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Geopolymer Concrete Paver Blocks Utilizing Fly Ash and Ground Granulated Blast Furnace Slag: A Review

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ABSTRACT

One of the newly popular concretes that contains no cement is geopolymer concrete. One of the main producers of carbon dioxide is the cement sector. Carbon dioxide gas, or greenhouse gas, is released into the atmosphere primarily due to the worldwide manufacturing of oil palm concentrates. However, disposing of solid waste is a significant issue. One solid waste that coal-fired power stations produce that is difficult to properly dispose of is fly ash. Thus, immediate action is needed to reduce emissions and increase the manufacture and use of environmentally friendly and sustainable materials. This gave rise to the concept of geo polymer concrete, which avoids the need for cement completely in the concrete. The purpose of this paper is to create geo-polymer paver blocks. The impact of fly ash, GGBS, and alkaline solution ratios on the geopolymer paver concrete was investigated. Although geopolymer concrete is so resistant to corrosive acids and sulphates, it exceeds traditional concrete in terms of durability. Geopolymer paver block has great strength and durability qualities, is inexpensive, and is environmentally friendly. The exceptional mechanical properties of geopolymers allow for compression strengths of up to 100 MPa. In general, carbonation resistance improves with increasing GPC strength. Because geopolymers have an inorganic skeleton that is influenced by the Si/Ai ratio, alkali concentration, and alkali cation, GPC has high fire resistance. Geopolymers contain a variety of Al-O and Si-O structures. Acid-resistant materials can be made with geopolymers since they do not react with acids at room temperature. Furthermore, GPC with a low porosity volume has strong permeability resistance. The principal theories behind the freezing-thawing failure process of geopolymer concretes are osmotic pressure and hydrostatic pressure. Geopolymer concrete is produced via the process of geopolymerization, in which oligomer molecules unite to creating networks of geopolymers with covalent connections. Its manufacture uses less thermal energy than Ordinary Portland Cement (OPC) concrete, resulting in a smaller carbon impact. All that is needed for the geopolymerization to occur is an alkaline activator that will catalyse the aluminosilicate sources, such as ground granulated blast furnace slag and fly ash, and create geopolymer binder. Because of its ecologically friendly development and practical application, geopolymer concrete's endurance to survive heat and chemicals aggressions is the main area of current study interest.

Key Words: Fly Ash, Ground granulated blast furnace slag, Sodium silicate, Sodium hydroxide, alkaline activator, Compressive strength.

1. Introduction

Geopolymer blocks represents a significant advancement in sustainable construction practices. Geopolymer concrete are a novel alternative to traditional Portland cement concrete, offering a more environmentally friendly option for various applications like street roads and construction sites. These concrete are produced using materials made from industrial by products like ground granulated blast furnace slag, fly ash and other alumina silicate materials, reducing the reliance on Portland cement that emits large amounts of CO2 and consumes substantial energy during production Geopolymer concrete have been developed to address the environmental challenges posed by cement production, which is a major contributor to CO2 emissions globally. By utilizing geopolymer technology, these concrete provide a durable and eco-friendly solution that minimizes the carbon footprint associated with conventional concrete production. Geopolymer concrete consist of Fly ash, Ground granulated blast furnace slag, Crusher dust, Super plasticizer, Sodium hydroxide & Sodium silicate.

1.1 Objectives

- Geopolymer is considered as a well-liked substitute for conventional cement.
- Decreases the need for OPC, which increases CO2 emissions.
- To locate substitute materials for cement in order to regulate and decrease the amount of carbon dioxide released into the atmosphere during the manufacturing of cement.

- Fly ash is created significant amount by all thermal power plants and is discarded into the ground.
- Waste materials like ground-granulated blast furnace slag and fly ash can be used as an exceptional substitute for cement.
- It has great strength and durability qualities, is inexpensive, and is environmentally friendly.

2. Literature Review

1. Ismail et.al (2014) found that the cementation phenomena of geopolymer concrete is caused by the polycondensation of aluminosilicate. Based only on indications, the microstructures of fly ash and alkali-activated slag geopolymers have been extensively investigated. Due to the chemical and physical differences between fly ash and slag ingredients, as well as the effects of varying activator concentrations and chemistries, significant structural, mechanical, and physical differences, have been found in activated binders using precursors from different sources.

2. Radhakrishna (2015): give examples of the many techniques used to create mortar specimens in order to determine the ideal dry density. Experimental data was used to examine strength qualities utilizing different factors. In order to build geopolymer blocks with the appropriate strength of outcomes, it helps to develop a phenomenal model to create with various combinations of materials. The models' validity was assessed using a collection of diverse experimental data. The result displays the same expected values when compared to the experimental data.

3. Tawalare et.al. (2018) concluded that the requirement for greener concrete for sustainable development is unquestionably being addressed by the study on geopolymer concrete. To create the geopolymeric binder phase, which binds the aggregate to create geopolymer concrete, fly ash can be utilized. The influence of the concentration of the NaOH solution revealed that when the alkaline to fly ash ratio increased from 2 to 2.5, the compressive strength likewise increased. The compressive strength of various geopolymer concrete mixes improves with an increase in alkaline solution. The geopolymer paver block's compressive strength rises as the ratio of ,Na2SiO3/NaOH increases. The geopolymer concrete paver block with natural aggregate had a water absorption that was within tolerance. Geopolymer paver blocks with natural aggregate had lower abrasion resistance. The mix proportion of this paper is given in table 1,

Table 1 Mix proportion

Trial mixes	Fly ash (Kg)	Natural aggregate (Kg)	Recycled + Slag aggregate (Kg)	Na2SiO3 /NaOH	Alkaline solution /Fly Ash
GPC1N	570	990		2	0.45
GPC2N	570	990		2.5	0.45
GPC3N	570	990		2	0.5
GPC4N	570	990		2.5	0.5
GPC1RC	377		1821.9	2	0.45
GPC2RC	377		1821.9	2.5	0.45
GPC3RC	377		1821.9	2	0.5
GPC4RC	377		1821.9	2.5	0.5

4. Reddy et.al (2018) found that for the purpose of creating GGBS and fly ash-based geopolymer concrete, a simple and reasonable mix design approach has been presented. The proposed methodology is unique in that it primarily takes into account the specific gravity of the raw materials and the idea of ACI strength in relation to the water to cement ratio. While the use of these characteristics in the mix design of regular concrete is quite frequent, this study is unusual in that it allows for the same parameters, specifically in the mix design of geopolymer concrete. It is acknowledged that even if there may be differences in the physical characteristics of the materials used, the inclusion of the particular gravity parameter may make it easier to produce consistent results (figure 1). The suggested mix design is so intuitive that it makes it easier to target either the intended objective. The properties of geopolymer concrete is given in table 2.

Table 2 properties of geopolymer

AAC / BS	Slump (mm)	28-day strength (MPa)	56-day strength (MPa)
0.4	40	66.23	67.82
0.5	62	56.42	58.40
0.6	75	49.58	51.66
0.7	110	39.6	41.65
0.8	160	32.73	34.82

Figure 1 Slump Test

(M Srinivasula Reddy et.al, 2018)

5. Herwani et.al (2018) determined that because the consistency of fresh geopolymer concrete is very high, and the mixture behaves rigidly. Super plasticizer could be added to the mortar to enhance this property and make it more elastic and workable. When making the concrete mixture, a 150–250 minute set time was noted. The longer setting time needed increases with the concentration of NaOH solution. The geopolymer concrete reached its maximum compressive strength at a molarity, of 12 M in the NaOH solution. The attained compressive strength was merely 50–60% of the intended value. The geopolymer, concrete with a molarity of 14M in the NaOH solution experienced the least amount of shrinkage.

The composition of chemical contents of fly ash. and geopolymer concrete mix design (In % of Weight) is shown in table 3 and table 4 respectively.

Table 3 Chemical contents of fly ash

Fly Ash	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	LoI
Specimen A	42.29	17.41	12.10	10.47	7.39	1.38	6.15
Specimen B	41.91	17.21	12.01	10.39	7.31	1.48	5.86
Specimen C	42.25	17.48	11.88	10.34	6.91	1.43	6.26

Table 4 Geopolymer concrete mixed design (in Kg/m^3)

Materials	Mix 1	Mix 2
Coarse Aggregate (SSD)	1200	1142.7
Dia. 4.5 – 9.5 mm	540	457.1
Dia. 9.5 – 19.5 mm	660	685.6
Fine Aggregate (SSD)	600	521.8
Fly Ash	450	410
NaOH Solutions	80	110
Na_2SiO_3 Solutions	120	120
Superplasticizer	9	8.2
Added water	-	2.3

6. Khan et al. (2019) concluded that the creation of the geopolymer composite involved combining rice husk ash, bottom ash, and fly ash as a common binder. Replacement percentages for rice husk and bottom ash were maintained at 20%, 30%, and 40% of the total solid contents, respectively. Additionally, the molarity of NaOH. was given at levels of 12 and 14, respectively. According to the results, the mechanical and water transport capabilities of the fly ash-bottom ash blend outperformed those of the fly ash-rice husk ash blend. Because of its ideal Si/Al ratio for the geopolymerization reaction, the geopolymer composite including a combination of fly and bottom ash achieved a remarkable compressive strength of 41.49 MPa.

7. Malliga et al. (2019) determined that when fly ash and GGBS are replaced in a 30:70 ratio, a highest compressive strength of 35.5 MPa is reached, compared to 34 MPa for standard concrete after 14 days of curing in portable water. As a result, 70% of GGBS replacement achieves maximal strength compared to other replacement levels. It is not only more cost-effective to build with fly ash and GGBS instead of cement, but it also makes it easier to dispose of the large amounts of waste slag produced by the steel industry in an environmentally responsible manner.

8. Bellum et al. (2020) according to the SEM pictures, graphene oxide changed the geopolymer concrete's shape from porous to considerably pore-filled with enhanced compressive strength. In comparison to a controlled mix cured at room temperature, the graphene-modified fly ash-GGBS based geopolymer concrete achieved low chloride permeability values, modulus of elasticity, and compressive strength parameters. In light of the experimental data, the following deductions are made: in comparison to the reference mix, fly ash-GGBS based geopolymer concrete with graphene oxide added saw higher compressive strength values. Among the various proportions (1, 2, 3, and 4%).

9. Kavipriya (2021) concluded that the several techniques utilized to create mortar specimens in order to determine the ideal dry density. Utilizing experimental data, strength qualities were analysed utilizing a variety of criteria. It facilitates the development of an amazing model for forming geopolymer blocks with various constituent combinations to get the required strength of outcomes. The models' validity was determined using a collection of different experimental data. When compared to the .experimental data, the outcome shows the same expected values. Examined a composite geopolymer matrix that had basalt fibers and reinforcement inserted in it. To assess the increase in mechanical characteristics compared to a material cast without reinforcement.

10. Mahdi et al. (2022) concluded that a mixture of BKRHA, SPFA, natural aggregates, and alkaline activators is used to create GEOPAV blocks, which are then cured at room temperature and under a variety of circumstances. The durability, freshness, and mechanical qualities of GEOPAV blocks are assessed and contrasted with those of traditional paver blocks. The following significant findings and conclusion are listed based on an experimental investigation. The workability of GEOPAV mixes has decreased as a result of BKRHA replacing SPFA. The morphology of BKRHA particles is micro porous and honeycombed, which explains this. The compressive strength of GEOPAV blocks increased very little when 5% BKRHA was substituted for SPFA. However, considerable improvements in flexural and split tensile strength as well as increased density for hardened GEOPAV blocks were noted for the same compositions. Such results show that the inclusion of BKRHA refined the microstructure. Additionally, GEOPAV bricks have considerably better strength characteristics than traditional paver blocks. When 5% BKRHA was added, the abrasion resistance of GEOPAV blocks was even higher than that of ordinary paver blocks, suggesting that the aggregates and alkali-activated gel had a strong connection (Figure 2, 3 and 4). The resistance to frost and acid attacks has been greatly enhanced by the addition of BKRHA to GEOPAV blocks. The increased amorphous silica concentration in thick polymeric gel formations is principally responsible for the enhanced durability qualities of BKRHA-GEOPAV blocks.

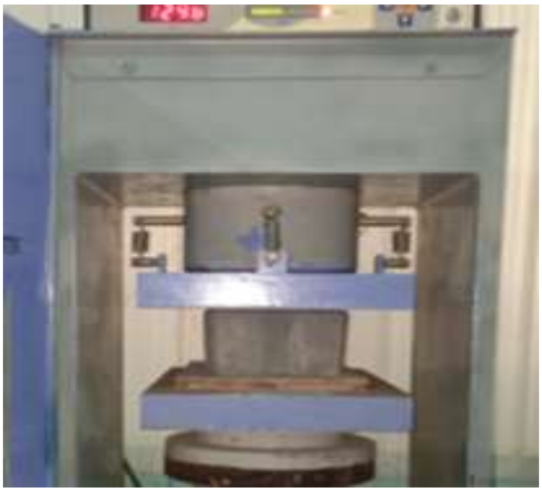

Figure 2 Compressive Strength Test (Mahdi et al. 2022)

Figure 3 Splitting Tensile Strength Test (Mahdi et al. 2022)

Figure 4 Flexural Strength Test (Mahdi et al. 2022)

3 Conclusion

This report reviewed previous research on geopolymer concrete uses and experiments. The review gives the following conclusions:

Geopolymer concrete has the potential to cut carbon dioxide emissions associated with concrete production by about 80% when compared to standard Portland cement concrete. Using geopolymers would also result in a drop in the cost and utilization of raw materials. The resistance against acid and frost attacks has been greatly enhanced by the addition of fly ash and GGBS to GEOPAV blocks. Concrete's compressive strength is increased when fly ash and GGBS are present. The compressive strength of various geopolymer concrete mixes improves with an increase in alkaline solution. The geopolymer paver block's compressive strength rises as the ratio of $Na_2SiO_3/NaOH$ does. GPC concrete with natural aggregate had a water absorption rate that was within tolerance.

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