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## Effect of synthesis parameters on the mechanical and elastic behaviour of ambient-cured geopolymer concrete modified with pozzolanic and cementitious materials

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Research Paper

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### Effect of synthesis parameters on the mechanical and elastic behaviour of ambient-cured geopolymer concrete modified with pozzolanic and cementitious materials

The adhesive nature of the binder determines the strength of concrete. Although cement is the most efficient binding material, it is not cost-effective or eco-friendly. Therefore, alternative building materials such as geopolymer concrete (GPC) deserve consideration. In the case of geopolymer concrete, the need for cement as a binding material is eliminated, and strength is achieved through the polymerisation reaction between alkali activators and fly ash/ground granulated blast furnace slag (GGBS). The adequate specimens were then tested at 7th day and 28th day to find their compressive strength, split tensile strength, and Young's modulus. Compared with cement concrete composites, GPC, in which fly ash is replaced with 100 % GGBS and 40 % OPC, showed superior strength without the need for curing at elevated temperatures. The strength was further improved by the addition of OPC to GGBS replaced GPC, and showed an ultimate increase in strength with OPC content as low as 12 %. The experimental investigation revealed a visible decrease in the cement requirement, establishing GPC to be economical and eco-friendly.

#### Key words:

alkaline solution, ambient curing, fly ash, geopolymer concrete, ground granulated blast furnace slag, ordinary portland cement

Prethodno priopćenje

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### Utjecaj sastava na mehanička i elastična svojstva geopolimernog betona očvrstnulo pri temperaturi okoliša uz primjenu pučolanskih i cementnih materijala

Veživna svojstva matrice uvelike određuje čvrstoću betona, zbog čega se cement tradicionalno koristi kao veživni materijal. Međutim, zbog velikih troškova i nepovoljnog utjecaja proizvodnje cementa na okoliš, razmatraju se alternativni veživni sustavi, među kojima geopolimerni beton (GPC) zauzima važno mjesto. U slučaju geopolimernog betona potreba za cementom kao veživom potpuno se eliminira, a čvrstoća se razvija polimerizacijskom reakcijom između alkalnih aktivatora i materijala poput letećeg pepela i mljevene granulirane zgure visoke peći (GGBS). Ispitivanja tlačne čvrstoće, vlačne čvrstoće cijepanjem i modula elastičnosti provedena su nakon 7 i 28 dana. U usporedbi s konvencionalnim betonom, geopolimerni beton s potpunom (100 %) zamjenom letećeg pepela GGBS-om te s 40 % dodatka OPC-a pokazao je višu čvrstoću, bez potrebe za toplinskim njegovanjem. Dodatno povećanje čvrstoće ostvareno je u GPC-u na bazi GGBS-a uz dodatak OPC-a, pri čemu je znatno poboljšanje postignuto već pri udjelu od 12 %. Rezultati eksperimentalnog istraživanja upućuju na mogućnost znatnog smanjenja potrošnje cementa uz zadržavanje ili poboljšanje mehaničkih svojstava, čime se potvrđuje ekonomska i okolišna opravdanost primjene modificiranoga geopolimernog betona.

#### Ključne riječi:

alkalna otopina, njegovanje pri temperaturi okoliša, leteći pepeo, geopolimerni beton, granulirana zgura visoke peći (GGBS), obični portlandski cement (OPC)

## 1. Introduction

Concrete is the most widely used material next to water. Cement, the aggregate binder in concrete, is expensive and emits an equal amount of carbon dioxide during production. Therefore, an alternative eco-friendly concrete is necessary to prevent carbon dioxide emissions [1]. Geopolymer concrete (GPC) has the potential to become an ideal substitute for conventional cement concrete composites. By exploiting the availability of fly ash and GGBS as industrial by-products, the use of cement can be avoided to support environmental sustainability [2].

Achieving high strength is also a challenge for GPC. Increased molarity and high temperature produce high-strength GPC, but at the same time make the manufacturing process complex and uneconomical. The polymerisation reaction in GPC is initiated and sustained by the external application of heat. Hence, the production of geopolymer elements is possible using heating chambers, whereas in situ applications are unattainable [3, 4].

The manufacturing of GPC requires caution with respect to the handling of the alkaline solution and control of the curing temperature. To eliminate the complexity and improve the strength, GPC is modified with pozzolanic and cementitious materials, which increases the strength and dispense with the requirement of a heating chamber for the curing of the GPC [5, 6]. The polymerisation reaction occurs at approximately 90 °C, and this high temperature is essential for the GPC to solidify. A variety of fly ash, GGBS, and Ordinary Portland cement (OPC) admixtures have been mixed to eliminate the need for curing at higher temperatures and increase the strength [7].

The objective of the experimental investigation was to analyse the influence of GGBS and OPC on the mechanical properties of fly ash-based GPC. This investigation may lead to the discovery of a new hybrid GPC capable of attaining high strength at ambient temperatures, making in situ applications possible.

The term geopolymer was coined by Davidovits in 1978. The two prime ingredients of geopolymers are alkaline liquids (NaOH and  $\text{Na}_2\text{SiO}_3$ ) and calcined source materials (Fly Ash, GGBS, Rice Husk Ash, etc.), which are based on alumina silicate and rich in aluminium and silicon [8, 9]. In contrast to OPC, which attains strength by producing calcium-silicate hydrates (CSHs) in the hydration reaction, geopolymers and polymeric materials attain strength by activating silica alumina-rich minerals with alkaline solutions at elevated temperatures, resulting in a three-dimensional polymeric chain and ring structure consisting of Si-O-Al-O bonds [10, 11]. Polymerisation reactions may occur with a combination of dissolution, orientation, and polycondensation in the course of an exothermic process [12, 13].

The alkali activator liquid to source material ratio by mass in the range of 0.25-0.30 is used [14]. Cement, along with GGBS

in varied proportions at ambient temperature, is adequate to initiate and sustain the polymerisation reaction, eliminating the requirement of curing at high temperatures. Geopolymers are alkaline in nature and resistant to reactions with acids. Furthermore, the paste content in GPC is higher than that in cement concrete composites; hence, the chemical attack due to the penetration of liquid is averted [15]. This study examined the various responses of GPC when mixed with OPC and GGBS in different proportions.

## 2. Experimental methodology

The goal of this experimental study is to investigate the influence of various synthesis parameters on the mechanical strength and elastic properties of ambient-cured GPC incorporating pozzolanic and cementitious materials.

Specifically, this study evaluated the effects of replacing fly ash with GGBS and OPC, as well as substituting GGBS with OPC, on the stiffness and mechanical performance of GPC. By identifying the optimal binder combinations and replacement percentages, this study seeks to enhance the mechanical behaviour while maintaining ambient curing conditions. To eliminate the requirement for curing at high temperatures and improve the strength of GPC, various preliminary studies with different combinations have been conducted. Based on the literature review and preliminary investigation, the replacement percentage of GGBS, OPC and fly ash was determined.

### 2.1. Mix proportioning

As cited by Hardjito and Rangan (2005) [16], unlike conventional cement concrete composites, GPCs are innovative construction materials with no standard mix design approaches yet available. A trial mix design was adopted for the GPC, as described in Table 1. The GPC manufactured by the trial mix requires curing at a high temperature; to overcome this problem, GGBS and OPC were mixed and replaced with fly ash to achieve ambient curing and higher strength.

The unit weight of the GPC is 2400 kg/m<sup>3</sup>. The combined aggregate (CA) content comprising both coarse and fine fractions was taken as 75 % of the total concrete mass, resulting in an aggregate mass of 1800 kg/m<sup>3</sup>. Of this, coarse aggregates accounted for 65 %, corresponding to 1170 kg/m<sup>3</sup>, while the remaining 35 % was designated for fine aggregates, contributing 630 kg/m<sup>3</sup>. These proportions were employed during the trial mix formulation to achieve an optimal balance among density, workability, and mechanical performance. The ratio of sodium silicate to sodium hydroxide was 2.5, and the liquid-to-fly ash ratio was 0.5 [17]. The dissolution of NaOH in water releases heat which supports the polymerisation reaction. To utilise this heat, the waiting period for dissolution is reduced from 24 h to 6 h, as the heat is reduced with an increase in the dissolution time [18].

Table 1. Mix proportions of geopolymer concrete

Trial mix	ID	Concrete mixture quantity [kg/m <sup>3</sup> ]					
		Combined aggregate	Coarse aggregate	Fine aggregate/sand	Fly ash	NaOH	Na <sub>2</sub> SiO <sub>3</sub>
T1	P0	1800	1170	630	400	57.15	142.85
T2	P4	1800	1170	630	384	57.15	142.85
T3	P8	1800	1170	630	368	57.15	142.85
T4	P12	1800	1170	630	352	57.15	142.85
T5	P16	1800	1170	630	336	57.15	142.85
T6	P20	1800	1170	630	320	57.15	142.85
T7	P40	1800	1170	630	240	57.15	142.85
T8	P60	1800	1170	630	160	57.15	142.85
T9	P80	1800	1170	630	80	57.15	142.85
T10	P100	1800	1170	630	0	57.15	142.85

## 2.2. Casting of test specimens

As shown in Figure 1, the weighed constituents of the geopolymer concrete, fly ash, fine aggregates, and coarse aggregates were initially mixed in a dry state and then mixed

with an alkaline solution according to the trial mix proportion. Fresh concrete was tested for workability, and the slump value was checked for each mix.

Cubes of size 150 × 150 × 150 mm for testing the compressive strength, and cylinders of size 150 mm diameter and 300

mm height for testing the split tensile strength were cast with the help of cast iron steel moulds. To achieve ambient curing of the GPC, the percentage of GGBS in the mix was increased by replacing the fly ash. The cubes were kept in mould for 24 hours and then de-moulded for curing in ambient temperature, which implies a surrounding temperature of 27 °C to 35 °C and relative humidity of 70 % to 80 %. The specimens were tested after 7 and 28 days to determine the optimum percentage of maximum strength. To improve the strength parameters, OPC was added as a replacement for GGBS, and the optimum strength percentage was tested after 7 and 28 days [19].

## 3. Materials used

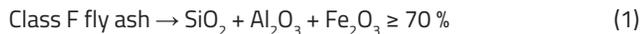
The physical and chemical properties of the constituent materials used in this study are listed in Tables 2 to 6. These values were obtained primarily from certified technical datasheets provided by the respective suppliers and verified through standard laboratory procedures, thus ensuring compliance with relevant specifications prior to use in the mix design.



Figure 1. Casting process and ambient curing of geopolymer concrete: a) Weigh batching; b) Mixing and casting cube/ cylindrical specimen; c) Ambient curing

### 3.1. Fly ash

The fly ash used in this study was procured from a thermal power station in Tuticorin, India. The available fly ash was classified as Class F fly ash, which contained the maximum amounts of alumina and silica. Fly ash by itself does not have adhesive properties but has ingredients favourable for GPC [20]. The pozzolanic properties of fly ash, comprising less than 10 % CaO and 5 % carbon, are superior. The properties of the fly ash are listed in Table 2.



**Table 2. Physical properties of fly ash**

S. No.	Material properties	Values
1.	Specific gravity	2.34
2.	Surface area	300 – 500 m <sup>2</sup> /kg
3.	Particle size	1 μm – 150 μm
4.	Bulk density	540 – 860 kg/m <sup>3</sup>
5.	Fineness modulus	2.73

### 3.2. Ground granulated blast furnace slag

GGBS is an industrial byproduct of the smelting process used to obtain iron and steel. Blast furnace slag mostly consists of calcium silicates and alumina silicates, which are formed under molten conditions. Blast furnace slag in molten state has a temperature of 1300 °C- 1600 °C and is cooled rapidly by water cooling process to prevent crystallisation.

The raw granulated blast furnace slag is a glassy granular product which is dried and ground into fine powder with particle size less than 45μ. When added to cement in the prescribed quantities, GGBS produces high-strength concrete with enhanced workability, reduced permeability, and resistance to chemical attacks [21]. The chemical composition and physical properties of granulated blast furnace slag are shown in Tables 3 and 4.

**Table 3. Chemical composition of GGBS**

S. No.	Chemical components	Percentage mass
1.	Calcium oxide (CaO)	45.45 %
2.	Silicon dioxide (SiO <sub>2</sub> )	29.96 %
3.	Sulfur trioxide (Al <sub>2</sub> O <sub>3</sub> )	12.25 %
4.	Sulfur trioxide (SO <sub>3</sub> )	3.62 %

**Table 4. Physical properties of GGBS**

S. No.	Material properties	Values
1.	Specific gravity	2.90
2.	Fineness modulus	3.75
3.	Bulk density	1200 kg/m <sup>3</sup>

### 3.3. Ordinary portland cement (OPC)

Cement, the binding material for aggregates in concrete, is a fine powder produced by the calcination of lime and clay at high temperatures. During hydration, cement generates C-S-H gel, exhibiting superior bonding characteristics which contribute to the strength of the concrete. Table 5 details the major chemical compounds present in OPC, and Table 6 lists its key physical attributes. The cement employed in this study was Ordinary Portland Cement (OPC) of 43 grade, conforming to IS 650:1966, which specifies a minimum compressive strength of 43 MPa after 28 d of curing.

**Table 5. Basic components of OPC**

Chemical components	Percentage mass
Calcium oxide (CaO)	61 – 67
Silicon dioxide (SiO <sub>2</sub> )	18 – 24
Aluminium oxide (Al <sub>2</sub> O <sub>3</sub> )	3 – 7
Sulphur trioxide (SO <sub>3</sub> )	2.3 – 3.7
Ferric oxide (Fe <sub>2</sub> O <sub>3</sub> )	0.5 – 5.5
Magnesium oxide (MgO)	0.5 – 3
Alkalis	0.5 – 1

**Table 6. Physical properties of OPC**

S. No.	Material properties	Values
1.	Compressive strength (At 28 days in N/mm <sup>2</sup> )	57
2.	Specific gravity	3.14
3.	Standard consistency [%]	32
4.	Initial setting time [min]	28
5.	Final setting time [min]	219

### 3.4. Alkaline solution

An alkaline solution is a blend of a sodium silicate solution and sodium hydroxide in a ratio of 2.5, mixed with water. The solution is an indispensable part of GPC and acts as a binder for aggregates when combined with fly ash [22].

**Table 7. Physical properties of fine and coarse aggregates**

Fine aggregates		Coarse Aggregates	
Material properties	Values	Material properties	Values
Fineness modulus	2.73	Fineness modulus	6.45
Particle size	425 $\mu$ to 2 mm	Particle size	4.75 mm to 20 mm
Specific gravity	2.67	Specific gravity	2.62
Bulk density	1668 kg/m <sup>3</sup>	Bulk density	1765 kg/m <sup>3</sup>
		Shape	Cubical

Sodium hydroxide pellets are produced by the electrolysis of a sodium chloride solution. NaOH or caustic soda is extremely alkaline, with PH values between 12 and 14. The molecular weight of NaOH is 40 and the specific gravity is 2.13. Sodium hydroxide pellets (99 % purity) were dissolved in distilled water to prevent chemicals and minerals from mixing with water. The molar concentration played a major role in the strength development of the GPC. The concentration of any substance dissolved per unit volume is known as the molar concentration or molarity. NaOH (10 M) with molecular weights of 40 and 400 g (10  $\times$  40 g) was dissolved in 1 litre of water.

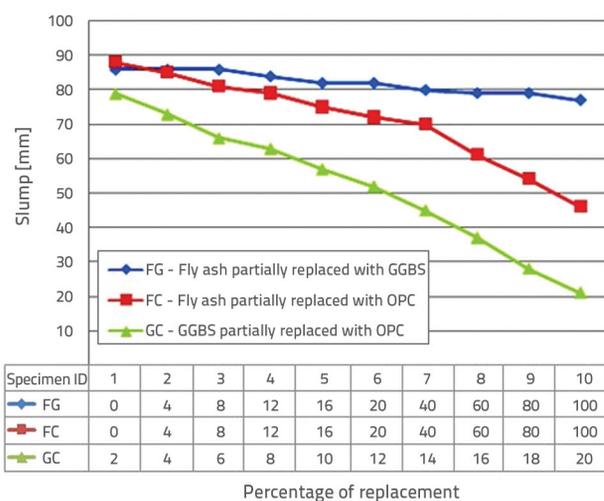
Sodium silicate solutions in the form of liquid/gel is produced by melting and fusing of sand (SiO<sub>2</sub>) with sodium carbonate at 1100-1200 °C. It is also identified as water glass, composed of water (55.52 %), SiO<sub>2</sub> (29.75 %), and Na<sub>2</sub>O (14.73 %). The specific gravity of sodium silicate is 1.39 and its PH value is in the range of 11 to 12. In this investigation, a 12 M NaOH concentration was adopted, and the PH value of the liquid silicates was maintained below 10.7 to achieve an effective polymerisation reaction. In addition, the reactions between NaOH, Na<sub>2</sub>SiO<sub>3</sub> and water generate a large amount of heat which increases the rate of polymerisation.

### 3.5. Aggregates

Aggregates which occupy a major volume in the concrete were scrutinised by sieve analysis, and the correct proportions of fine and coarse aggregates by weight were incorporated. sand (fine aggregate) with a low clay content (less than 4 %) was used in saturated dry conditions. Table 7 summarises the physical characteristics of the fine and coarse aggregates used in the experimental study.

## 4. Results and discussion

An experimental investigation was conducted to validate the approach for achieving high strength at ambient temperatures for GPC modified with GGBS and OPC. Laboratory assessments of slump, compressive strength, split tensile strength, and Young's modulus were performed with an average of three specimens per mix.


**Figure 2. Variation in slump for geopolymer concrete with various mixes**

### 4.1. Workability

Workability plays a major role in the development of concrete strength, given that the ability to mix, place, and compact fresh concrete is the basic factor for achieving effective bonding of aggregates and high density. Confirming to IS 1199, a slump value was determined for all mixes to assess workability at the time of casting. The formation of an amorphous structure owing to polymerisation is faster compared to the hydration reaction of cement. The workability of all mixes was satisfactory, and the addition of GGBS and OPC to the mix resulted in a steady decrease in workability.

### 4.2. Young's modulus

The elasticity of concrete, which is a brittle material, must be investigated to assess its stiffness behaviour under a load. The modulus of elasticity depends on the strength of the aggregates and cement matrix. As shown in Figure 3, a compressometer was centrally fixed to the concrete cylinder specimen, and the compressive load was gradually applied until collapse; the load and deformation values were noted and analysed to determine the Young's modulus in confirming IS 516.



Figure 3. Test setup for Young's modulus

The variation in the Young's modulus for the modified GPC incorporating different binder replacements revealed notable trends. When GGBS was used as a partial replacement for fly ash, a progressive increase in Young's modulus was observed—from 24.20 GPa at 0 % GGBS replacement (FG1) to 41.78 GPa at 100 % replacement (FG10). In another series of experiments, fly ash was replaced with OPC (designated as FC), and Young's modulus peaked at 35.10 GPa when 40 % of the fly ash was substituted (FC7). However, a further increase in the OPC content beyond this level led to a noticeable reduction in Young's modulus. Similarly, when the GGBS was partially replaced with OPC (series GC), the highest Young's modulus value of 47.80 GPa was achieved at a 12 % replacement level (GC6). A decline in the modulus was observed beyond this point, likely owing to the reduced workability and difficulty in compaction. These variations are illustrated in Figure 4.

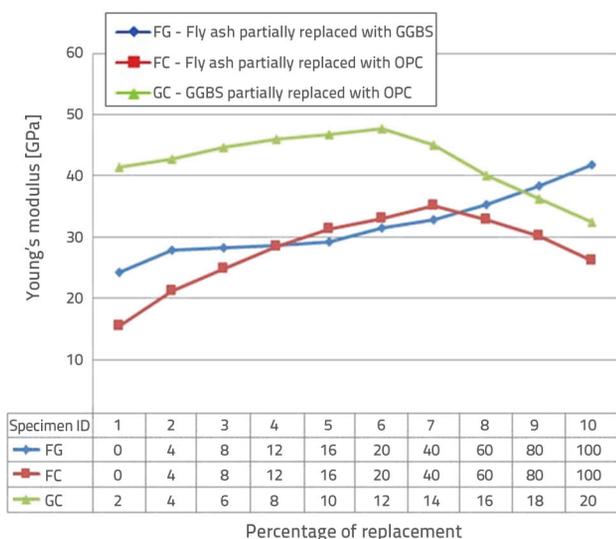


Figure 4. Variation in Young's modulus of geopolymer concretes with various mixes

### 4.3. Compressive and tensile strength

Good compressive strength reflects the effectiveness of the concrete mix, which is the primary property of concrete. Compressive strength represents a quality parameter for any concrete. It directly represents the good practices followed during the casting process, such as accurate batching, effective

mixing, compacting, placing, and curing, and indirectly represents the binder content and quality of the ingredients. Split tensile strength gains importance because the concrete is superior in compression and weak in tension. Taking into account this weakness can ensure the reliability of the overall performance of concrete. The splitting tensile strength also provides indirect insights into the shear resistance of concrete.

The specimens confirmed to IS 516 and IS 5816, and were subjected to a uniform gradual load until failure; the test specimens were then tested under a compression testing load taken by the specimen at different stages with a capacity of 2000 kN. Cubes and cylinders were used to obtain the compressive strength and split tensile strength. The test setup is shown in Figure 5.



Figure 5. Test setup for split tensile and compressive strength tests

Fly ash-based GPC was the standard for the trial mix, as fly ash was replaced with varying percentages of GGBS. The combination of fly ash and GGBS increased the paste content and provided excellent workability. As illustrated in the first part of Figure 6, the replacement of fly ash with GGBS resulted in a steady increase in both the compressive strength and split tensile strength over time. The inherent binding character of GGBS, high alumina and silica content, and fineness of the GGBS particles played a major role in the development of compressive strength. The gradual increase in split tensile strength was a result of increased workability which made the concrete very dense and compact.

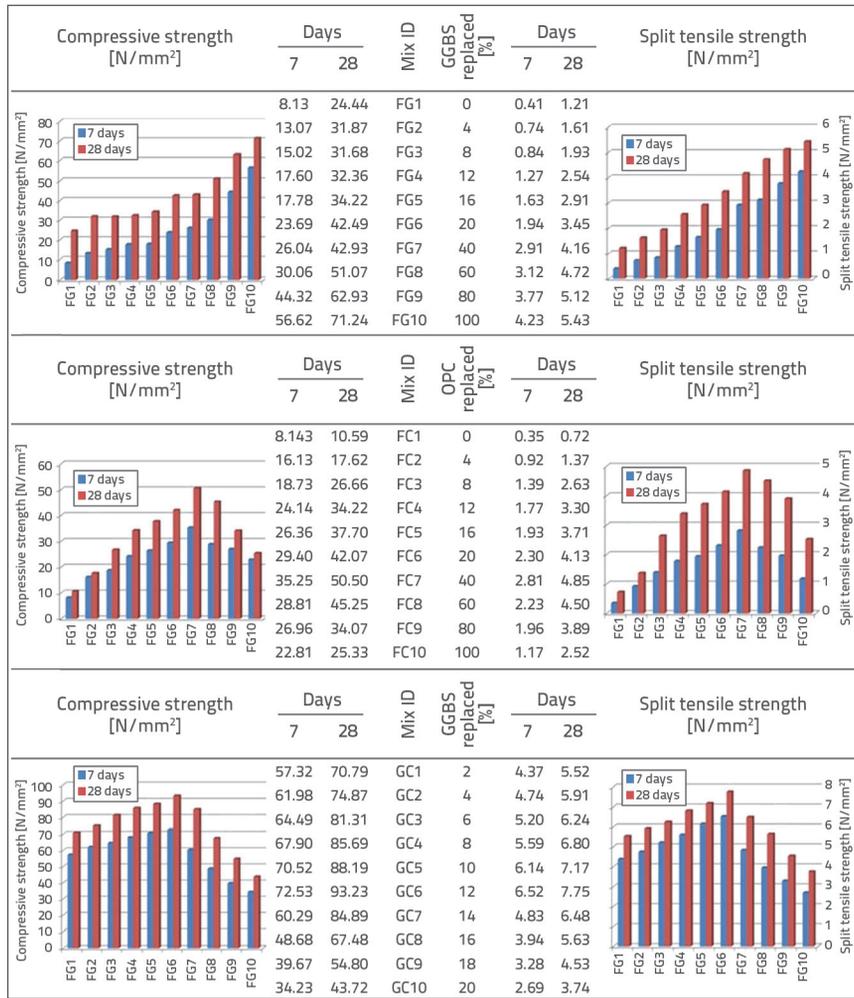


Figure 6. Compressive strength and split tensile strength of geopolymer concrete

requires heat for curing, which is provided by the exothermic reaction of sodium hydroxide solution with water during the dissolution process. The strength and workability steadily increased up to 40 %, beyond 40 %, the workability and strength and workability decreased. The reason for the decrease in workability and eventual strength is the formation of amorphous solids of alumina and silica at the very early stages of fresh concrete because of the hydration reaction (OPC) and the exothermic reaction of the sodium hydroxide solution with water, which reduces the setting time and forms stiff concrete.

To amplify the strength of GPC under ambient curing conditions, OPC was added to the GGBS-based GPC, as shown in the third part of Figure 6. Because GGBS and OPC are excellent binders for aggregates, the strength achieved was superior to that of normal concrete. Beyond a 12 % replacement of GGBS with OPC, the strength and workability were drastically reduced because of the accelerated strength gained owing to the hydration and polymerisation reaction of GGBS and OPC, making the concrete stiff and difficult to compact.

As noted in previous experiments, fresh concrete loses its workability and becomes stiff when more GGBS is replaced with OPC. To maintain the

The second part of Figure 6 shows the mechanical behaviour of fly ash-based GPC when OPC is added, which is similar to ordinary cement concrete composites. Fly ash-based GPC

workability and reduce the stiffness of fresh concrete, the replacement of OPC was limited to 20 %. The compressive strengths of the GGBS-based GPC and fly ash-based GPC

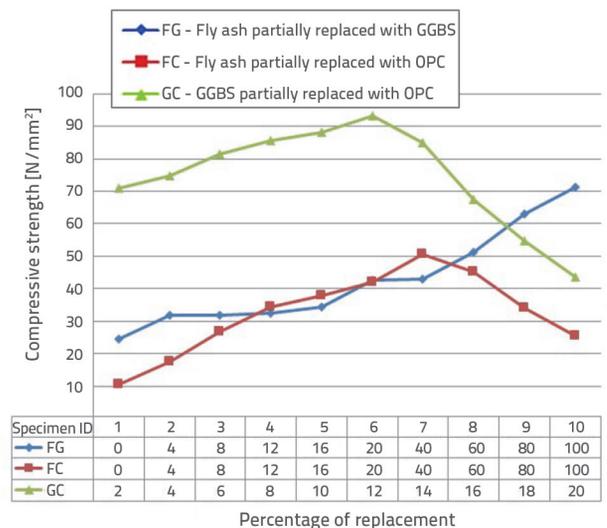
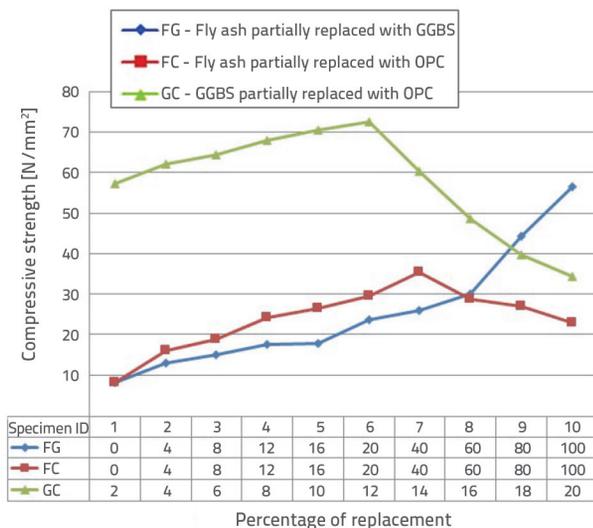


Figure 7. Compressive strengths of FG, FC, and GC at 7 and 28 days

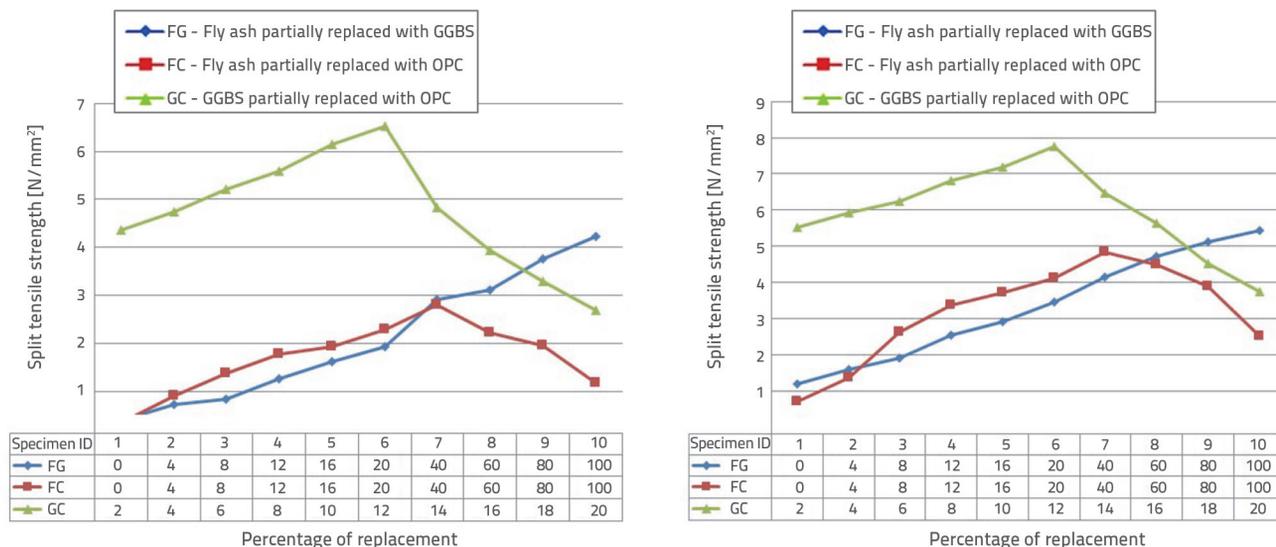


Figure 8 Splitting tensile strengths of FG, FC, and GC at 7 and 28 days

with OPC increased gradually, reaching optimum values of 40 % and 100 %, respectively. Unlike GGBS-based GPC and fly ash-based GPC with OPC, the binding properties of GGBS combined with OPC resulted in a high compressive strength at the onset itself.

The influence of OPC on GPC is evident, as there is a salient similarity in the shapes of the curves representing the compressive and split tensile strengths. The magnitude of the split tensile strength was higher than that of conventional concrete and fly ash-based GPC, Figures 7 and 8.

### 5. Conclusion

The replacement of cement concrete composites with GPC is beneficial in many ways, such as the utilisation of industrial wastes such as fly ash and GGBS. GPC contributes to the reduced use of cement for concreting, thereby reducing CO<sub>2</sub> emissions, energy consumption, and raw materials required for manufacturing cement. The empirical proportioning of fly ash, GGBS, and OPC resulted in a GPC which could be cured under ambient conditions without the need for heat or a curing chamber. This was one of the highlights of this study. The GPC proportions used in this study at ambient temperature can be used for in situ concreting and adapted for normal construction processes, similar to conventional concrete with high strength. All combinations showed excellent workability at the beginning, reasonable workability at optimum strength, and decreased workability as the strength decreased. The compressive strength improved significantly with the addition of OPC as an admixture during ambient curing. The compressive strengths for different combinations show that the GGBS-based GPC is more suitable for ambient-cured GPC, and 40 % OPC is the optimum quantity for fly ash-based GPC with ambient curing. The combinations were further varied,

and the findings showed that the addition of a small quantity of OPC to the GGBS-based GPC increased the strength to 93 MPa, which was superior to the inherent properties of fly ash-based GPC. A split tensile strength of 7.75 MPa was achieved when OPC was added to the GGBS-based GPC. Satisfactory split tensile strengths of 4 and 5.5 MPa were observed for other combinations of fly ash and GGBS, respectively. The modulus of elasticity of GPC with various combinations showed a steady increase in magnitude, reaching 41.785 GPA with 100 % replacement of fly ash with GGBS.

The increase in the elastic properties was due to the GGBS in the paste zone, which enhanced the resistance to deformation. The elastic characteristics were further improved by OPC. When fly ash was replaced with 40 % OPC, Young’s modulus was 35.178 GPA, and the OPC as an admixture in the GGBS-based GPC produced 47.81 GPA at 12 %. Water expelled during the polymerisation reaction was used by the cement paste for the hydration reaction, eliminating the requirement of water for curing and improving strength. The shrinkage cracks were significantly reduced owing to the accessibility of water expelled from the polymerisation reaction which prevented the formation of cracks intended to be formed during the ambient curing process.

There was a considerable reduction in binder content from the perspective of reduced usage of OPC without compromising the strength. Curing in a heating chamber is not required, as in cases such as prefabrication, because GPC can be cured under ambient conditions; hence, prefabrication is completely eliminated, reducing the cost incurred in the heating chamber, transportation, and erection processes. Further studies should be conducted in the future to investigate the mechanical behaviour of modified GPC when fibre reinforcement is added, as there is a high possibility of thermal stresses and crack formation

owing to thermal variation, which may be prevented by fibre reinforcement and increased strength. Moreover, the performance of the GPC under different environmental conditions must be studied to ensure its durability and longevity. The response to thermal stress, acid attack, and permeability must be investigated and validated because GPC is expected to perform similar to conventional concrete. The structural applications of the modified GPC should be analysed and experimentally validated, as GPC is expected to be used for in-situ structural elements.

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