Library Progress International
Vol.44 No.3, Jul-Dec 2024: P.4939-4955

Print version ISSN 0970 1052
Online version ISSN 2320 317X

Original Article

Available online at www.bpasjournals.com

Evaluating Economic indexing between various kinds of Geopolymer Concrete to Ordinary Cement Concrete

Akshay Dhawan[1], Manvendra Verma[1]*, Rajesh Goel[2]

[1]Department of Civil Engineering,GLA University, Mathura, 281406, India.
Akshay.dhawan2789@gmail.com
[2]School of Construction Management, NICMAR Delhi NCR, Bahadurgarh 124507, India
rajeshgoel78@gmail.com
***Corresponding Email: mv075415@gmail.com**

How to cite this article: Akshay Dhawan, Manvendra Verma, Rajesh Goel (2024). Evaluating Economic indexing between various kinds of Geopolymer Concrete to Ordinary Cement Concrete. *Library Progress International,* 44(3), 4930-4938.

ABSTRACT

Concrete is a crucial structural component used in civil engineering projects. Many different types of building structures use concrete. The concrete construction technique is measured the quality of the concrete structure due to the mostly encouragement of construction structure durability. The enhancement of good quality in concrete construction and maximize the management of concrete construction, this research work primarily summarizes the current concrete construction situation and thoroughly analyses a few issues and technical details in the construction process. Geopolymer concrete presents a significant answer to the global structural degradation issue as well as the environmental one. Yet, there is little to no research on the financial effects of it. The utilization of source materials are fly ash and ground granulated blast furnace slag (GGBFS) to manufacturing the geopolymer concrete.The source material concentrations were achieved by preparing alkaline solutions. The source materials were activated by the concentration. The proportion of GGBFS varies, and the composition of other source materials also varies. The geopolymer concrete (GPC) outcome of this research work is to easy access the index of economy and cost of manufacturing compared to traditional manufacturing of ordinary Portland concrete (OPC). The obtained resultshave been represented theGPC-2 and GPCS-7 of economy index is worse than OPC's, its manufacturing costs are 31.13% and 43.74% cheaper. The findings suggest that GPC is a more practical and affordable option than OPC. When compared to OPC, the GPC's compressive strength has increased.

Keywords: Geopolymer; Concrete; Portland; Compressive Strength; Application.

1. Introduction

Recently, civil oriented construction projects are mostly prepared the base materials of concrete. Because concrete itself has benefits over other building materials that cannot be replaced, the technological level of concrete construction also influences the construction level to some extent. The quality issue in construction engineering has drawn more and more attention from the public due to the swift growth of civil engineering's infrastructure in China. The interests of the general public and the financial gains of construction companies are linked to the safety of concrete technology. The performance of concrete is influenced by numerous aspects during the construction process, despite the fact that concrete materials have numerous benefits and features. The quality of concrete will suffer greatly during the building process if each construction ingredient is not properly controlled. The construction procedure has a very comparable detrimental effect [1].

In past decades, the manufactured GPCof the basic binder of alkali solution are mostly used and the durability is very high to be an alternative to ordinary Porland concrete. The source materials are GGBFS, fly ash, metakaolin (MK), and other aluminosilicate-basedmaterials to create alkali activated binders. These binders could be the answer to the waste creation and construction sector issues. More focus is placed on low calcium source materials that produce geopolymers because Ca rich source materials, especially slags, are scarce. Joseph

Davidovits originally used the word "geopolymer" in 1978 [2].This inorganic polymer was created via the polycondensation reaction between alkalis and a specific waste material that contained aluminosilicate. The geopolymer are created using the tetrahedra combination of $[SiO_4]^{4-}$ and $[AlO_4]^{5-}$.The created framework construction is three-dimensional aluminosilicate which is conversion from amorphous to semi-crystalline. Because accessible alkalis like Na^+ replace silicon in the tetrahedral layer with aluminium, the structure retains its electrical neutrality [3]. Uncertainty surrounds the geopolymer setup and hardening mechanism. Aluminosilicate-containing raw materials may dissolve in alkali solutions during the geopolymerization process, forming silicate and aluminate monomers. The geopolymerization process involves the condensation, polymerization, and dissolution and rearrangement. In Figure 1 indicates the form of massive polymers from the dissolves of aluminosilicate and restructures to create a variation of oligomers [4].

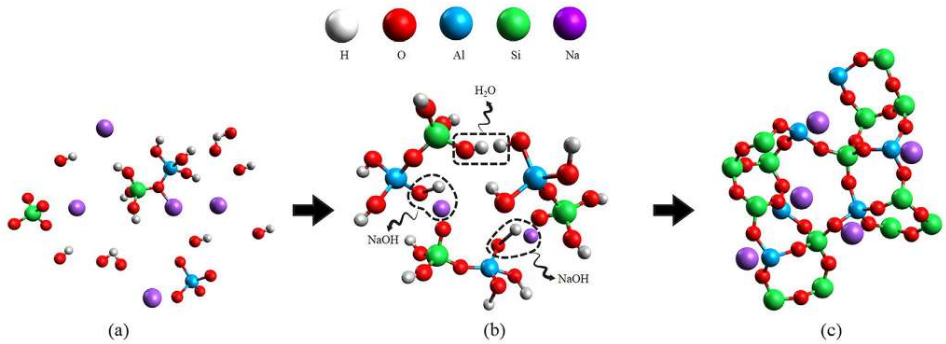

Figure 1. *The geopolymerization process represent the a) restructuring of aluminosilicate, b) condensation process to gel formation and c) polymerization.*

An OH groups at the ends of oligomers join together when they form a bond, distribution atom of oxygen and water release [4]. Numerous historical buildings made of geopolymers have TO_4 tetrahedrons as their primary building block (where T is Si or Al) [5, 6]. With its strong engineering qualities, geopolymer cement concrete looks perfect replacement for ordinary Portland concrete [7], [8], and [9]. The GPC is represented as green concrete. Ithas a good environmental effect [10], [11], [12]. It not only efficiently recycles solid waste and conserves resources, but it can also lower CO_2 emissions. It might provide a solution to the environmental pollution and cement industry concerns [13], [14], [15], [16], and [17]. To shed light on the possible uses of this material in the construction sector, this paper thoroughly explores the literature and covers the geopolymerizationprocesses, water absorption techniques, characterization techniques, and attributes of GPCs.

It denotes a strategy that is appropriate for designing concrete mixes, guided by the macro and micro qualities of the concrete as well as the properties of the dynamic soil and the soil mechanics that regulate the load applied to the soil foundation. The serviceability of the soil foundation and structure, as well as the interaction between soil and structure, are directly impacted by the construction material. Through the introduction of appropriate techniques for improving the soil foundation, the shear morphology, applied force, deflection, and time to failure of concrete beams can be controlled. When it comes to the seismic force behaviour applied to the structural parts, the earth foundation is crucial.

The majority of experimental programs have been conducted in this instance; however, the comparative examines of the ordinary Portland concrete and geopolymer concrete of the different composition evaluated. From this existing work, the key factors are predicated, these are must be taken into consideration in the present research.

- To enhance the mechanical and curing properties of influence of silica composition in geopolymer concrete.
- To perform the water absorption efficiency of geopolymer concrete at different concentrations of the solutions.
- To performance of the index of economy in geopolymer concrete with addition of silica composition and efficiency of the regression model.

2. Background

Geopolymers belong to the family of mineral polymers, which is represented the amorphous microstructure moderately than crystalline and their chemical combinations are comparable to those of zeolite materials. Geopolymer concrete (GPC) is created by using polymers, such as concrete adhesives, and can serve as an acceptable replacement for ordinary Portland cement (OPC). In addition to these advantages, the existing researchers have been suggested the GPC as a Portland cement concrete (PCC) substitute. In latest article of Albitar et al. [18] emphasized that chemically stable offly ash is more than conventional concrete and durability condition of GPC is more compared to PCC under the same curing conditions.

According to Liew et al. [19], using green concrete in construction work is great benefits to the environment. The following advantages of green concrete used in this world such as workability improvement, strength is maximum, durability is longer, minimum permeability, bleeding control, good resistance to acid attack, and plastic shrinkage crack reduced. The characteristics of green concrete manufacture is curing times shorter, construction costs are minimized, project completion as earlier, maintenance costs minimum, and project lifespans are higher. According to a recent researchwork by Li et al. [20], the improved the GPCstrength is 50 MPa at 28 days with source materials, and GGBS. The compressive strength of concrete after 28 days is usually tested in a laboratory. Nevertheless, based on the results obtained compressive strength from the geopolymer, it appears that the strength increases slightly between 28 and 90 days. For this reason, it is strongly recommended that the compressive strength of this kind of concrete be tested at 90 days as well. The majority of GPC's compressive strength developed after seven days, despite a minor rise noted at 28 days. This occurred because heat curing accelerated the geopolymerization reaction, which represented the improved strength of concrete.

Joseph Davidovits created GPC in 1978 by utilizing industrial leftovers to create concrete. The prepared geopolymer concrete the main source materials are used such as fly ash, GGBS, and metakaolin, it has maximum amount of alumina and silica content. Alkali solutions like potassium and sodium hydroxide is essential for the usage of source material to dissolve [21]. The interaction of highly concentrated alkaline solutions with aluminosilicate powder produces geopolymer. The process of acquiring strength is reliant on geopolymerization. The concrete strength has been controlled the influence of the silicon dioxide and aluminium oxide [22]. The maximum strength of 75 MPa has been reached geopolymer concrete with class C fly ashat oven curing conditions [23]. In contrast, GPC withclass C fly ashmanufactured at ambient curing conditions (at room temperature of 25–30 °C) has been found 47–56.5 MPa of compressive strength [24]. This strength has occurred due to more amount of calcium interferes with polymerization and microstructural characteristics; it is preferred to employ minimal calcium to make GPC [25].

Chen et al. [26] they have represented the innovative idea of the reinforcement used in GPC, it has increased durability of the concrete and robustness is also long term in the field of construction work. Saranya et al. [27] they have been obtained the withstand load carrying maximum capacity of GPC with dolomite and GGBFS at the location of the construction is joints of beam-column. In addition, include of steel fiber in GPC has improved the properties like ductility and energy absorptivity. Due to less emission of carbon and enhanced the mechanical properties of GPC with reinforcement of steel fiber.Based on the above results are considered this GPC is suitable for gas exploding subterranean tunnels construction work [28]. Alrshoudi et al. [29] they have implemented the GPC with addition of glass and carbon fiber-reinforced polymers to enhanced the good results of ductility and compressive strength.Compared to source materials fiber based concrete exhibits the good mechanical properties [30].

3. Materials and Methodology

The current research project is comprised of the following materials. Materials like coarse aggregate, sand, fly ash, GGBFS, calcined clay, sodium hydroxide (SH), sodium silicate (SS), water, and super plasticizer (SP) are used in the manufacturing of geopolymer concrete. In addition of micro silica added to this concrete. The binder combination of the GPC and OPC are contrasted.

The preparation of the OPC and GPC according to the Americanconcrete institute's (214R 2011 and 211.1 2002) proceduresare followed in designing the mix proportions. This allowed for the consideration of various factors, including the specific gravities, moisture contents, and water absorption capacities of the materials utilized. Tables 1 and 2 display the mix replacement levels.

Table 1: Proportion of the GPC with different proportions of Fly Ash, GGBS, and CC

Kg	Coarse Aggregate	Sand	Fly Ash	GGBFS	Calcined Clay	SH	SS	Water	SP	Cement
GPC-1	1222	658	400	-	-	40	100	8	6	-
GPC-2	1222	658	-	400	-	40	100	8	6	-
GPC-3	1216	655	-	-	400	40	100	8	6	-
GPC-4	1222	658	400	-	-	47	94	8	6	-
GPC-5	1222	658	-	400	-	47	94	8	6	-
GPC-6	1222	658	-	-	400	47	94	8	6	-
GPC-7	1222	658	400	-	-	56	84	8	6	-
GPC-8	1216	655	-	400	-	56	84	8	6	-
GPC-9	1216	655	-	-	400	56	84	8	6	-
OPC	1054	740	-	-	-	-	-	151	4.2	376

Table 2: Proportion of the GPC with different proportions of Fly Ash, GGBS, CC, and Micro Silica

Kg	Coarse Aggregate	Sand	Fly Ash	GGBFS	Calcined Clay	SH	SS	Water	SP	Cement	Micro Silica
GPCS-1	1222	658	40	360	-	40	100	8	6	-	-
GPCS-2	1222	658	80	320	-	40	100	8	6	-	-
GPCS-3	1216	655	200	200	-	40	100	8	6	-	-
GPCS-4	1222	658	-	360	40	40	100	8	6	-	-
GPCS-5	1222	658	-	320	80	40	100	8	6	-	-
GPCS-6	1222	658	-	200	200	40	100	8	6	-	-
GPCS-7	1222	658	40	320	-	40	100	8	6	-	40
GPCS-8	1216	655	40	340	-	40	100	8	6	-	20
GPCS-9	1216	655	-	320	40	40	100	8	6	-	40
GPCS -10	1216	655		340	40	40	100	8	6	-	20
OPC	1054	740	-	-	-	-	-	151	4.2	376	-

The normal chemical laboratory methods outlined by [31] were followed in the preparation of the alkaline liquids, which took place 24 hours before the concrete was cast. It took roughly five minutes of mixing to produce a uniform mixture. Superplasticizer was added at a mass percentage of 1.0% to the binder. For the preparation of geopolymer is not required the superplasticizer, it is not for regular Portland concrete, as it has no discernible impact on the material's workability and strength [32], [33]. Every sample was cured in ambient conditions at room temperature (23 ± 5 ºC). For the testing purpose, three samples are collected from each mixture. A digital compressive testing equipment is used to measure the compressive strength with the capacity of 2000 kN at 28 and 90 days after curing using British Standards (EN 12390-3 2000). Equation (1) is used to compute the concrete's economy index.

$$Economy\ Index = \frac{Compressive\ Strength}{Total\ Cost\ of\ Production} \tag{1}$$

4. Economic Analysis

Tables 3 and 4 show the production costs per kilogram for geopolymer concrete and regular Portland concrete, respectively. Table 3 demonstrates that the entire cost of production for regular Portland concrete is Rs. 6058.1, with cement accounting for a sizeable portion of that amount at 49.65 per unit. Comparably, Table 4 shows that the entire cost of manufacture for geopolymer concrete is Rs. 7524.3, with a sizeable portion of the cost26.58 percentbeing attributed to SH solution.

Table 3: Production cost for OPC

Constituent	Quantity	Rate/Kg	Amount	Constituent Cost (%)
Coarse Aggregate	1054	1.5	1581	26.09
Sand	740	1.25	925	15.26
Water	151	1.1	166.1	2.74
SP	4.2	90	378	6.23
Cement	376	8	3008	49.65
Total (Kg)			**6058.1**	**100**

Table 4: Production cost for Geopolymer concrete (GPC-1)

Constituent	Quantity	Rate/Kg	Amount	Constituent Cost (%)
Coarse Aggregate	1222	1.5	1833	24.36
Sand	658	1.25	822.5	1093
Water	8	1.1	8.8	0.11
SP	6	90	540	7.17
Fly Ash	400	1.8	720	9.56
GGBFS	-	2.85	-	-
Calcined Clay	-	4.8	-	-
SH	40	50	2000	26.58
SS	100	16	1600	21.26
Micro Silica	-	23	-	-
Total (Kg)			**7524.3**	**100**

An assessment of the economic, environmental, and performance benefits and costs of geopolymer concrete's whole lifecycle, from raw material extraction to manufacture, usage, and recycling or disposal, is included in a study known as a life cycle cost analysis (LCCA). An outline of the geopolymer concrete LCCA is provided below, emphasizing its durability, long-term maintenance, and environmental impact:

- Raw Materials: The geopolymer concrete are prepared using the Industrial byproducts of fly ash and slag are frequently used, as they can be more affordable and environmentally friendly than the raw materials used in conventional Portland cement.
- Production Costs: Due to less developed supply networks and technology, initial production costs may be higher; but, as usage grows and economies of scale are obtained, these costs should eventually decline.
- Durability: The exceptional fire resistance and outstanding resistance to chemical attacks like sulfate and acid attacks, geopolymer concrete is incredibly durable. When compared to conventional concrete, this lengthens its lifetime.
- Long-term Maintenance Costs: Geopolymer concrete often requires fewer repairs and maintenance due to its increased durability, which lowers long-term maintenance expenses.
- Reduced Repair Frequency: Less prone to degradation and cracking, requiring less repairs throughout the course of the building's life.
- Lower Rehabilitation Costs: Improved performance in challenging environments, which results in a decreased requirement for expensive rehabilitation techniques.
- Carbon Emissions: The carbon emission has minimum of GPC compared to OPC. Up to 90% less CO_2 is released during the production process, which lowers greenhouse gas emissions.
- Waste Utilization: Geopolymer concrete lessens trash sent to landfills and the environmental effect of mining and processing raw materials by utilizing fly ash and slag from industry by products.
- Energy Consumption: An environmental impact of geopolymer concrete is further mitigated by its less energy-intensive production process.
- End-of-Life Impact: Geopolymer concrete contributes to a circular economy since it may frequently be recycled more effectively than regular concrete at the end of its existence.
- Initial Investment vs. Long-term Savings: Due to modern production techniques and material prices, geopolymer concrete may have a larger initial investment; however, over time, these costs are frequently offset by long-term savings on maintenance, repairs, and environmental advantages.
- Total Cost of Ownership: In comparison to typical concrete, geopolymer concrete frequently turns out to be more cost-effective over the course of its lifetime when taking into account the whole cost of ownership, which includes initial expenditures, maintenance, durability, and environmental benefits.

An examination of the comparative economic performance of geopolymer concrete in various contexts, including different project sizes and locations, can yield important information on the material's viability and affordability. Here's a closer look at how these variables affect geopolymer concrete's financial performance:

i. Initial Costs: The unit costs are higher due to minimum number of batch production and minimum purchasing power.
ii. Implementation: In economical scale point of view the implementation and logistical costs are higher.
iii. Maintenance Savings: The major advantages obtained from minimum repair and maintenance costs with respect to time.
iv. Feasibility: The major limitation of the initial investment for long-term analysis without proper justification.

In the geopolymer concrete applications are based on the geographicalfactors considered.

i. Availability of Raw Material: From power plant has produced the fly ash, it can minimize the material transportation costs.
ii. Labor Costs: It always high, industry has fixed the labour in skilled person and minimise the material transportation also.
iii. Market Demand: The material demand in construction, the market price also raised and competitor also increasing the materials cost.
iv. Regulatory Environment: Geopolymer concrete is very attractive source for environmental regulations in construction.

5. Results and Discussion

The economy index of the OPC and GPC of the different composition are compared. to calculate the economy index using compressive strength and the total production cost of the concrete structures. Curing is a key component of the source of the water absorption test needed for structural applications.

5.1 Compressive Strength of Concretes

Figures 2 and 3 display the computed compressive strengths of GPC and OPC. In Figure 2 indicated the compressive strength has achieved at maximumof GPC-2. Similarly, the geopolymer concrete(GPC-5) has been achieved highest compressive strength than other samples made with other sources GPC-1 and GPC-8. In contrast to other geopolymer concrete and regular Portland concrete, GPC-2 geopolymer concrete has achieved the maximum compressive strength. Because silica has been added to geopolymer concrete, Figure 3 represents theGPC-7has been achieved the maximum compressive strength.

The residual compressive strength representsat the damaged materialhas achieved maximum compressive stress occurred during application of loading condition. The residual compressive strength of geopolymer concrete is influenced by its resistance to fracture propagation. When exposed to extremely high temperatures, geopolymer concrete's residual compression resistance tends to diminish. One of the most significant factors influencing the form, color, and surface attributes of concrete is high temperature, or heat exposure. Consequently, one crucial aspect of geopolymer concrete's endurance is its residual compressive strength.

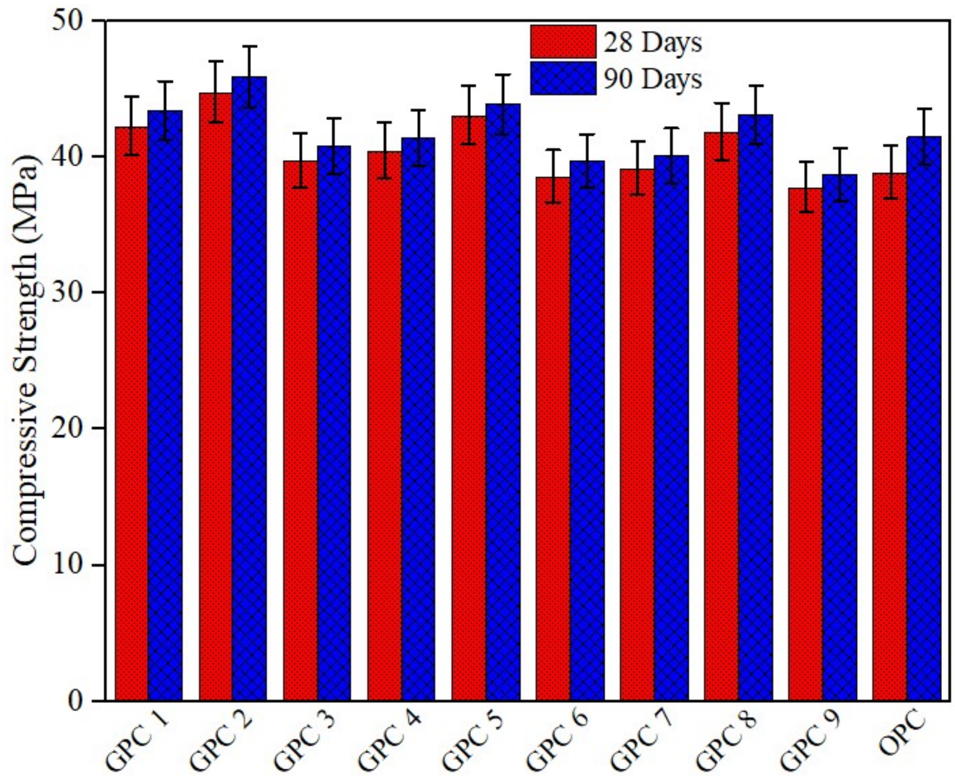

Figure 2. *Compressive strength of ordinary Portland concrete and geopolymer concrete.*

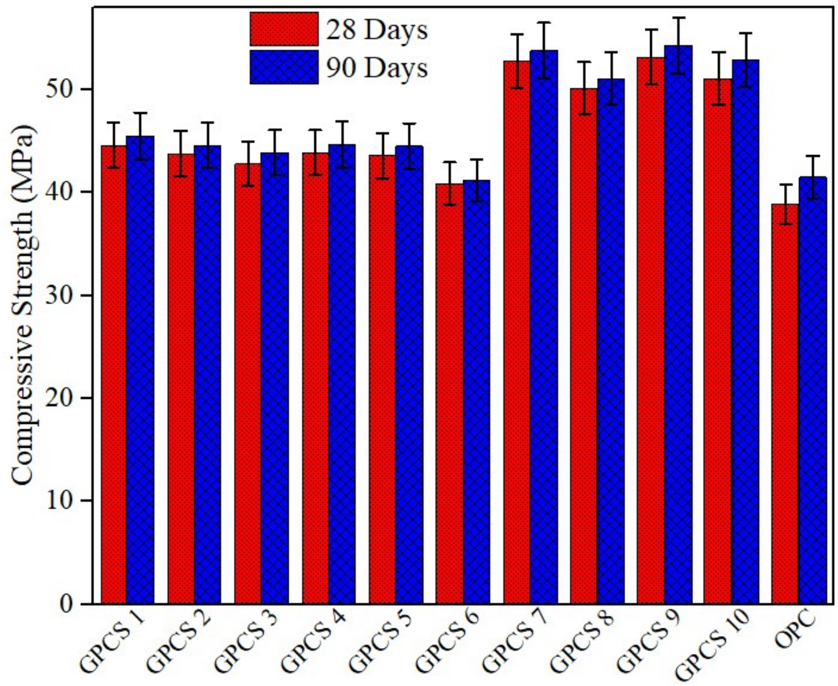

Figure 3. *Compressive strength of ordinary Portland concrete and geopolymer concrete with silica content.*

5.2 Economy Index of concretes

According to the results, typical Portland concrete has an economy index of 5.87. Tables 5 and 6 display the economy index for geopolymer concrete and regular Portland concrete. Compared to regular Portland concrete, all created geopolymer concretes occurred minimum economy index. This is mainly because the higher compressive strength of the geopolymer concrete based on GGBFS.The ordinary concrete and geopolymer concrete the majordifference in cost of the cement and source materials. Source material costs are average. The source materials come from the steel and GGBFS waste industries, respectively.

Table 5: Economy index of the geopolymer and ordinary Portland concrete

Materials	Production Cost/m^3	Compressive Strength (MPa)	Economy Index
OPC	7.10	41.5	5.87
GPC-1	8.83	13.4	1.51
GPC-2	9.32	15.9	1.7
GPC-3	10.22	40.8	3.99
GPC-4	9.12	41.4	4.53
GPC-5	9.62	43.9	4.56
GPC-6	10.53	39.7	3.77
GPC-7	9.46	40.1	4.23
GPC-8	9.94	43.1	4.33
GPC-9	10.86	38.7	3.56

Table 6: Economy index for the geopolymer with silica and ordinary Portland concrete

Materials	Production Cost/m^3	Compressive Strength (MPa)	Economy Index
OPC	7.10	41.5	5.84
GPCS-1	9.27	45.5	4.9
GPCS-2	9.22	44.6	4.83
GPCS-3	9.07	43.9	4.84

GPCS-4	9.41	44.7	4.75
GPCS-5	9.5	44.5	4.68
GPCS-6	9.78	41.2	4.21
GPCS-7	10.21	53.8	5.26
GPCS-8	9.74	51.1	5.24
GPCS-9	10.36	54.3	5.24
GPCS-10	9.88	52.9	5.35

5.3 Regression Model for OPC and GPC

Figures 4 and 5 for OPC and GPC show the regression equation's result. The coefficients of determination (R^2) for OPC and GPC economy index at 28 days of curing, respectively, are 81.7% and 17.6% in terms of compressive strength. This indicates that, at 95% confidence levels, compressive strength is strongly dependent on the economic index and the prepared model is perfectly fit in the respective locations.

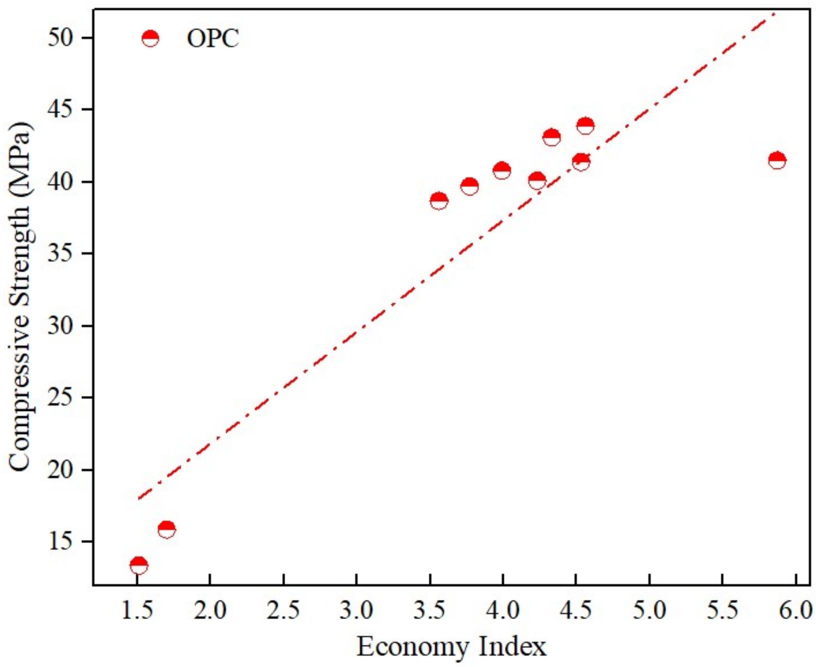

Figure 4. Regression model for OPC.

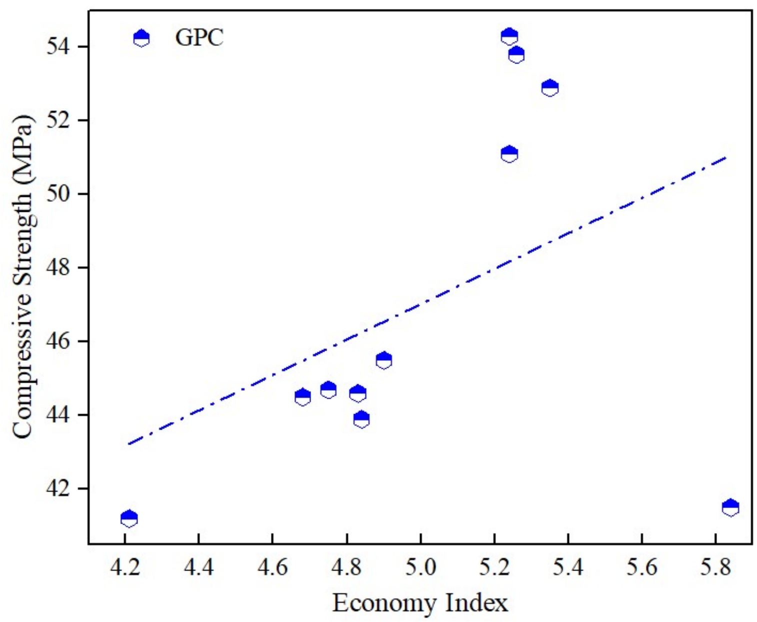

Figure 5. Regression model for GPC.

5.3 Water Absorption of concretes

In compliance with ASTM C642-06 the specimens are considered the 100 mm and 75 mm of diameter and height to the test;the results are depicted in Figures 6 and 7. After 28 daysthe specimen is weighed and desiccated in an oven at the temperature of 100 ± 10°C for a minimum 1 day. Thenspecimens arepermitted to cool in a desiccator to find oven-dry mass (W_d). The obtained weight difference (final and initial) is < 0.5% only considered. Following at least 48 hours of submersion in water, the specimens' weight is used to measure the saturated mass after immersion (W_s). The obtained weight (final and initial)is<0.5% only considered.The water absorption percentage results are represented in terms of the following equation (2) is,

$$Water\ Absorption\ test\ (\%) = \left[\frac{W_s - W_d}{W_d}\right] \times 100 \qquad (2)$$

Where, (W_i) is denoted as initial weight. The water absorption test readings are presented in table 7 and 8.

Table 7: Absorption weight measurement of OPC and GPC

Mix ID	Cube Weight	After Soaking	Differential Weight	Absorption (%)
GPC -1	7.96	8.35	0.39	4.90
GPC -2	7.99	8.27	0.28	3.50
GPC -3	8	8.42	0.42	5.25
GPC -4	7.98	8.38	0.4	5.01
GPC -5	8.08	8.39	0.31	3.84
GPC -6	8.05	8.51	0.46	5.71
GPC -7	8.02	8.45	0.43	5.36
GPC -8	8.02	8.38	0.36	4.49
GPC -9	8	8.52	0.52	6.50
OPC	7.99	8.36	0.37	4.63

Table 8: Absorption weight measurement of OPC and GPC with Silica

Mix ID	Cube Weight	After Soaking	Differential Weight	Absorption (%)
GPCS -1	7.96	8.28	0.32	4.02
GPCS -2	7.99	8.34	0.35	4.38
GPCS -3	8	8.44	0.44	5.50
GPCS -4	7.98	8.36	0.38	4.76
GPCS -5	8.08	8.49	0.41	5.07
GPCS -6	8.05	8.51	0.46	5.71
GPCS -7	8.02	8.22	0.2	2.49
GPCS -8	8.02	8.25	0.23	2.87
GPCS -9	8	8.24	0.24	3.00
GPCS - 10	8.09	8.35	0.26	3.21
OPC	7.99	8.36	0.37	4.63

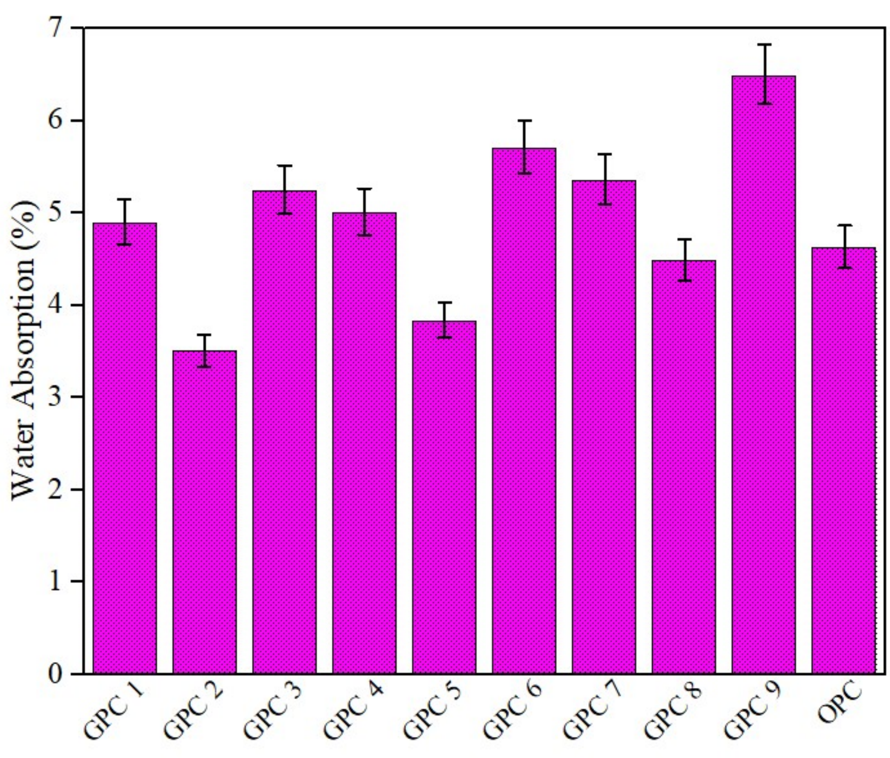

Figure 6. *Water absorption percentage of OPC and GPC.*

Figure 6 illustrates how the absorption values of the various geopolymer concrete compositions vary significantly. Absorption after immersion, according to Nagaratnam et al. [34], indicates how much water a material absorbs while submerged in water for a specific amount of time. The aforementioned findings demonstrate that mix GPC-2 has the lowest value of 3.5% for absorption upon immersion. When silica content is added to geopolymer concrete, the obtained results of the absorption and immersion is represented it 2.49% (Figure 7). Other studies are obtained the geopolymer concrete results of absorption percentage [35], which is represented the water to binder ratio is very low. The ordinary Portland concrete has the maximum absorption results represented it6.5% and 5.71% respectively.

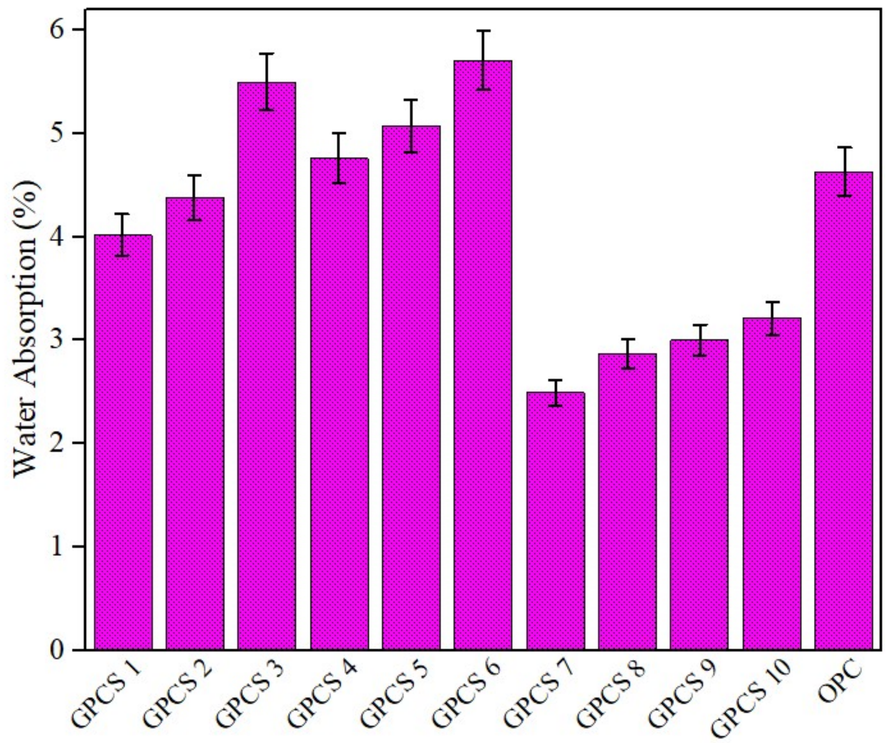

***Figure** 7. Water absorption percentage of OPC and GPC with Silica.*

A global shortfall of 1.7 billion tons exists when one takes into account the quantity of slag cement required to replace OPC 100 percent. Merely 2.4% of the yearly production of ordinary Portland cement (OPC) may be substituted with geopolymer concrete based on slag cement, based on the United States, which has the most restricted availability of slag cement. Globally, the yearly surplus slag cement would enable the manufacturing of geopolymer concrete based on slag cement to replace 6.5% of the yearly production of OPC concrete. Furthermore, metakaolin cannot be produced in large enough quantities each year to allow metakaolin-based geopolymer concrete to completely replace OPC. Metakaolin-based geopolymer concrete has the potential to replace less than 1% of the current output of OPC concrete, based on the most restricted market (China). Only 1.4% of concrete production could be substituted with metakaolin-based geopolymer concrete, depending on the yearly supply of metakaolin worldwide. In addition to being the costliest raw material, sodium hydroxide has the fewest alternatives available at the moment. In addition to being extremely expensive, replacing OPC with geopolymer concrete would only account for 2% of the world's annual concrete production, depending on the availability of sodium hydroxide.

The building industry is using geopolymer concrete more and more because of its many natural advantages over ordinary concrete and its drawbacks [36]. Researchers have prepared the concrete with source materials are lightweight, fly ash with maximum volume and performance of the concrete is very high.The major advantages of the GPC is maximum strength, long time capacity, minimize the permeability and shrinkage crack is low compared to OPC [37]. According to Laskar and Talukdar, they have prepared a greater number of concrete samples with different proportion volume of ultra fine GGBFS. The fly ash percentage of the binding agent ranged from 0% to 50%. Sodium hydroxide (NaOH) in solutions ranging from 8 M to 14 M was utilized as an alkali activator. It was discovered that the geopolymer concrete develops its initial strength quickly. The outcome of the concrete strength has measured after 1 day (60%) [38]. Conversely, adding fly ash to the concrete mix made it easier to work, unfortunately the binder agent has been crossed after 40% the concrete strength has been reduced gradually.

Deb et al. (2014) carried out a comparable study wherein Class F fly ash was employed as the principal binding agent; fly ash was substituted in part in this inquiry. The chemical mixture of sodium hydroxide and silicate combination of the produce alkaline solution. Based on the existing research outcome it is confirmed that the ratio of sodium hydroxide and silicate increase from 1.5 to 2.5. The source material of slag mixture is 0% to 20%. The samples are cured at atmosphere temperature and relative humidity (roughly 75 %) after compaction. The concrete samples' compressive strength rose in tandem with the amount of slag in them.The concrete strength was gradually decreased while increase the sodium hydroxide and silicate ratio content [39]. According to Top and Vapur have expressed the compressive strength is 50 MPa after curing (28 days) condition of the GPC with fly ash. Lee et al. have been represented the GPC with fly ash and GGBFS.The proportion of the concrete is fly ash (70%) and slag (Three quarters). Actually, the preparation of the GPC with sodium hydroxide and silicate solutions. The ratios of geopolymer to sand to gravel were kept at 1:2.5:2.4, and solutions of activator sodium hydroxide at concentrations of 2, 3, 4, 5, and 6 M were joined after thorough mixing. Both outside on a roof and indoors are used to cure the cylindrical samples.

Compressive strength was assessed at 14, 28, 56, 90, 180, and 270 days. It has shown that samples cured outside underwent drying and shrinkage, which decreased their compressive strength, in contrast to those wrapped in plastic bags and storage of materials are in indoors. Furthermore, it has been monitored the GPC strength continuously, it represents the strength increased with increase of curing time [40]. According to Glasby et al they have used GPC at Brisbane West Wellcamp airport, Australia. According to layout of construction they have used GPC at the runway (northern end), zones of turning, taxiway (western side), and hangars (eastern side), Wagners provided about 40,000 cubic meters of geopolymer concrete based on fly ash. The airport is operational and has been used by Qantas Link for commercial flights since November 2014.

6. Challenges and Future Directions

The expense of raw ingredients and the specialized knowledge needed to make GPC production at high initial cost. This makes it more difficult for small-scale construction projects to adopt. For geopolymer concrete, standards have not yet been fully defined and embraced. This has an impact on how widely used it is in the building sector. Although research has demonstrated that this type of concrete has an incredible strength-to-weight ratio and a high level of resilience to hostile environments, nothing is known about this product's long-term endurance.There are still issues with the uniformity and quality of the materials produced when production of geopolymer concrete is scaled up, hence large-scale production is not yet fully established. It is necessary to develop novel and creative uses for geopolymer concrete in order to create new avenues for its acceptance in a larger variety of construction projects [41-45].

Despite the fact that the experimental investigation has demonstrated the versatility of geopolymer concrete in construction applications. But in order to promote the increased usage of geopolymers, further research is required in the following areas:

- Assessing the financial and environmental effects of employing GPC. Doing a thorough analysis of GPC's effects on sustainability and cost would contribute to raising awareness of the technology and advancing its use. The research work has suggested that the different type of innovative idea to reduce the costs of production and there is no environmental affection of GPC.
- Even though GPC has been around for a while, more in-depth research has to be done. In contrast to OPC concrete, less is known about the long-term performance of GPC, particularly with regard to durability and GPC manufactured using non-traditional precursors. Therefore, more research on the long-term performance is needed in addition to the short-term trials. The evaluation of GPC's long-term performance may also benefit from the application of several accelerated tests.

The comparison of OPC and GPC is a cutting-edge and environmentally responsible substitute that has various advantages, including reduced carbon emissions, increased durability, and the use of waste materials from the industrial sector [46-50]. A variety of policies and initiatives can be put in place by policymakers to encourage the usage of geopolymer concrete. Here are a few policy recommendations:

1. Tax Credits and Rebates: Industry has used geopolymer concrete materials, corresponding industry head has acknowledged the tax benefits and rebates for construction work.
2. Subsidies for Raw Materials: For geopolymer concrete production of fly ash and others, industry has used to reduced overall construction costs.
3. Incorporate Geopolymer Concrete in Building Codes: Industry has created general standard codes for geopolymer concrete for the purpose of the construction projects.
4. Environmental Regulations: Currently for conventional cement production industry carbon dioxide (CO_2) emission has more, instead of this geopolymer concrete has introduced in construction projects.
5. Funding for R&D: Industry has focused on the GPCis to improve the characterizations and performance. Because, the reduction of production cost, durability for long term.
6. Public-Private Partnerships: Currently geopolymer concrete has used in all over institute for the purpose of the increase the performance by researchers.
7. Industry Training Programs: Nowadays it is required to organise the training about the geopolymer concrete usage in construction in all the institutions.
8. Public Awareness Campaigns: Geopolymer concrete advantages and environmental performance benefits to give awareness to public and industry stakeholders.
9. Green Procurement Policies: Geopolymer concrete has used in public constrction work for procurement policies.
10. Pilot Projects: In real life application geopolymer concrete has used in government funded construction work for benefits of this materials.
11. Develop Standards and Certifications: From ISO provide the quality of the geopolymer concrete and corresponding certificates also for the usage of construction work in all over world.
12. Third-Party Verification: According to industry has introduce the third-party verification about usage and benefits of geopolymer concrete.
13. Carbon Pricing: Based on the carbon taxes in traditional cement production unit is more luxurious and currently introduced geopolymer concrete is more competitive in this world.
14. Financial Incentives for Waste Utilization: The major source materials of GPC is fly ash and slag. This part is to produce in industry required financial incentives for production of this.
15. Global Standards: In geopolymer concrete has collaborate with international bodies to promote the global standards and best performs.
16. Knowledge Sharing: From industry peoples have arranged the meeting in all over world to deliver the usage of geopolymer concrete to other industry partner. Because the geopolymer concrete has implement the other industry construction work.

7. Conclusions

It is determined that the evaluation of the ordinary Portland concrete and geopolymer concrete with the source materials of sodium hydroxide and sodium silicate solutions has been showed that the economy index and production cost of manufacturing concrete. The research study facilitated assess the economic implications of producing sustainable concrete compared to traditional Portland concrete. The research project also included a regression model's equation and forecast the relationship between compressive strength and the economic index. Therefore, it is advised that standard operating guidelines and protocols be adhered to at all times while assessing the cost of producing geopolymer concrete. It has been obtained the outcome of the economy index and water absorption percentage of a geopolymer concrete. The lowest absorption is found in geopolymer concrete with the greatest activator/binder ratio. The absorption value does not differ much depending on the composition of geopolymer concrete. An ordinary Portland concrete has a maximum absorption percentage than the geopolymer concretes are GPC-2 and GPCS-7 respectively. The compressive strength has been higher for GPC-2 and GPCS-7 compared to ordinary Portland concrete. A suitable addition of micro-silica, or ultra-fine silica material, to geopolymer concrete may improve the material's residual compressive strength (GPCS-7). The production of geopolymer concrete might be achieved at a cost savings of between 31.13% and 43.74% if it were substituted for regular Portland concrete. Naturally, to regulate the yield and enhance the properties of geopolymer. Usually, the concrete industry and soil stabilization are the most frequent uses. In addition, GPC can be utilized to develop railway sleepers, bricks, barriers, pavements, retaining walls, water tanks, boat ramps, precast bridge decks, and a host of other structural applications in addition to beams, columns, and slabs.

References

1. Guo, Yuzhen. "Analysis on Concrete Construction Technology in Civil Engineering Construction." In Journal of Physics: Conference Series, vol. 2011, no. 1, p. 012023. IOP Publishing, 2021.
2. Davidovits, J. Geopolymer chemistry and applications. InstituteGéopolymère, Geopolymer Institute, Saint-Quentin, France. ISBN 2-951-14820-1-9, 2008.
3. K. El Hafid, M. Hajjaji, H. El Hafid, Influence of NaOH concentration on microstructure and properties of cured alkali-activated calcined clay, J. Build.Eng. 11 (2017) 158–165.
4. X. Hua, J.S.J. Van Deventer, 1999. The geopolymerisation of natural alumino-silicates. In: Proc. 2nd Internat. Conf. Geopolymere ’99, pp. 43–63.
5. J. Davidovits, Pyramids of Egypt Made of Man-Made Stone, Myth or Fact, Symposium on Archaeometry, Smithsonian Institution, Washington DC, 1984.
6. J. Davidovits, Geopolymer chemistry and properties [M]. In: J. Davidovits and J. Orlinsl (eds.). Proceedings of the First European Conference on Soft Mineralogy, France: The Geopolymer Institute, 1(1988) 25-48.
7. T. Suwan, M. Fan, Effect of manufacturing process on the mechanisms and mechanical properties, of fly ash-based geopolymer in ambient curing temperature, Mater. Manuf. Processes 32 (5) (2017) 461–467.
8. A. Mehta, R. Siddique, an overview of geopolymers derived from industrial by-products, Constr. Build. Mater. 127 (2016) 183–198.
9. Y.-M. Liew, C.-Y. Heah, A.B. Mohd Mustafa, H. Kamarudin, Structure and properties of clay-based geopolymer cements: a review, Prog. Mater. Sci. 83 (2016) 595–629.
10. W.K. Part, M. Ramli, C.B. Cheah, an overview on the influence of various factors on the properties of geopolymer concrete derived from industrial byproducts, Constr. Build. Mater. 77 (2015) 370–395.
11. Cholker, A. and Tantray, M., 2019. Strain and damage sensing property of self-compacting concrete reinforced with carbon fibers. International Journal of Engineering, 32(11), pp.1577-1583.
12. B. Singh, G. Ishwarya, M. Gupta, S.K. Bhattacharyya, Geopolymer concrete: a review of some recent developments, Constr. Build. Mater. 85 (2015) 78–90.
13. R.H. Geraldo, L.F.R. Fernandes, G. Camarini, Water treatment sludge and rice husk ash to sustainable geopolymer production, J. Cleaner Prod. 149 (2017) 146–155.
14. S.M.A. El-Gamal, F.A. Selim, Utilization of some industrial wastes for eco-friendly cement production, Sustainable Mater. Technol. 12 (2017) 9–17.
15. A. Gharzouni, E. Joussein, B. Samet, S. Baklouti, S. Rossignol, Effect of the reactivity of alkaline solution and metakaolin on geopolymer formation, J.Non-Cryst. Solids 410 (2015) 127–134.
16. Z. Abdollahnejad, F. Pacheco-Torgal, T. Félix, W. Tahri, J.B. Aguiar, Mix design, properties and cost analysis of fly ash-based geopolymer foam, Constr. Build. Mater. 80 (2015) 18–30.
17. J.G. Sanjayan, A. Nazari, L. Chen, G.H. Nguyen, Physical and mechanical properties of lightweight aerated geopolymer, Constr. Build. Mater. 79 (2015) 236–244.
18. Albitar, M.; Ali, M.M.; Visintin, P.; Drechsler, M. Durability evaluation of geopolymer and conventional concretes. Constr. Build. Mater. 2007, 136, 374–385.
19. Liew, K.; Sojobi, A.; Zhang, L. Green concrete: Prospects and challenges. Constr. Build. Mater. 2007, 156, 1063–1095.
20. Li, Y.; Qiao, C.; Ni, W. Green concrete with ground granulated blast-furnace slag activated by desulfurization gypsum and electric arc furnace reducing slag. J. Clean. Prod. 2020, 269, 122212.
21. Cholker, A.K. and Tantray, M.A., 2020. Strain-sensing characteristics of self-consolidating concrete with micro-carbon fibre. Australian Journal of Civil Engineering, 18(1), pp.46-55.
22. De Silva P, Sagoe-Crenstil K, Sirivivatnanon V (2007) Kinetics of geopolymerization: role of Al2O3 and SiO2. Cem Concr Res 37(4):512–518.
23. Görhan G, Kürklü G (2014) The influence of the NaOH solution on the properties of the fy ash-based geopolymer mortar cured at different temperatures. Compos B Eng 58:371–377.
24. Sofi M, Van Deventer JSJ, Mendis PA, Lukey GC (2007) Engineering properties of inorganic polymer concretes (IPCs). Cem Concr Res 37(2):251–257.

25. Gourley JT (2003) Geopolymers, opportunities for environmentally friendly construction materials, conference, adaptive materials for a modern society. Sydney Inst Mater Eng Australia 15–26:49.
26. Chen, K.; Wu, D.; Xia, L.; Cai, Q.; Zhang, Z. Geopolymer concrete durability subjected to aggressive environments—A review of influence factors and comparison with ordinary Portland cement. Constr. Build. Mater. 2021, 279, 122496.
27. Saranya, P.; Nagarajan, P.; Shashikala, A.P. Behaviour of GGBS-dolomite geopolymer concrete beam-column joints under monotonic loading. Structures 2020, 25, 47–55.
28. Meng, Q.; Wu, C.; Hao, H.; Li, J.; Wu, P.; Yang, Y.; Wang, Z. Steel fibre reinforced alkali-activated geopolymer concrete slabs subjected to natural gas explosion in buried utility tunnel. Constr. Build. Mater. 2020, 246, 118447.
29. Alrshoudi, F.; Abbas, H.; Abadel, R.; Albidah, A.; Altheeb, A.; Al-Salloum, Y. Compression behavior and modeling of FRP-confined high strength geopolymer concrete. Constr. Build. Mater. 2021, 283, 122759.
30. Xu, H.; Wang, Z.; Shao, Z.; Cai, L.; Jin, H.; Zhang, Z.; Qiu, Z.; Rui, X.; Chen, T. Experimental study on durability of fiber reinforced concrete: Effect of cellulose fiber, polyvinyl alcohol fiber and polyolefin fiber. Constr. Build. Mater. 2021, 306, 124867.
31. Rajamane, N. P., and Jeyalakshmi, R., Quantities of Sodium Hydroxide Solids and Water to Prepare Sodium Hydroxide Solution of given Molarity for Geopolymer Concrete Mixes, Indian Concrete Institute Technical Paper, SRM University, India, 2014.
32. Chindaprasirt, P. W. C., Effect of Sodium Hydroxide Concentration on Chloride Penetration and Steel Corrosion of Fly Ash-Based Geopolymer Concrete Under Marine Site, Construction and Building Materials, 63, 303-310, 2014.
33. Daniel, G., Kong, L., and Sanjayan. J., Effect of Elevated Temperatures on Geopolymer Paste, Mortar and Concrete, Cement and Concrete Research, 40, 334-339, 2010.
34. Nagaratnam B H, Faheem A, Rahman M E, Mannan M A and Leblouba M 2015 Mechanical and durability properties of medium strength self-compacting concrete with high-volume fly ash and blended aggregates Period. Polytech. Civ. Eng. 59 155–64.
35. Olivia M, Sarker P and Nikraz H 2008 Water Penetrability of Low Calcium Fly Ash Geopolymer Concrete Iccbt2008 517–30.
36. S. Top, H. Vapur, Effect of basaltic pumice aggregate addition on the material properties of fly ash-based lightweight geopolymer concrete, J. Mol. Struct.1163 (2018) 10–17.
37. K.M. Liew, A.O. Sojobi, L.W. Zhang, Green concrete: Prospects and challenges, Constr. Build. Mater. 156 (2017) 1063–1095.
38. S.M. Laskar, S. Talukdar, Preparation and tests for workability, compressive and bond strength of ultra-fine slag based geopolymer as concrete repairing agent, Constr. Build. Mater. 154 (2017) 176–190.
39. P.S. Deb, P. Nath, P.K. Sarker, the effects of ground granulated blast-furnace slag blending with fly ash and activator content on the workability and strength properties of geopolymer concrete cured at ambient temperature, Mater. Des. (1980-2015) 62 (2014) 32–39.
40. W.-H. Lee, J.-H. Wang, Y.-C. Ding, T.-W. Cheng, A study on the characteristics and microstructures of GGBS/FA based geopolymer paste and concrete, Constr. Build. Mater. 211 (2019) 807–813.
41. M. Verma; N. Dev, "Sodium hydroxide effect on the mechanical properties of fly ash-slag based geopolymer concrete" Structural Concrete, 22(S1), E368-379, 2021. ISSN: 1751-7648 (IF 3.2) DOI: 10.1002/suco.202000068
42. M. Verma; N. Dev, "Effect of Liquid to Binder Ratio and Curing Temperature on the Engineering Properties of the Geopolymer Concrete" Silicon, 14 (2022), 1743-1757, 2022. ISSN: 1876-9918 (IF 3.4) DOI: 10.1007/s12633-021-00985-w
43. M. Verma; N. Dev, "Effect of Ground Granulated Blast Furnace Slag and FlyAsh ratio and the curing conditions on the Mechanical Properties of Geopolymer Concrete," Structural Concrete, 23(4), 2015-2029, 2022. ISSN: 1751-7648 (IF 3.2) DOI: 10.1002/suco.202000536
44. M. Verma; N. Dev, "Effect of SNF-Based Superplasticizer on Physical, Mechanical and Thermal Properties of the Geopolymer Concrete" Silicon, 14(2022), 965-975, 2022. ISSN: 1876-9918 (IF 3.4) DOI: 10.1007/s12633-020-00840-4

45. M. Verma; N. Dev; I. Rahman; M. Nigam; M. Ahmed; J. Mallick, “Geopolymer Concrete: A Material for Sustainable Development in Indian Construction Industries” Crystals, 2022 (12), 514, 2022. ISSN: 2073-4352 (IF 2.7) DOI: 10.3390/cryst12040514
46. M. Verma; M. Nigam “Experimental Investigation on the Properties of Geopolymer Concrete after Replacement of River Sand with the M-Sand” AIP Conference Proceedings, 2721(1), 020029, 2023. ISSN No: 1551-7616 DOI: 10.1063/5.0154113
47. M. Verma; M. Nigam “Effect of FRP on the Strength of Geopolymer Concrete” AIP Conference Proceedings, 2721(1), 020030, 2023. ISSN No: 1551-7616 DOI: 10.1063/5.0154114
48. M. Verma; M. Nigam “Investigation on the Effect of Curing Time on the Mechanical Properties of Geopolymer Concrete” AIP Conference Proceedings, 2721(1), 020031, 2023. ISSN No: 1551-7616 DOI: 10.1063/5.0154116
49. U. Sharma; N. Gupta; M. Verma “Prediction of the compressive strength of Flyash and GGBS incorporated geopolymer concrete using artificial neural network” Asian Journal of Civil Engineering, 24 (8), 2837–2850, 2023. ISSN: 2522-011X DOI 10.1007/s42107-023-00678-2
50. U. Sharma; N. Gupta; M. Verma “Prediction of Compressive Strength of GGBFS and Flyash based Geopolymer Composite by Linear Regression, Lasso Regression and Ridge Regression” Asian Journal of Civil Engineering, 24 (8), 3399–3411, 2023. ISSN: 2522-011X DOI: 10.1007/s42107-023-00721-2