

Mechanical Properties and Elastic Modulus of Ambient-Cured Fly Ash-GGBS Geopolymer Concrete

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Abstract — Nowadays concrete plays a major role in the human life. It is the prominent material to the construction industry and also usage of concrete became second only to water around the world. In this, cement is the most commonly used as a binding material in the concrete industry. But usage of concrete is enormously increased to produce structural elements. In this, cement is the most promising binding material to produce conventional concrete. But there are many environmental issues are associated with producing cement. Portland cement (PC) production has resulted in high amount of CO₂ emissions into the atmosphere and PC is one of the major energy-intensive material and it requires huge amount of natural resources i.e; limestone. In the present scenario emission of greenhouse gas contributes about 1.5 billion tons annually or about 7% of the total greenhouse gas emissions to the earth's atmosphere due to PC production. However, many efforts have been started in the construction industry to overcome this by utilizing industrial by products and developing substitute binders in concrete. To preventing this there must be study needs to focus to develop alternative and sustainable material towards cement free concrete. Which can be replaced by supplementary binder materials in the form of silica fume, metkaolin, rice-husk ash, GGBS and fly ash? Geopolymer concrete is an inorganic polymer aluminum silicon Acid material and it was introduced by the French chemist J. Davidovits in the last century in the late 1970. Geopolymer generated at the same time as excited by alkaline substances, while consuming one of these various industrial wastes have the characteristics of low energy consumption and low resource consumption. Geopolymer has received much attention in recent years as an environmentally friendly material. Geopolymer materials need a broad range of naturally available industrial bi-products. Geopolymer concrete has advantages like; simple process, Inexpensive, low energy consumption, high mechanical performance and durability, etc. The broad application development prospect has always been an internationally active research material.

Keywords— concrete; sustainable construction; experimental investigation; mechanical properties; durability.

I. INTRODUCTION

Nowadays concrete plays a major role in the human life. It is the prominent material to the construction industry and also usage of concrete became second only to water around the world. In this, cement is the most commonly used as a binding material in the concrete industry. But usage of concrete is enormously increased to produce structural elements. In this, cement is the most promising binding material to produce conventional concrete. But there are many environmental issues are associated with producing cement. Portland cement (PC) production has resulted in high amount of CO₂ emissions into the atmosphere and PC is one of the major energy-intensive material and it requires huge amount of natural resources i.e; limestone. In the present scenario emission of greenhouse gas contributes about 1.5 billion tons annually or about 7% of the total greenhouse gas emissions to the earth's atmosphere due to PC production. However, many efforts have been started in the construction industry to overcome this by utilizing industrial by products and developing substitute binders in concrete. To preventing this there must be study needs to focus to develop alternative and sustainable material towards cement free

concrete. Which can be replaced by supplementary binder materials in the form of silica fume, metkaolin, rice-husk ash, GGBS and fly ash? Geopolymer concrete is an inorganic polymer aluminum silicon Acid material and it was introduced by the French chemist J. Davidovits in the last century in the late 1970. Geopolymer generated at the same time as excited by alkaline substances, while consuming one of these various industrial wastes have the characteristics of low energy consumption and low resource consumption. Geopolymer has received much attention in recent years as an environmentally friendly material. Geopolymer materials need a broad range of naturally available industrial bi-products. Geopolymer concrete has advantages like; simple process, Inexpensive, low energy consumption, high mechanical performance and durability, etc. The broad application development prospect has always been an internationally active research material.

Fly ash and GGBS materials are the industrial by-products from the thermal and iron industries. Which are successfully converts a left-over material into a useful material in concrete industry and also offers possible solution to overcome the several environmental issues such as Co₂ emission. However,

GPC technology could also be an alternative and eco-friendly to the conventional concrete.

Geopolymer is a mixture of concrete in which the use of Portland cement material as the binder is replaced by other materials such as fly ash, rice husk ash and many others containing silica and aluminum (Davidovits, 1996). Replacement of Portland cement base material considered more environmentally friendly and more effective by utilizing materials waste industrial plant waste to be more environmentally concerned. Geopolymer is a geosynthetic concrete product in which the binding reaction occurs as polymerization reaction. In polymerization reactions, silica (Si) and aluminum (Al) has an important role in the polymerization bonds aluminum with alkaline will produce SiO and AlO_4 .

Portland cement as binder is the one of the most important material used in conventional concrete manufacturing. Nowadays, rapid development of infrastructure is increasingly day by day resulting in demand for cement. However, in the case of cement production process, CO_2 emissions into the atmosphere is very high (Davidovits, 1994), so it leads to air pollution. This is one factor incentive for the discovery of other alternative materials that can replace position the cement in the concrete mixture to get the friendly concrete environment. To minimize the cost, it requires waste alternative materials for replace the use of cement. In this study, the authors do experiment with making geopolymer concrete. Geopolymer is a mixture of concrete in which the use of cement material Portland as a binder is replaced by other materials such as fly ash (fly ash), ash husk ash (rise husk ash), and many others contain silica and aluminum (Davidovits, 1996). In this study fly ash and GGBS is used as binder instead of PC. The composition of geopolymer concrete material is still widely performed. Thereafter, several authors were experimented on strength, durability and workability properties of GPC (Wang et al., 1995). The results shown that GPC producing by fly ash having satisfactory strength. The GPC achieved about 50 MPa strength at higher concentration of alkaline solution and high temperatures (Puertas et al., 2000). Thus, fly ash based GPC have good strength, it has few drawbacks i.e., flash set, curing period, curing regime (ambient curing) and low workability (Fernandez-Jimenez et al., 2002). Generally, fly ash-based GPC needs high temperatures ($60\text{--}90^\circ\text{C}$) to achieve early strength. GPC is feasible to cast in laboratory by applying heat curing condition but it is very difficult to cast in situ condition for the full-scale projects. So, in order to overcome the drawbacks, alkali activated slag (GGBS) was used as a binder in GPC. The addition of slag to GPC has negative impact on setting behaviour and workability (Nath et al., 2014). To prevent the flash setting, super plasticizer is suggested to achieve required

workability of fly ash-based GPC's (Hardjito et al., 2004). Subsequently to utilize GPC for common practice as that of conventional concrete, researchers proposed various mix design methodologies (VijayaRangan, 2008). In the present scenario, the requirement of high-performance concrete is increased. For this reason, research moved towards utilization of fly ash and GGBS in concrete making. Though the several studies reported by authors emphasize the applicability of GPC with combination of fly ash and GGBS to replace high strength OPC concrete (Manjunatha et al., 2014) but still there is a less attention paid on confined geopolymer concrete. Thus, several authors developed mix design for fly ash and GGBS based GPC but there is a less research on stress-strain behaviour of tie-confined concrete (and Rangan et al. 2008). With this background, an experimental investigation is proposed in this research work to assess the effect of parameters viz. tie reinforcement, alkaline/binder ratio, grade of concrete on the behaviour of geopolymer concrete under axial compression. The aim of the investigation is to propose a stress-strain model for tie confined geopolymer concrete and use it for assessing the moment curvature response of GPC beams subjected to flexural loading.

Nowadays, geopolymer concrete gaining attention of researchers and industries as it can totally replace cement in PC concrete. Thus, substituent to the cement "new material by" geopolymer material is reducing air pollution by two ways- Less emission of CO_2 into atmosphere by less utilization of cement; and consumption of fly ash in huge quantity, which is a waste product from thermal industries. The fly ash being dumped by the thermal power stations is occupying large cultivable area too. Geopolymer concrete contains the main binder ingredients as met kaolin, rice husk ash, pumice, fly ash, Ferro chrome slag, red mud, GGBS etc. along with activator solution such as Sodium Hydroxide (NaOH) and Sodium Silicate (Na_2SiO_3). The selection of silica and alumina rich raw materials mostly depends on type, local availability, applicability of the materials hereafter called as source material. The activation process of source materials can be accelerated by the use of alkaline activator such as "sodium hydroxide or potassium hydroxide and; sodium silicate or potassium silicate".

The alkaline activation of aluminosilicate materials is a complex process that isn't still completely explained. The reaction of aluminosilicate materials in a strong alkaline environment results in the rupture of Si-O-Si bonds, Si-O-Al and Al-O-Al; and in the next stage, the formation of two new phases whose mechanism seems to be a process that requires an alkaline activator ("synthesis through the solution"). The orientation of Al ions into the structure of Si-O-Si, represents a

characteristic important part of this reaction. Aluminosilicate gels are essentially formed. Their composition can be characterized by the $Mn + [- (Si-O)_2]_n \cdot w H_2O$, where z and $M +$ represent, respectively, the Si / Al molar ratio and a cat ion monovalent and where n is assimilated to the degree of polymerization. Figures 1.1 and 1.2 show the elementary chains or basic forms of geopolymer according to the Si / Al ratio (Davidovits, 1999) and a model of geopolymer structure (Davidovits, 1999).

II. MATERIALS AND METHODS

The aim of the present research work is to experimentally investigate the behaviour and mechanical properties of fly ash and ground granulated blast furnace slag (GGBS) based geopolymer concrete under ambient curing conditions. The study focuses on developing geopolymer concrete mixes with different proportions of fly ash and GGBS and evaluating their suitability as an environmentally sustainable alternative to conventional Portland cement concrete. The research further aims to assess the workability, compressive strength, flexural strength, split tensile strength, stress-strain behaviour, and modulus of elasticity of different grades of geopolymer concrete. Particular attention is given to understanding the influence of increasing GGBS content on the strength, deformation characteristics, and stiffness of geopolymer concrete. The study also seeks to establish the relationship between compressive strength and modulus of elasticity and to develop an empirical equation for estimating the modulus of elasticity of geopolymer concrete within the investigated strength range.

- To develop fly ash and GGBS-based geopolymer concrete suitable for ambient curing.
- To study the effect of GGBS content on workability and strength of GPC.
- To determine the compressive, flexural and split tensile strengths of GPC.
- To evaluate the stress-strain behaviour and modulus of elasticity of GPC.
- To establish the relationship between compressive strength and modulus of elasticity.
- To propose an empirical equation for predicting the modulus of elasticity of GPC.

Material Selection ↓ Characterization of Fly Ash, GGBS and Aggregates ↓ Preparation of Alkaline Activator ↓ Mix Proportioning of GPC20, GPC40 and GPC60 ↓ Mixing and Workability Assessment ↓ Casting of Cubes, Cylinders and Prisms ↓ Ambient Curing for 28 Days ↓ Compressive Strength Test ↓ Flexural Strength Test ↓ Split Tensile Strength Test ↓

Stress-Strain and Modulus of Elasticity Test ↓ Analysis of Mechanical and Deformation Properties ↓ Development and Validation of Empirical Equation ↓ Conclusions and Recommendations.

Though various authors reported that GPC has comparable mechanical properties to that of OPC concrete, not much literature is available on the modulus of elasticity of GPC under ambient curing. This study examines the performance of geopolymer concrete and aims to determine the mechanical properties and modulus of elasticity of GPC20, GPC40 and GPC60 with a combination of fly ash and GGBS as binders under ambient curing. A comprehensive assessment of their mechanical properties has been evaluated for making geopolymer concrete.

The available literature shows that the stress strain behaviour of fly ash and GGBS-based GPC under compressive loading is similar to that of conventional concrete, and it has further been reported that the Poisson's ratio for GPC falls between 0.2 - 0.24. Various researchers proposed models for stress-strain behaviour of geopolymer concrete and concluded that the proposed GPC model has many similarities to OPC concrete and that there is an increased stiffness of GPC than that of OPC concrete. The mechanical properties and stress-strain behaviour of geopolymer concrete is presented in this present chapter.

Fly ash obtained from the NTPC Ramagundam Thermal Power Station, India, and GGBS obtained from Toshali Cements, Vizag, India, their chemical composition. Fly ash and GGBS have a relative density of 2.17 and 2.9, respectively.

River sand was used as fine aggregate (FA) and corresponds to Zone-II of IS 383:1978. Crushed rock was used as coarse aggregate (CA). The fine aggregate and coarse aggregate have specific gravities of 2.58 and 2.70 with fineness moduli of 2.70 and 6.36, respectively.

A combination of sodium silicate and sodium hydroxide in a mass ratio of 2.5 was used as an alkaline activator solution. NaOH in a pellet form and Na_2SiO_3 in a liquid form obtained from Finer Chemicals, India. The concentration of NaOH solution is 8M. The sodium silicate solution with a chemical composition of $Na_2O = 8.5\%$, $SiO_2 = 26.5\%$, $H_2O = 65\%$ by mass was used. The alkaline activator solution has a Na_2O/SiO_2 (molar ratio) of 0.6. For proper mixing of the solutions, it is having been suggested to prepare the alkaline activator solution one day prior to the casting.

A sulphonated naphthalene-based high range water reducer, i.e.; CONPLAST SP 430, which was obtained from Fosroc

Chemicals, India was used as a super plasticizer (SP) to improve the workability of the mix. The dosage of super plasticizer (SP) mentioned in Table 2 is with respect to the weight of the binder (fly ash and GGBS).

Table 1. Mineral composition of GGBS and fly ash

Composition	Al ₂ O ₃	CaO	SiO ₂	MgO	SO ₃	Fe ₂ O ₃	Na ₂ O	LOI
GGBS (%)	20.00	32.60	34.06	7.89	0.90	0.80	NIL	NIL
Fly ash (%)	26.53	4.00	60.11	1.25	0.35	4.25	0.22	0.88

Table 2. Sieve analysis of coarse aggregate

IS Sieve Size	Wt. Retained (Kg)	Wt. Retained (Kg)	Cumulative % Wt. Retained	% Passing
80mm	0	0	0	100
40mm	0	0	0	100
20mm	1.52	1.52	15.2	84.8
10mm	3.33	4.85	48.5	51.5
4.75mm	5.15	10	100	0
2.36mm	0	10	100	0
1.18mm	0	10	100	0
600μ	0	10	100	0
300μ	0	10	100	0
150μ	0	10	100	0
TOTAL	10		663.7	

Table 3. Sieve analysis of fine aggregate

IS Sieve Size	Wt. Retained (Kg)	Wt. Retained (Kg)	Cumulative % Wt. Retained	% Passing
80mm	0	0	0	100
40mm	0	0	0	100
20mm	0	0	0	100
10mm	0	0	0	100
4.75mm	0.07	0.07	3.5	96.5
2.36mm	0.11	0.18	9	91
1.18mm	0.33	0.51	25.5	74.5
600μ	0.48	0.99	49.5	50.5
300μ	0.68	1.67	83.5	16.5
150μ	0.33	2	100	0
TOTAL	2		271	

Table 4. Quantities of geopolymer concrete ingredients

Mix	Fly ash	GGBS	Fine Agg.	Coarse Agg.	Na ₂ SiO ₃	NaOH	SP (%)
GPC20	252	108	774	1090	141	56	3.0
GPC40	270	180	760	972	177	70	4.0
GPC60	260	260	717	915	204	81	5.0

Table 5. Workability of GPC

GPC Mix	Binder: FA: CA: Alkaline soln.	Slump (mm)
GPC20	1: 2.15: 3.05: 0.55	122
GPC40	1: 1.69: 2.16: 0.5	110
GPC60	1: 1.38: 1.76: 0.5	78

Table 6. Workability of GPC

Binder	Binder	Flexural Compressive Split Tensile	Flexural Compressive Split Tensile	Flexural Compressive Split Tensile
Mix	Content Strength	Content Strength	Content Strength	Content Strength
	(kg/m ³)	Strength (MPa)	Strength (MPa)	(MPa)
GPC20	360	26.76	2.16	2.20
GPC40	450	43.44	3.73	4.21
GPC60	520	62.89	5.49	6.16

Table 7. Modulus of elasticity for the GPC.

Modulus of Mix Elasticity	Modulus of Mix Elasticity	Peak Stress	Strain at peak
	(GPa)	(N/mm ²)	stress
GPC20	10.59	18.82	0.0024
GPC40	14.11	33.31	0.0022
GPC60	21.21	43.69	0.0021

Table 8. Validation of empirical equation

Compressive strength	Experimental values	Theoretical values	Error(%) Avg error(%)
GPC 20	10.59	9.83	7.10
GPC 40	14.11	12.71	9.91 9.15
GPC 60	21.21	19.00	10.44



Figure 1. Casting of GPC specimens

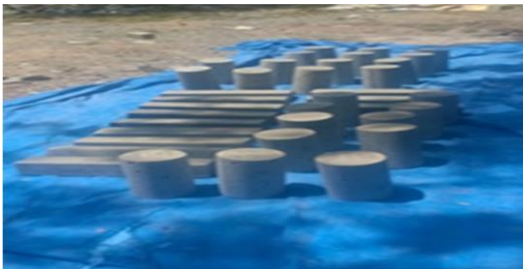


Figure 2. Curing of GPC specimens

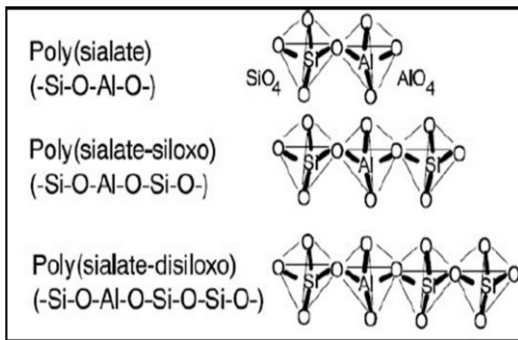


Figure 3. Basic forms of geopolymer.



Figure 4. Test steps for elastic modulus

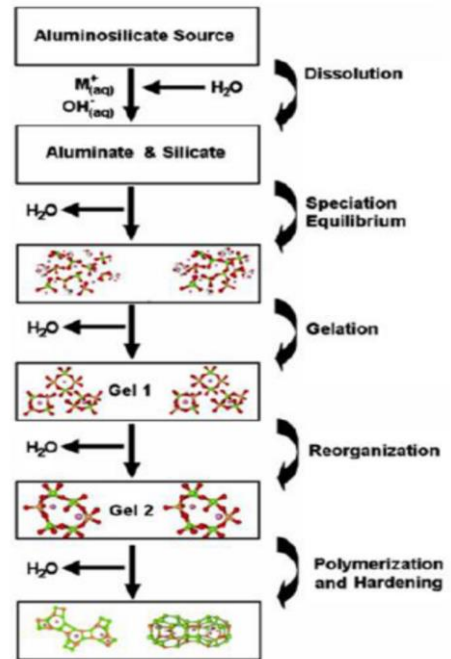


Figure 5. Various steps involved in the formation of geopolymer.

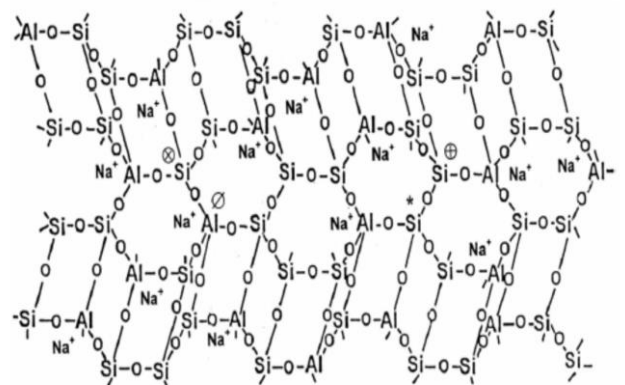


Figure 7. Davidovits model of the geopolymer structure

III. RESULTS AND DISCUSSION

The workability of GPC mix decreases with increase in compressive strength of concrete, as seen from Table 4.5. The decrease in workability (slump) is due to presence of high amounts of GGBS content. The GGBS content for GPC20, GPC40 and GPC60 was 30%, 40% and 50% with respect to weight of binder. Therefore, it can be concluded that the increase in GGBS content negatively affects the workability,

due to faster polymerization at a higher GGBS content, which results in decreased workability.

The compressive, flexural and split tensile strength were determined after 28 days of curing, and the results obtained.

For the compressive strength of 20 MPa (GPC20), the fly ash and GGBS proportions were selected in a ratio of 70:30. For the GPC40 and GPC60, the fly ash: GGBS ratios are 60:40 and 50:50 respectively. As seen in Table 4.6, the increase in compressive strength is due to increase in the binder content and also due to increase in the GGBS quantity. With a higher binder content, a greater amount of alkaline solution is available for polymerization, which results in the increased strength of the concrete. With a higher GGBS content more calcium is available for polymerization, which results in the formation of additional C-A-S-H gel along with N-A-S-H gel, thereby leading to an enhancement in strength.

The indirect tensile strength of concrete was evaluated. The flexural and split tensile strengths were around 8% of their respective compressive strengths. The flexural strength of the GPC specimens was determined under two-point loading with the longitudinal axes perpendicular to the loads. The split tensile and flexural strengths of the GPC specimens cured under ambient conditions showed acceptable results of OPC concrete. The results concluded that with an increase in the slag content the split tensile and flexural strength of GPC increases. The rate of development of the tensile strength increased considerably with the inclusion of GGBS in the binder. The reaction of the slag is higher compared to that of fly ash, thereby resulting in higher strength (Puertas, 2000).

As compressive strength of concrete can be used to assess the materials ability, it can also be used to measure the flexural and split tensile strengths. Thereby increasing the compressive strength of concrete its corresponding splitting tensile and flexural strength are seen to increase in a similar manner. The results obtained indicated that the GPC mixes with GGBS and fly ash as a binder indicate good mechanical properties under ambient curing conditions without the need for heat curing as in the case of fly ash-based geopolymer concrete. Our findings are in agreement with others as well (Siddique, 2007).

The stress-strain curve of the GPC specimens tested under compression, and the modulus of elasticity results along with corresponding peak stress and peak strains of GPC 20, GPC 40 and GPC 60.

The elastic modulus of the GPC is directly proportional to the compressive strength of the GPC, but the elastic modulus of

GPC is comparatively less than conventional concrete for similar compressive strengths. An increase in GGBS content enhances the modulus of elasticity and compressive strength of concrete. An increase in compressive strength from 20 MPa to 40 MPa, increases the modulus of elasticity by 33%. Whereas, increase in the compressive strength from 40 MPa to 60 MPa, increases the modulus of elasticity by 50%. This might be due to an increase in the volume of the paste, which resulted in the increased homogeneity (a reduction in the voids) of the concrete by improving its compressive strength and modulus of elasticity. Higher compressive strength of GPC tends to brittle behaviour shown by decreased values of strain.

An equation is proposed for calculating the modulus of elasticity from the experimental results based on the compressive strength of geopolymer concrete. The proposed equation shown in Eq. 4.1 is valid for a compressive strength range of 20 MPa to 60 MPa.

$$E = [4.26C^2 - 111.74C + 10365] \times 10^{-3} \text{ GPa} \text{ ---Eqn. 4.1}$$

Where C = compressive strength of GPC

The average percentage error of the empirical equation was incorporated in the thesis. The average percentage error is less than 10%. Hence this equation can be used for geopolymer concrete.

The use of fly ash and GGBS as geopolymer binders provides a suitable alternative to conventional Portland cement concrete, particularly under ambient curing conditions.

The incorporation of increasing amounts of GGBS significantly improves the compressive strength of geopolymer concrete. The compressive strengths obtained for GPC20, GPC40 and GPC60 were 26.76 MPa, 43.44 MPa and 62.89 MPa, respectively. Increasing the GGBS content results in a reduction in workability. The slump values decreased from 122 mm for GPC20 to 110 mm for GPC40 and 78 mm for GPC60, mainly due to the faster polymerization associated with higher GGBS content.

The flexural and split tensile strengths increase with increasing GGBS content. The improved tensile properties are attributed to the higher reactivity of GGBS and the formation of additional binding gels during geopolymerisation.

The study demonstrates that the addition of GGBS enables ambient curing of fly ash-based geopolymer concrete, reducing the dependence on conventional heat curing.

The modulus of elasticity increases with compressive strength. The experimentally obtained modulus of elasticity was 10.59 GPa, 14.11 GPa and 21.21 GPa for GPC20, GPC40 and GPC60, respectively.

The strain at peak stress decreases as the compressive strength increases, indicating a transition from relatively ductile behaviour at lower strength to more brittle behaviour at higher strength geopolymer concrete.

The proposed empirical equation, $E = [4.26C^2 - 111.74C + 10365] \times 10^{-3}$ GPa, provides a reasonable estimate of the modulus of elasticity for geopolymer concrete within the investigated compressive-strength range of 20–60 MPa.

Table 9. Workability of GPC.

Mix	Binder : FA : CA : Alkaline solution	Slump (mm)
GPC20	1 : 2.15 : 3.05 : 0.55	122
GPC40	1 : 1.69 : 2.16 : 0.50	110
GPC60	1 : 1.38 : 1.76 : 0.50	78

Table 10. Workability of GPC.

Mix	Binder Content (kg/m ³)	Compressive Strength (MPa)	Flexural Strength (MPa)	Split Tensile Strength (MPa)
GPC20	360	26.76	2.16	2.20
GPC40	450	43.44	3.73	4.21
GPC60	520	62.89	5.49	6.16

Table 11. Modulus of elasticity for the GPC..

Mix	Modulus of Elasticity (GPa)	Peak Stress (N/mm ²)	Strain at Peak Stress
GPC20	10.59	18.82	0.0024
GPC40	14.11	33.31	0.0022
GPC60	21.21	43.69	0.0021

Table 12. Modulus of elasticity for the GPC.

Mix	Experimental Value	Theoretical Value	Error (%)	Average Error (%)
GPC20	10.59	9.83	7.10	
GPC40	14.11	12.71	9.91	9.15
GPC60	21.21	19.00	10.44	

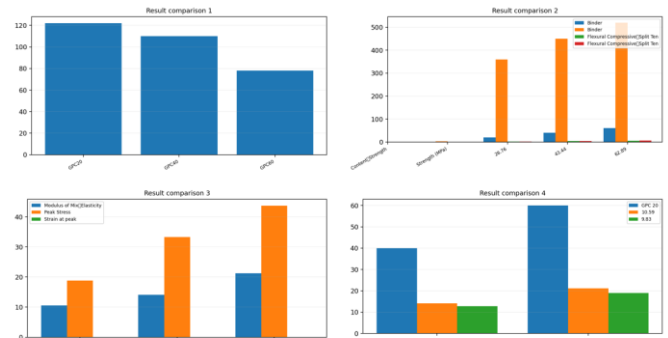


Figure 8. Bar-graph comparison of experimental results.

IV. CONCLUSIONS

- The use of fly ash and GGBS as geopolymer binders provides a suitable alternative to conventional Portland cement concrete, particularly under ambient curing conditions.
- The incorporation of increasing amounts of GGBS significantly improves the compressive strength of geopolymer concrete. The compressive strengths obtained for GPC20, GPC40 and GPC60 were 26.76 MPa, 43.44 MPa and 62.89 MPa, respectively. Increasing the GGBS content results in a reduction in workability. The slump values decreased from 122 mm for GPC20 to 110 mm for GPC40 and 78 mm for GPC60, mainly due to the faster polymerization associated with higher GGBS content.
- The flexural and split tensile strengths increase with increasing GGBS content. The improved tensile properties are attributed to the higher reactivity of GGBS and the formation of additional binding gels during geopolymerisation.
- The study demonstrates that the addition of GGBS enables ambient curing of fly ash-based geopolymer concrete, reducing the dependence on conventional heat curing.
- The modulus of elasticity increases with compressive strength. The experimentally obtained modulus of elasticity was 10.59 GPa, 14.11 GPa and 21.21 GPa for GPC20, GPC40 and GPC60, respectively.
- The strain at peak stress decreases as the compressive strength increases, indicating a transition from relatively ductile behaviour at lower strength to more brittle behaviour at higher strength geopolymer concrete.
- The proposed empirical equation, $E = [4.26C^2 - 111.74C + 10365] \times 10^{-3}$ GPa, provides a reasonable estimate of the modulus of elasticity for geopolymer concrete within the investigated compressive-strength range of 20–60 MPa.

- The proposed equation showed an average error of less than 10% when compared with the experimental results, indicating satisfactory agreement between the experimental and predicted values.
- Overall, fly ash–GGBS based geopolymer concrete exhibits good mechanical performance under ambient curing, demonstrating its potential as a more sustainable alternative to conventional cement-based concrete while utilizing industrial by-products

Declarations

Conflict of interest: The authors declare no conflict of interest.
 Funding: No external funding was reported. Data availability: The experimental data reported in this manuscript are derived from the supplied study.

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