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Mechanical and Durability Performance of Geopolymer Concrete Using Industrial By-Products

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Abstract- — Concrete has occupied an important place in the construction industry in the past few decades and it is used widely in all types of constructions ranging from small buildings to large infrastructural dams or reservoirs. Cement is a major ingredient of concrete. The cost of cement is increasing day by day due to its limited availability and large demand. At the same time global warming is increasing day by day. Manufacturing of cement releases carbon dioxide. In the present study an attempt has been made on concrete and an experimental investigation on the concrete by replacing cement with FLYASH and GGBS to decrease the usage of cement as well as emission of carbon dioxide. Experimental studies were performed on plain cement concrete and replacement of cement with Fly ash and GGBS was done. In this study the concrete mix was prepared by using fly ash, GGBS, sodium silicate, sodium hydroxide. A comparative analysis has been carried out for concrete to the Geo polymer concrete in relation to their compressive strength, workability, tests on aggregate. The Geo- polymer concrete is an innovative and eco-friendly in construction. To reduce carbon dioxide emission, we are making geo-polymer concrete. The concrete made with fly ash (50%) and GGBS (50%) performed well in term of compressive strength, shows higher performance at the age of 7,14,28 days than conventional concrete. slump cone, compaction factor test was conducted to find the workability of Geo-polymer concrete and normal concrete. And test conducted on aggregate such as crushing strength, abrasion test, impact test.

Keywords: Fly Ash, GGBS, Sodium Hydroxide, Sodium Silicate.

I. INTRODUCTION

The escalating problem of environmental pollution has emerged as one of the most critical challenges facing the world today, driven largely by rapid industrialization, urbanization, and excessive exploitation of natural resources. Among the various industrial sectors contributing to environmental degradation, the construction industry plays a dominant role due to its high demand for energy-intensive materials, particularly ordinary Portland cement (OPC). The manufacturing of OPC involves the calcination of limestone and clay at temperatures exceeding 1400 °C, a process that consumes vast quantities of fossil fuels and releases substantial amounts of carbon dioxide and other harmful emissions into the atmosphere. As global infrastructure development continues to accelerate, the environmental burden associated with cement production has intensified, raising serious concerns regarding the long-term sustainability of conventional construction practices.

Cement production has been increasing steadily at an average annual growth rate of approximately 2.5%, reflecting the growing demand for housing, transportation networks, and industrial infrastructure across both developed and developing nations. In 2006, global cement production was estimated at around 2.55 billion tons; however, projections indicate that this figure is expected to rise dramatically to approximately 3.7–4.4 billion tons by the year 2050. Such a substantial increase in cement output poses significant environmental risks, including accelerated depletion of natural limestone reserves, increased energy consumption, and heightened greenhouse gas emissions. The scale of this growth highlights the urgent need for alternative construction materials and technologies that can reduce the environmental footprint of the cement industry without compromising structural performance.

One of the most severe environmental consequences associated with OPC production is the emission of carbon dioxide (CO_2), a primary greenhouse gas responsible for global warming. It is widely reported that the production of one ton of Portland cement releases nearly one ton of CO_2 into the atmosphere, originating from both the combustion of fossil fuels and the chemical decomposition of calcium carbonate during clinker formation. As a result, the cement industry alone contributes approximately 7–8% of total global CO_2 emissions, making it one of the largest single industrial sources of greenhouse gases. These emissions significantly exacerbate climate change by increasing atmospheric temperatures, disrupting weather patterns, and intensifying the frequency of extreme climatic events.

Global warming, driven by the accumulation of greenhouse gases in the atmosphere, has become a major environmental concern over the past few decades. The continuous rise in global temperatures has led to melting of polar ice caps, rising sea levels, altered rainfall patterns, and increased occurrence of natural disasters such as floods, droughts, and heatwaves. Human activities, particularly industrial manufacturing, energy generation, and construction-related processes, are the primary contributors to greenhouse gas emissions. In this context, the construction industry is under increasing pressure to adopt sustainable practices and develop low-carbon materials that can mitigate environmental impacts while supporting global development needs.

Although the complete elimination of Portland cement from construction activities is not currently feasible due to its well-established performance, availability, and economic advantages, significant efforts have been made to reduce its consumption in concrete. These efforts primarily focus on the use of supplementary cementitious materials (SCMs) such as fly ash, silica fume, ground granulated blast furnace slag (GGBS), and rice husk ash as partial replacements for cement. The incorporation of these materials not only reduces cement content and associated CO_2 emissions but also improves the workability, durability, and long-term mechanical performance of concrete. Furthermore, the use of SCMs promotes the beneficial utilization of industrial and agricultural waste materials, contributing to resource conservation and sustainable waste management.

Beyond partial replacement strategies, extensive research has been directed toward the development of alternative binder systems capable of completely replacing OPC in concrete. Among these, geopolymer technology, introduced by Davidovits in the late 1980s, has gained significant attention as a promising low-carbon alternative. Geopolymers are inorganic polymers formed through the alkaline activation of aluminosilicate-rich materials, resulting in a hardened binder system with mechanical and durability properties comparable or superior to those of OPC-based concrete. The geopolymerization process requires significantly lower energy input and produces substantially lower CO_2 emissions, making geopolymer concrete an environmentally sustainable construction material.

II. METHODOLOGY

The methodology commenced with the systematic collection and selection of all constituent materials required for the preparation of geopolymer concrete. Class F fly ash was procured from a nearby thermal power plant to serve as the primary aluminosilicate source material, while ground granulated blast furnace slag (GGBS) was obtained from a steel manufacturing industry to enhance early-age strength and calcium content. Fine aggregate in the form of natural river sand conforming to relevant IS standards and coarse aggregates of nominal maximum size were collected and tested for grading, specific gravity, and water absorption. Alkaline activators, namely sodium hydroxide pellets and commercially available sodium silicate solution, were sourced with known purity and chemical composition. Portable water free from impurities was used for mixing and curing. All materials were stored under controlled conditions to prevent moisture contamination and variability.

Mixing of Materials:
The mix proportions were designed based on target strength requirements and existing geopolymer mix design guidelines. Initially, dry materials including fly ash, GGBS, fine aggregates, and coarse aggregates were thoroughly mixed in a mechanical mixer to ensure uniform distribution. This dry mixing process was continued for a sufficient duration to eliminate segregation and ensure homogeneity. The alkaline activator solution was prepared separately at least 24 hours prior to mixing to allow stabilization of the solution temperature and chemical reactions. During mixing, the dry blend was gradually combined with the activator solution to achieve a uniform and workable geopolymer concrete mix. Proper sequencing of material addition was maintained to ensure consistecy acros all batches.

Addition of Chemicals:
Chemical admixtures, such as superplasticizers compatible with alkaline environments, were incorporated to improve workability and flow characteristics of the geopolymer concrete. The dosage of chemical admixtures was carefully optimized through trial mixes to avoid excessive retardation or rapid setting. The admixtures were added to the activator solution before introduction into the dry mix to ensure uniform dispersion. Particular attention was given to maintaining the sodium silicate to sodium hydroxide ratio and overall alkaline solution-to-binder ratio, as these parameters significantly influence geopolymerization. Continuous monitoring was conducted to prevent loss of workability due to rapid chemical reactions. The addition of chemicals was carried out under controlled laboratory conditions to ensure repeatability and accuracy.

Preparation of Samples:
Fresh geopolymer concrete was poured into standard moulds immediately after mixing. Cube specimens were prepared for compressive strength testing, while cylindrical and prism

specimens were cast for split tensile and flexural strength tests, respectively. Each mould was filled in layers and compacted using either a vibrating table or manual rodding to eliminate entrapped air and ensure dense packing. The top surfaces were finished smoothly to maintain uniform specimen geometry. Proper labeling of specimens was carried out to identify mix proportions, curing conditions, and testing age. The specimens were left undisturbed for an initial setting period at room temperature to prevent premature cracking or deformation.

Curing:

After the initial setting period, the specimens were demoulded and subjected to the selected curing regime. Depending on the experimental program, specimens were cured under ambient conditions or exposed to controlled curing environments such as sunlight or low-temperature oven curing. Ambient curing was adopted to simulate practical field conditions and assess real-world applicability. For oven curing, specimens were maintained at a predetermined temperature for a specified duration to accelerate geopolymerization. Care was taken to maintain consistent curing conditions for all specimens. The curing process played a vital role in the development of microstructure and mechanical properties of geopolymer concrete.

Testing of Samples:

Hardened geopolymer concrete specimens were tested at different curing ages to evaluate their mechanical performance. Compressive strength tests were conducted using a calibrated compression testing machine in accordance with standard testing procedures. Split tensile strength and flexural strength tests were also performed to assess tensile behavior and load-carrying capacity. In addition to mechanical tests, fresh properties such as workability were evaluated using standard methods. All tests were repeated on multiple specimens to ensure accuracy and reliability of results. Observations related to failure patterns and crack propagation were carefully recorded during testing.

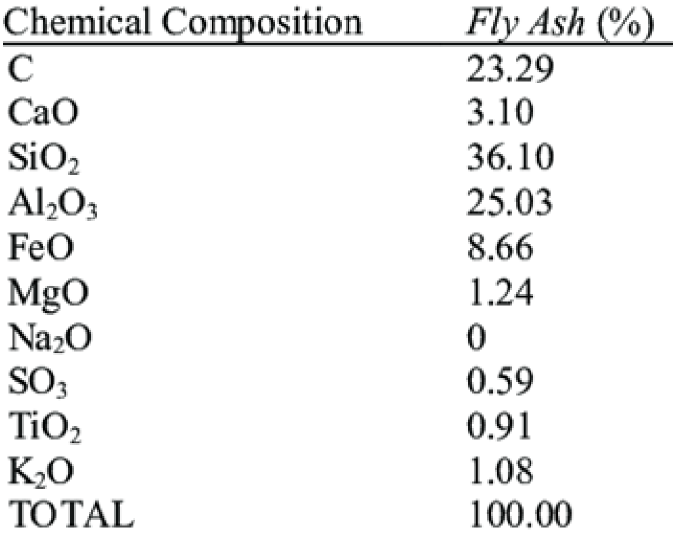
Results and Conclusion:

The experimental results obtained from various tests were systematically analyzed and compared to assess the performance of geopolymer concrete. Strength development trends were studied with respect to mix composition, activator concentration, and curing regime. The results demonstrated the effectiveness of mineral admixtures in enhancing mechanical performance and sustainability. Based on experimental findings, conclusions were drawn regarding the suitability of geopolymer concrete for structural applications. The study highlighted the advantages of reduced cement usage, improved strength characteristics, and environmental benefits. Overall, the methodology provided a comprehensive framework for evaluating geopolymer concrete, supporting its potential as a sustainable alternative to conventional cement-based concrete.

III. MATERIALS

Fly Ash

Fly ash is a recycling material which comes under sustainable development. Fly ash is a coal combusted residue and pulverized fly ash. It can be obtained from the coal industries from the boilers with fuel gases. Also Fly ash can be obtained from the coal related power plant industries. Fly ash has minerals components like Silicon dioxide (SiO2), Aluminum oxide (Al2O3), Ferric oxide (Fe2 O3) and Calcium Oxide (Cao). Fly ash can be used as a Partial replacement material to the Portland cement and can be said to be Hydraulic Cement. As per American Society for Testing and Materials (ASTM) C618 Fly ash is classified into two classes. One is Class F - Fly ash and the other is Class C Fly ash. The difference between these two classes is the percentage of minerals present in it. Class F - Fly ash is made from the burning of older bituminous coal having less than 7% lime. Class C Fly ash can form as geo-polymer. Class C Fly ash is made from the burning of sub bituminous. It has some self-cementations materials. Class C Fly ash has lime content more than 20%.



Chemical Composition	*Fly Ash (%)*
C	23.29
CaO	3.10
SiO_2	36.10
Al_2O_3	25.03
FeO	8.66
MgO	1.24
Na_2O	0
SO_3	0.59
TiO_2	0.91
K_2O	1.08
TOTAL	100.00

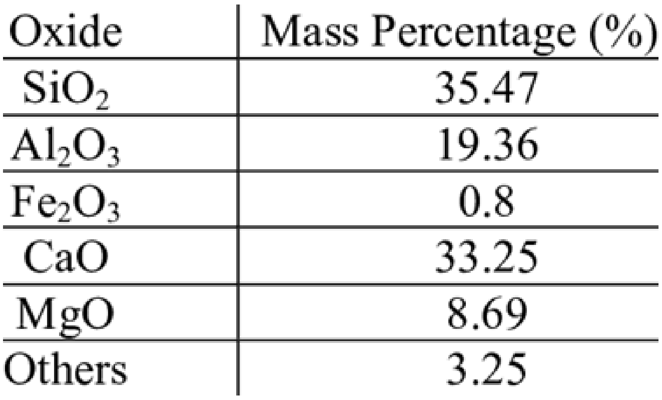
Table 1. CHEMICAL COMPOSITION OF FLY ASH

Physical Properties of Fly Ash

Specific gravity	2.07
Fineness	290m^2/kg
Color	Light grey
Particle shape	spherical
Bulk density	1100-1200kg/m^3

Figure 1. FLY ASH

Ground Granualted Blast Furnance Slag (GGBS)
Slag is a by-product from steel plants obtained from blast furnaces, during the separation of iron from iron ore. The process involves cooling of the slag through high-pressure water jets, which enables the formation of granular particles. The granulated slag is further processed by drying and then grinding in a vertical roller mill or rotating ball mill or roller press to a very fine powder, which is called GGBS.



Oxide	Mass Percentage (%)
SiO_2	35.47
Al_2O_3	19.36
Fe_2O_3	0.8
CaO	33.25
MgO	8.69
Others	3.25

Table 3. Chemical Composition Of Ggbs

GGBS is wastes by product generated from the iron ore industry which can be replaced with cement in concrete for the increasing of workability and improve the strength and durability of concrete. GGBS is the mixture of iron ore, lime and coke together temperatures with a 15000C. Therefore, the material is called as blast furnace slag. GGBS can be used as a partial replacement of OPC cement in concrete production at batching plants. It is highly cementations and high in Calcium Silicate Hydrates (CSH) which is a strength enhancing compound which improves the strength, durability and appearance of the concrete. The main constituents of GGBS are Cao, SiO2, Al2O3 and MgO. The chemical composition of a slag varies considerably depending on the composition of the raw materials in the iron production process.

IV. EXPERIMENTAL WORKS

Preparation Of Geo-Polymer Concrete

- **Sodium Hydroxide Preparation and Purity Considerations**

In the preparation of geopolymer concrete, the sodium hydroxide (NaOH) used as an alkaline activator was laboratory grade, provided in the form of small, hard pellets with a purity of 99%. The purity of NaOH is a critical parameter because any impurities can interfere with the dissolution and geopolymerization reactions, potentially reducing the mechanical performance of the hardened concrete. Prior to mixing, the pellets were weighed accurately using an analytical balance to ensure precise molarity in solution preparation. The mass of NaOH solids required for the desired molarity was calculated based on the molecular weight of NaOH, which is 40 g/mol. For instance, to prepare a 16 molar (16M) solution, 640 grams of NaOH pellets were dissolved in one liter of distilled water. Distilled water was used exclusively to avoid any contamination or presence of ions that could hinder the chemical reaction between the aluminosilicate precursors and the alkaline solution. This step is critical to maintain consistency in experimental results and ensure reproducibility across multiple batches of geopolymer concrete.

- **Calculation of Molarity and Solution Preparation**

The concentration of sodium hydroxide solution is expressed in terms of molarity (M), which is defined as the number of moles of solute per liter of solution. Accurate calculation of molarity is essential because the alkalinity of the solution directly affects the dissolution of aluminosilicate materials such as fly ash and ground granulated blast furnace slag (GGBS), which are the primary binders in geopolymer concrete. For example, a 16M NaOH solution requires the dissolution of 16 moles of NaOH per liter, equivalent to $16 \times 40 = 640$ grams. This high concentration ensures sufficient hydroxyl ions are available to break the Si–O–Si and Al–O–Si bonds in the fly ash particles, facilitating the formation of geopolymer gel during polymerization. Lower molarities result in incomplete dissolution, slower reaction kinetics, and ultimately reduced compressive strength of the hardened concrete. Therefore, precise weighing, gradual addition to distilled water, and thorough stirring are necessary to obtain a homogeneous solution without local supersaturation or pellet residue.

- **Preparation of Sodium Silicate Solution and Alkaline Liquid**

In addition to sodium hydroxide, sodium silicate solution (commonly referred to as water glass) was used as part of the alkaline activator. The sodium silicate solution used in this study was procured from local chemical suppliers and had a chemical composition of Na_2O = 8%, SiO_2 = 28%, and water = 64% by mass. The sodium silicate acts as a source of soluble silica, which reacts with dissolved alumina from fly ash or GGBS to form a three-dimensional aluminosilicate network. The mixture of sodium hydroxide and sodium silicate solutions forms the alkaline liquid that activates the geopolymerization process. Before combining with the solid constituents, the two solutions were thoroughly mixed to ensure homogeneity and to maintain the desired silicate-to-hydroxide ratio. This careful mixing is crucial because the molar ratio of SiO_2/Na_2O in the activator significantly affects the microstructure, setting time, and compressive strength of geopolymer concrete.

- **Mixing of Solid Constituents**

The solid constituents of the geopolymer concrete, including coarse aggregates, fine aggregates (sand), fly ash, and GGBS, were measured according to the designed mix proportions. Coarse and fine aggregates were selected based on grading, shape, and specific gravity to achieve optimum packing density. Fly ash, which is rich in silica and alumina, and GGBS, which provides calcium for early strength development, were thoroughly dry-mixed with the aggregates to achieve a uniform blend before the addition of the alkaline solution. Dry mixing is an important step because it ensures uniform distribution of fine particles, prevents segregation during subsequent liquid addition, and promotes consistent geopolymerization. Care was taken to avoid dust accumulation and aggregation of fine particles, as these factors can lead to inconsistencies in mechanical properties.

- **Addition of Alkaline Solution and Mixing Sequence**

After the dry components were uniformly blended, the prepared alkaline solution (mixture of NaOH and Na_2SiO_3) was gradually added to the dry mix while stirring continuously. The mixing sequence is critical: adding the solution to the dry constituents in small increments ensures proper wetting and uniform dispersion of the alkaline liquid throughout the mixture. Improper or delayed mixing can result in localized gel formation or inconsistent geopolymerization, leading to lower compressive strength and reduced durability of the hardened concrete. It was observed that excessive mixing or extended mixing time, especially in mixtures with higher water content, caused bleeding and segregation of aggregates, which adversely affected the microstructure of the geopolymer matrix and compromised mechanical properties. Therefore, an optimal mixing time was established to achieve a homogeneous, workable mixture while avoiding segregation.

- **Prevention of Bleeding and Segregation**

Bleeding and segregation are common problems in geopolymer concrete due to its low initial viscosity and sensitivity to water content. Bleeding occurs when excess water rises to the surface, creating a weak layer with reduced strength, while segregation results in uneven distribution of aggregates, leading to heterogeneous material properties. To prevent these issues, the water content and alkaline solution volume were carefully optimized. Additionally, sodium hydroxide and sodium silicate solutions were pre-mixed before introduction to the dry constituents, ensuring a consistent chemical environment throughout the mixture. The combination of controlled liquid addition and moderate mixing speed maintained uniformity of the paste and aggregates. This step is vital for achieving high-density geopolymer concrete with enhanced compressive strength and durability. Observations from trial mixes were used to adjust proportions and minimize bleeding.

- **Final Remarks on Preparation and Workability**

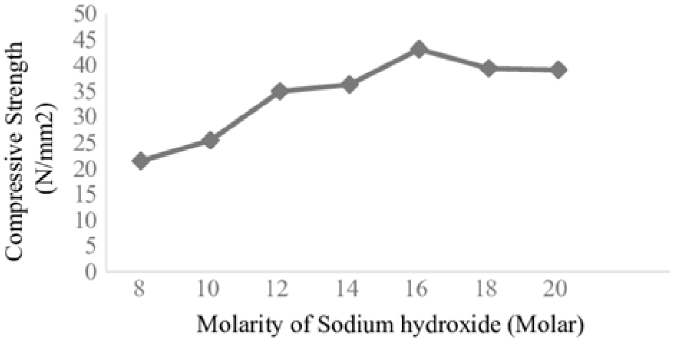
The preparation of geopolymer concrete requires a careful balance between chemical composition, solution concentration, mixing sequence, and workability. Ensuring the correct molarity of NaOH, the appropriate ratio of sodium silicate, and thorough blending of all components directly influences the geopolymerization reaction and the final mechanical properties of the hardened material. The optimal preparation process also minimizes defects such as voids, cracks, and weak interfacial zones between aggregates and binder. The resulting geopolymer concrete exhibits a dense microstructure, improved compressive strength, and enhanced durability compared to conventional OPC concrete. Proper attention to detail during preparation ensures reproducibility, consistency, and reliability in experimental investigations, forming a critical foundation for subsequent casting, curing, and mechanical testing.

Figure 9 Curing

Effect of Sodium Hydroxide Concentration On Compressive Strength:

The use of high concentration solution of sodium hydroxide leads to greater dissolution of the initial solid materials and increases geo polymerization reaction and gives higher strength.

By using 10M of sodium concentration it gives less compressive strength. So,16M of concentration is used.



Graph 1 EFFECT OF SODIUM HYDROXIDE ON COMPRESSIVE STRENGTH

EXPERIMENTAL TESTS

Impact Test

The property of a material to resist impact is known as toughness. The aggregates should have sufficient toughness to resist disintegration due to impact. This characteristic is measured by impact value test. The aggregate impact value is a measure of resistance to sudden impact or shock, which may differ from its resistance to gradually applied compressive load.

Figure 10. Impact Test

V. RESULTS

Results of Aggregate Impact Value Test

The aggregate impact value test was conducted to evaluate the toughness and resistance of aggregates to sudden impact or shock. From the experimental results, the aggregate impact value was found to be 26.67%, calculated based on the ratio of the weight of fines passing the 2.36 mm IS sieve to the total weight of the sample. This value indicates that the aggregates possess adequate toughness to withstand impact loads encountered in pavement and concrete applications. According to standard specifications, aggregates with impact values less than 30% are considered suitable for use in wearing surfaces of roads and structural concrete. Therefore, the obtained result confirms that the aggregates used in this study are of acceptable quality. The moderate impact value suggests reduced chances of aggregate disintegration under dynamic loading conditions. Hence, the aggregates are suitable for both conventional concrete and geopolymer concrete applications.

Results of Aggregate Crushing Strength Test

The aggregate crushing value test was performed to assess the resistance of coarse aggregates under gradually applied compressive load. The crushing value obtained from the test was 24.33%, which indicates good crushing strength of the aggregates. Aggregates with crushing values less than 30% are generally considered strong and suitable for use in pavement construction and structural concrete. The relatively low crushing value signifies that the aggregates can effectively resist compressive stresses without excessive crushing. This characteristic is essential for ensuring long-term durability and load-bearing capacity of concrete structures. The test result confirms that the aggregates possess sufficient mechanical strength. Consequently, the aggregates are appropriate for use in both normal concrete and geopolymer concrete mixes.

Results of Los Angeles Abrasion Value Test

The Los Angeles abrasion test was carried out to determine the hardness and wear resistance of the aggregates subjected to abrasion and impact. The abrasion value obtained was 51.3%, indicating a comparatively higher percentage of wear. Abrasion value reflects the resistance of aggregates to surface wear caused by traffic loads and mechanical action. Higher abrasion values suggest that aggregates may be less resistant to wearing action. However, depending on the application and governing standards, such aggregates may still be acceptable for non-wearing surfaces or low traffic conditions. The test result highlights the need for careful selection of aggregates when high abrasion resistance is required. Nevertheless, the aggregates can be effectively used in controlled concrete applications where abrasion demand is moderate.

Results of Slump Cone Test

The slump cone test was conducted to evaluate the workability of both geopolymer concrete (GPC) and normal concrete mixes. The slump value obtained for geopolymer concrete containing 50% fly ash and 50% GGBS was 110 mm, whereas normal concrete exhibited a slump of 100 mm. The higher slump value of geopolymer concrete indicates better workability compared to conventional concrete. This improvement may be attributed to the presence of fly ash and GGBS, which enhance particle packing and reduce internal friction. Adequate workability ensures ease of placing and compaction without segregation. The observed slump values fall within acceptable limits for structural concrete. Hence, geopolymer concrete demonstrates superior fresh-state performance.

Results of Compaction Factor Test

The compaction factor test was performed to assess the degree of compaction and workability of the concrete mixes. The compaction factor value obtained for geopolymer concrete was 0.85, while that of normal concrete was 0.90. The slightly lower compaction factor of geopolymer concrete indicates comparatively reduced ease of compaction under self-weight. However, the value still lies within the acceptable range for medium workable concrete. The difference in compaction factor values may be due to the viscosity and binding characteristics of the alkaline activator solution used in geopolymer concrete. Despite this variation, geopolymer concrete can achieve adequate compaction with proper vibration. Therefore, the workability of geopolymer concrete is considered satisfactory for practical construction.

Results of Compressive Strength Test at 7 Days

The compressive strength test results at 7 days curing reveal a clear performance difference between normal concrete and geopolymer concrete. The 7-day compressive strength of normal concrete was 18.83 N/mm², whereas geopolymer concrete achieved a higher strength of 23.23 N/mm². This significant improvement indicates rapid strength development in geopolymer concrete. The early-age strength gain can be attributed to the polymerization reaction between fly ash, GGBS, and alkaline activators. Higher early strength is beneficial for early formwork removal and accelerated construction schedules. These results demonstrate the superior performance of geopolymer concrete at early curing stages.

Results of Compressive Strength Test at 14 Days

At 14 days curing, normal concrete attained a compressive strength of 19.43 N/mm², while geopolymer concrete reached 27.14 N/mm². The strength increment in geopolymer concrete is considerably higher compared to normal concrete. This trend indicates continuous geopolymerization and formation of dense alumino-silicate gel structures. The enhanced bonding between aggregates and binder contributes to improved mechanical strength. The results clearly show that geopolymer concrete outperforms normal concrete at intermediate curing ages. Such strength characteristics make geopolymer concrete suitable for structural applications. The test confirms the effectiveness of fly ash and GGBS as cementitious materials.

Results of Compressive Strength Test at 28 Days

The 28-day compressive strength results show a substantial difference between the two concrete types. Normal concrete achieved a compressive strength of 20.35 N/mm^2, whereas geopolymer concrete attained a significantly higher value of 34.36 N/mm^2. This indicates a strength improvement of nearly 69% over conventional concrete. The superior performance of geopolymer concrete is due to the formation of a dense and homogeneous microstructure. The reduced porosity and improved interfacial transition zone enhance load resistance. These results confirm the long-term strength advantage of geopolymer concrete. Hence, geopolymer concrete proves to be a strong and sustainable alternative to traditional cement concrete.

Overall Performance Evaluation Based on Test Results

Based on the experimental investigation, geopolymer concrete demonstrated superior mechanical and fresh properties compared to normal concrete. Aggregate tests confirmed that the selected aggregates possess adequate toughness, strength, and durability for concrete applications. Workability tests showed acceptable slump and compaction characteristics for both mixes, with geopolymer concrete exhibiting slightly better flowability. Most importantly, compressive strength results revealed consistent strength enhancement in geopolymer concrete at all curing ages. The utilization of fly ash and GGBS not only improved strength but also contributed to sustainable construction practices. Overall, the results validate the effectiveness of geopolymer concrete as a durable and high-strength construction material.

VI. IMPACT VALUE RESULTS

The aggregate impact value is the ratio of the weight of the fraction passing through 2.36 mm (weight W2) by the total weight of the sample (weight W1 + W2).

Were,
W1= Weight of the fraction passing through a 2.36 mm IS sieve. (220 gm)
W2= Weight of sample retained on 2.36 mm IS sieves. (80 gm)
Aggregate Impact Value = (W2/ (W1+W2)) ×100
= 80 gm / 300 gm
= 26.67 (Impact Value)

Crushing Value

Crushing value = (W2/W1) x 100
If W1 = 4.11KG
W2 = 1 KG
Crushing value = (W2/W1) x 100
= (1/4.11) × 100
= 24.33%

Abrasion Value

Original weight of aggregate sample W1=4.11Kg
Weight of aggregate sample retained Weight passing 1.7mm IS sieve W2= 2Kg
Abrasion Value = (W1 - W2) / W1 X 100
= (4.11-2)/4.11×100
=51.3%

Slump Cone Value Of Gpc And Normal Concrete

The slump value with the mix of fly ash (50%) and GGBS (50%) is 110mm.
The slump value of normal concrete is 100mm.

Compaction Factor Values Of Gpc And Normal Concrete

The compaction factor range of geo polymer concrete is 0.85
The value of normal concrete is 0.9

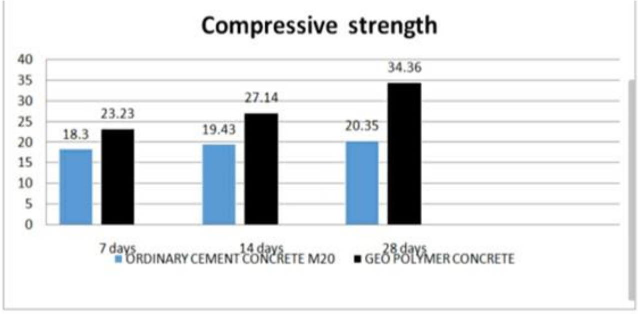
Compressive Strength Value:

The strength values obtained after curing for 7 days, 14 days, 28 days are given below for normal concrete and geopolymer concrete:
Compressive strength=applied load ÷ Area

The compressive strength value of geo polymer concrete increases with the age of 7, 14, 28 days.
COMPRESSIVE STRENGTH OF NORMAL AGGREGATE
For 7 days = 411.75×103÷150×150mm = 18.83N/mm2
For 14 days = 437.175×103÷150×150mm = 19.43N/mm2
For 28 days = 457.875×103÷150×150mm = 20.35N/mm2

Compressive Strength Of Geo-Polymer Concrete

For 7 days = 522.675×103÷150×150mm = 23.23N/mm2
For 14 days = 610.65×103÷150×150mm = 27.14N/mm2
For 28 days = 773.1×103÷150×150mm = 34.36N/mm2



Graph 2 Compressive Value

VII. CONCLUSIONS

The aggregate impact value obtained was 26.67%, which indicates that the aggregates possess adequate toughness to resist sudden impact loads. Aggregates with impact values within this range are generally considered suitable for construction purposes, particularly in concrete works and pavement layers subjected to moderate impact forces. Hence, the aggregates used in this study satisfy the required standards for structural applications.

The aggregate crushing value was found to be 24.33%, demonstrating good resistance to gradually applied compressive loads. A lower crushing value signifies stronger aggregates with higher load-bearing capacity. Therefore, the obtained crushing strength confirms that the aggregates are suitable for use in building construction and pavement structures where compressive stresses are significant.

The Los Angeles abrasion value of the aggregate was determined as 51.33%, indicating its resistance to wear and abrasion under mechanical action. Although higher abrasion values indicate greater wear, the obtained result is acceptable for general building construction where extreme abrasion resistance is not critical. Thus, the aggregates can be effectively used in concrete for structural applications.

The workability of geopolymer concrete was observed to be higher than that of normal concrete. This improvement in workability is mainly attributed to the incorporation of 50% Ground Granulated Blast Furnace Slag (GGBS), which enhances particle packing and reduces internal friction within the mix. As a result, geopolymer concrete exhibits better flow characteristics and ease of placement.

The compressive strength of geopolymer concrete was found to be significantly higher than that of normal concrete. This increase in strength is primarily due to the higher concentration of sodium hydroxide, which accelerates the geopolymerization process and improves the binding mechanism. Additionally, the use of geopolymer concrete contributes to a reduction in carbon dioxide emissions by minimizing cement consumption, thereby promoting sustainable and eco-friendly construction practices.

VIII. ADVANTAGES OF GEO POLYMER CONCRETE

- geopolymer concrete has high compressive strength.
- It has high tensile strength.
- Also has low creep.
- Low drying shrinkage.
- It has resistant to heat and cold.
- They are chemically resistant.
- It is highly durable.

IX. DISADVANTAGES OF GEOPOLYMER CONCRETE:

- They are difficult to produce.
- Also, requires special handling.
- Chemicals like sodium hydroxide are harmful to humans.
- They have a high cost of alkaline solutions.
- Pre-mixed with pre-mix or pre-cast material.
- The geo-polymerization process is sensitive.
- It loses uniformity.

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