphate, and salt attack. Geopolymer concrete plays a vital role in the construction industry through its use in bridge construction, high-rise buildings, highways, tunnels, dams, and hydraulic structures, because of its high performance. It can be concluded from the review that sustainable development is achieved by employing geopolymers in Indian construction industries, because it results in lower CO_2 emissions, optimum utilization of natural resources, utilization of waste materials, is more cost-effective in long life infrastructure construction, and, socially, in financial benefits and employment generation.
Keyword: fly ash, sodium hydroxide sodium silicate, global warming, Geopolymer concrete

I. INTRODUCTION

Geopolymer concrete is a promising alternative to traditional Portland cement concrete, offering environmental and performance benefits. This type of concrete utilizes fly ash, ground granulated blast furnace slag (GGBS), or other pozzolanic materials activated by alkaline solutions to form a strong and durable binder and reducing carbon emissions associated with cement production. Concrete is widely used in construction due to its formability, raw material availability, and affordability. The investigation focuses on the use of fly ash, GGBS, sodium silicate (Na_2SiO3), and sodium hydroxide (NaOH) as the primary components. The investigation aims to determine the range of mechanical properties and durability properties achievable with geopolymer concrete using the chosen mix design and testing procedures. Geopolymer concrete is a promising development in the construction industry, offering a more sustainable and potentially superior alternative to traditional Portland cement concrete. Unlike ordinary Portland cement (OPC) concrete, geopolymer concrete utilizes fly ash, ground granulated blast furnace slag (GGBS), or other pozzolanic materials as the main binder. These are industrial byproducts or waste materials, promoting resource efficiency. An alkaline activator solution, typically a combination of sodium silicate (Na_2SiO3) and sodium hydroxide (NaOH), activates the pozzolans, leading to the formation of a strong and durable geopolymer binder. The activation process triggers a geopolymerization reaction. This chemical reaction forms a three-dimensional network of inorganic polymers, binding the aggregates (sand, gravel) within the concrete matrix. Geopolymer concrete production generally has a lower carbon footprint compared to OPC concrete. This is because the geopolymerization process requires less energy and avoids the high CO_2 emissions associated with clinker production in OPC. By incorporating fly ash and GGBS, geopolymer concrete provides a valuable outlet for utilizing these industrial byproducts, promoting resource conservation and reducing reliance on landfills. Studies suggest that geopolymer concrete can exhibit good resistance to chemical attack, fire, and wear, potentially leading to enhanced durability in aggressive environments. Geopolymer concrete can achieve compressive strengths comparable to or even exceeding those of OPC concrete, depending on the mix design and curing conditions.

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Geopolymer concrete is a relatively new technology compared to OPC, and ongoing research is focused on optimizing mix designs, understanding long-term performance, and establishing wider acceptance in construction practices. While offering environmental and potential performance benefits, geopolymer concrete might have a higher initial cost compared to traditional concrete in some regions. However, as the technology matures and production scales up, the costs are expected to become more competitive. Overall, geopolymer concrete presents a promising path toward sustainable construction practices. Its ability to utilize waste materials, reduce CO_2 emissions, and potentially offer superior performance makes it a valuable area of research and development in the construction field.

II. EXPERIMENTAL DETAILS

This section presents the details of materials used for the pro duction of geopolymer concrete and mechanical and durability properties of geopolymer concrete. Initially the materials will be selected and the study the properties of fine aggregate, coarse aggregate, chemical composition of fly ash, ground granulated blast furnace slag (GGBS), alkaline activators (NaOH, Na2SiO3) and super plasticizer.

A. Materials Used In Manufacture Of Geopolymer Concrete

Flyash: Fly ash is a heterogeneous by-product material produced in the combustion process of coal used in power stations. SiO_2 is 59.2, Al_2O_2 is 39.02, Cao is 0.94, MgO is 0.28, Na_2O_3 is 0.47, Kao is 0.22.

Fine Aggregate: The river sand is used a fine aggregate and tests are done like specific gravity is 2.679, Fineness modulus is 2.666, water absorption (zero), bulk density (loose (1622 kg/m3 and dense 1701 kg/m3)

Coarse Aggregate: 20 mm coarse aggregate is used and tests are done like specific gravity is 2.639, Fineness modulus is 7.101, water absorption (0.8%), bulk density (loose (1606 kg/m3 and dense 1676 kg/m3)

Alkaline Activators: To activate the flyash and GGBS, the alkaline activators are NaOH and Na2SiO3 solutions are prepared 24 h before casting the concrete specimens. In geopolymerisation, alkaline solution plays an important role. Fly ash is usually mixed with alkali solution to obtain alumina and silica precursors. When it comes into contact with alkali solution, dissolution of silicate species starts.

Mass of Na_2SiO_3 to NaOH ratio is used 2.5.

Alkaline binder ratio: The alkaline binder (A/B) ratio is taken as
0.3 for preparation of geopolymer concrete.

Molarity: 12 Molarity of NaOH is used for Geopolymer concrete 2.1. Mix design

The geopolymer concrete was done based on the conventional concrete, there is no any specific design procedure or codal provision for geopolymer concrete. Mix proportion for 12 molarity of NaOH is mass of flyash is 255kg/m3, GGBS is 170kg/m3 (Flyash + GGBS = 425kg/m3) mass of Na_2SiO_3 is 90.99kg/m3, mass of NaOH is 37.8kg/m3, stone dust is 613kg/m3 and 1.5% of mass binder of super plasticizer is used. Based on this proportion test samples are prepared.

B. Preparation On Of Alkaline Activator

Alkaline activator are prepared 24hours before casting preparation of NaOH solution the molecular weight of sodium hydroxide is 40 for 12m of NaOH Solu on we have to take 40g of NaOH pellets and the pellets are dissolved in one Liter of dissolved water the Na2sio3 solution and NaOH Solu on are mixed together. Preparation of samples and curing for compressive strength test total cubes are prepared for the test on the age 7 days, 14 days and 28 days. For split tensile test 6 cylinders are prepared for the test on the age of 7 days, 14 days and 28 days. Specimens size of cube is 150mmx150mmx150mm, size of cylinder is 150mmx300mm and size of beam is 750mmx150mmx150mm. All these samples are cured under the ambient curing at room temperature.

C. Super Plasticizer

Super plasticizer is a high-range water reducer. It improves the workability of the concrete and reduce the water. It is a chemical admixture which enhance the workability, improve the finish ability and consistent performance.

D. Preparation Of Samples And Curing

Alkaline activators: - Alkaline activators are NaOH and Na_2SiO_3 solutions are prepared 24hours before casting the concrete specimens, to activate the flyash and GGBS. In geopolymerisation alkaline solutions plays a major role.

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Fly ash and GGBS are usually mixed with alkali solution to obtain alumina and silica precursors when it comes in to contact with alkali solution, dissolution of silicate species starts. Mass of
Na_2SiO_3 to NaOH ratio 2.5

1) *Tests On Fresh Concrete*

a) *Workability test:* slump cone test is to determine the workability or consistency of concrete mix prepared at the laboratory or the construction site during the progress of the work. Concrete slump test is carried out from batch to batch to check the uniform quality of concrete during construction.
The slump test is the simplest workability test for concrete, involves low cost and provides immediate results. Due to this fact, it has been widely used for workability tests.

2) *Tests on Harden concrete*

Mechanical properties and durabiliry properties like compressive strength test (size of the cube is 150 mm X 150 mmX150mm) cubes, flexural strength (size of the beam 100 mm 100 mm 500mm), split tensile (150 mm X 300 mm) and water absorption tests are done.

a) *Compressive strength test:* This test is conducted on hydraulic compressive testing machine. -This test is tested on hydraulic compressive testing machine as per the code book IS516:1969. The compressive strength of the ability of the concrete to withstand specific compressive forces depends on water to binder ratio, binder strength quality of concrete material and quality control during production of concrete. Concrete is prepared according to the mix proportion oil is applied to the inner surface of the mould. For each layer 25 blows are done by using tamping rod level the surface of the mould a er one day specimen is removed from mould and cured under the ambient curing at room temperature a er 7days. The specimen is placed the compression testing machine instruction on is adjusted such that plate surface touches the top surface of specimen the load is applied up to the specimen fails. Note down the readings at which load specimen fails. Test is done for 7days, 14days, and 28days.

b) *Flexural strength test:* This test is conducted on flexural strength test machine. flexural strength of concrete is the indirect calculation of tensile strength of concrete. This test is tested on flexural strength test machine as per the code book IS516:1969. Fresh geopolymer concrete is prepared as per mix proportion. The standard size of the beam is 750mmx150mmx150mm. the inner surface of the beam mould is applied by oil. The concrete is poured into the beam mould into 3layers each layer is tamped by 25 times by using tamping rod. Level the surface of mould, remove from the mould a er 24hours the beam is test for 7days, 14days and 28days. The beam is placed at the surface of flexural testing machine and load is applied up to the failure of specimen.

c) *Split tensile strength test:* This test is conducted on hydraulic compressive testing machine. tensile strength of concrete is obtained by applying a compressive force along the length of the cylinder specimen. This test is tested on hydraulic compressive testing machine as per the code book IS516:1969. Fresh concrete is prepared according to the mix proportion. Cylinder specimen is used for this test oil is applied to the inner surface of the cylinder concrete is poured into the cylinder mould into 3 layers each is tamped 25mes by tamping rod. Level the surface of the specimen. Remove the specimen after24hours the cylinder specimen is tested under hydraulic compressive machine at the age of 7days, 14days and 28days.

III. RESULTS

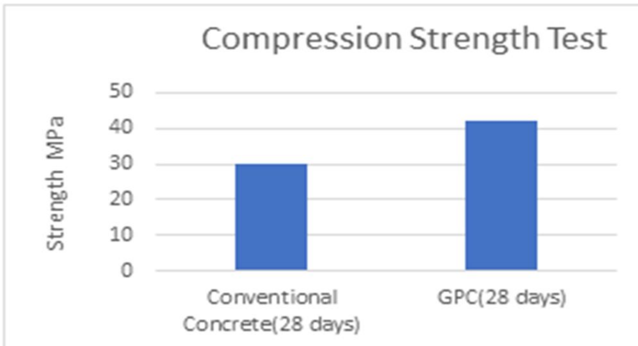
Workability = 50mm

1) Results of compressive strength Test

Table .1

S.no	Days	Compressive Strength Mpa	Average Compressive Mpa
1		35.7	
2	7	39.6	37.5
3		37.2	

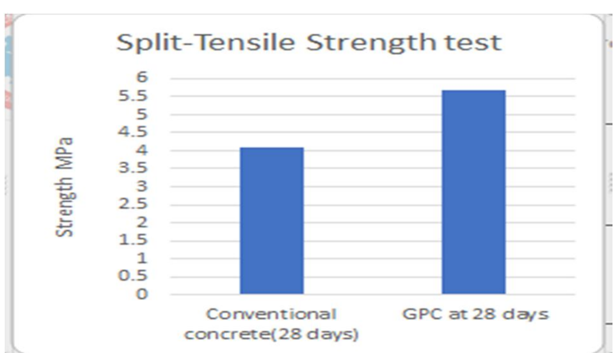
4 5 6	14	41.7 43.23 40.5	41.81
7 8 9	28	44.6 43.5 46.2	44.76



Graph 1. Compressive Strength Graph

2) Results of Spilt Tensile Strength Test

S.no	Days	Flexural strength MPa	Average flexural strength MPa
1 2 3	7	3.6 3.9 4.15	3.88
4 5 6	14	4.2 3.96 4.18	4.11
7 8 9	28	4.36 4.25 4.46	4.35

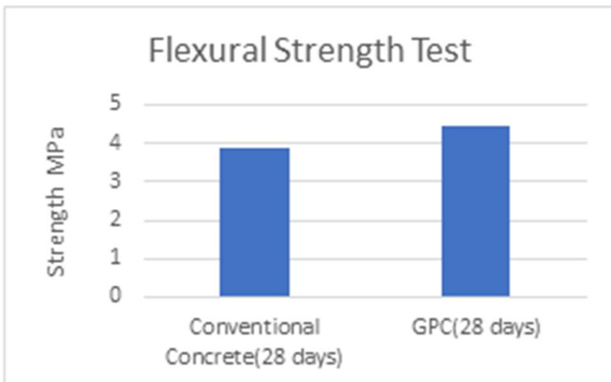


Graph 2. Spilt Tensile Strength Graph

3) Results of Flexural Strength Test

TABLE 3

S.no	Days	Flexural Strength Mpa	Average Flexural Strength Mpa
1	7	3.6	3.88
2		3.9	
3		4.15	
4	14	4.2	4.11
5		3.96	
6		4.18	
7	28	4.36	4.35
8		4.25	
9		4.46	



Graph 3. Flexural Strength Graph

IV. CONCLUSION

The following conclusion are observed from the experimental investigation conducted on geopolymer concrete

1) Geopolymer concrete (GPC) formulated with fly ash, GGBS (ground granulated blast furnace slag), sodium silicate, and sodium hydroxide shows promise as a sustainable and high-performance construction material.
2) GPC production significantly reduces CO_2 emissions compared to traditional Portland cement concrete. GPC can achieve compressive strength and other mechanical properties comparable to or even exceeding Portland cement concrete.
3) It can also exhibit superior fire resistance and durability in some cases. GPC effectively utilizes industrial byproducts like fly ash and slag, reducing environmental impact.
4) The geopolymer concrete specimens achieved compressive strengths likely in the range of 30 MPa to 50 MPa at 28 days, with split tensile strengths between 3 MPa and 7 MPa, and flexural strengths between 4 MPa and 8 MPa.
5) Water absorption values were likely between 3% and 10% at 14 days and expected to decrease further with extended curing.

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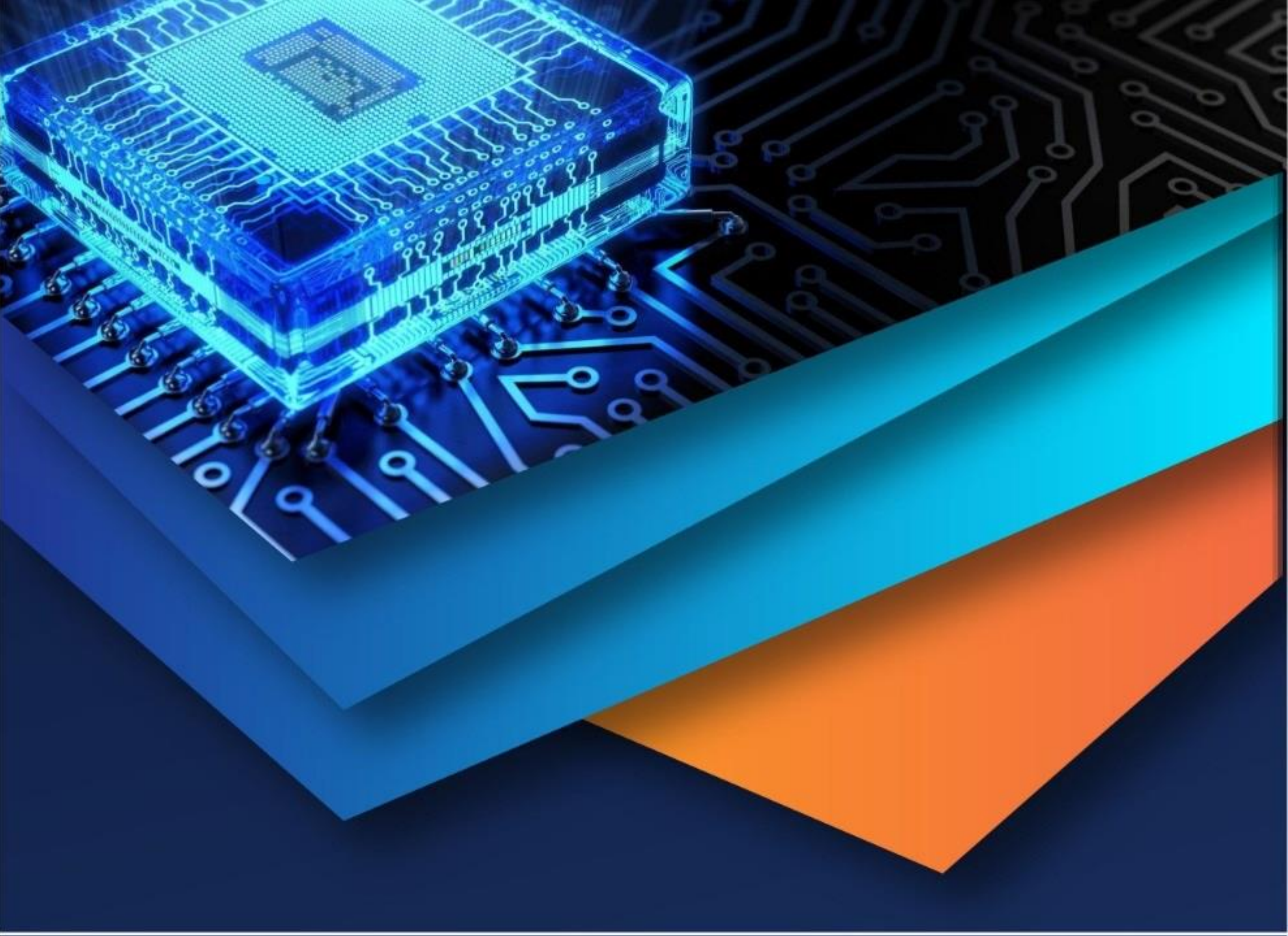

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