Suitability of geopolymer concrete in paver blocks

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Abstract— **Geopolymer paver blocks, an environmentally friendly substitute for traditional cement-based blocks, utilize industrial by-products like fly ash and slag to reduce carbon emissions. These blocks offer superior durability, chemical resistance, and thermal stability compared to ordinary concrete paver blocks, promoting sustainable construction, waste reduction, and long-term performance. The research explores its suitability for paver blocks by optimizing the mix design based on fly ash, water-to-binder ratio (0.35), fine aggregate grading, and alkaline solution ratio ($Na_2SiO_3/NaOH$ = 1.0). A 13M sodium hydroxide solution and a sodium silicate solution were used, resulting in concrete with excellent workability, as confirmed by the flow table test and achieving the target compressive strength. The findings demonstrate that geopolymer concrete meets the necessary mechanical, workability, and strength requirements, making it a practical and eco-friendly material for durable paver blocks. For industrial applications, the suggested mix design approach ensures reliable performance, further validating geopolymer blocks as a viable green alternative in construction.**

Keywords: Geopolymer concrete, Paver blocks, Fly ash, Alkaline activation, Compressive strength.

I. INTRODUCTION

Concrete is still the most used construction material in the world due to its structural adaptability. The construction industry is a major contributor to global carbon emissions, with Ordinary Portland Cement (OPC) production alone accounting for nearly 8% of worldwide CO_2 emissions, driving the urgent need for sustainable alternatives in infrastructure development, particularly in the manufacturing of paver blocks used for walkways, driveways, parking lots, and road surfaces, owing to their durability, aesthetic appeal, and ease of installation. Traditional OPC-based paver blocks, which are widely utilized, impose significant environmental burdens owing to the energy-intensive cement production processand have prompted the exploration of geopolymer technology as a promising eco-friendly alternative that leverages industrial by-products such as fly ash, and metakaolin activated by alkaline solutions to form inorganic alumina silicate polymers with comparable or superior mechanical and durability properties while drastically reducing the carbon footprint. Despite the potential of geopolymer concrete, its practical application in paver blocks remains under-researched, particularly with respect to the compressive strength, flexural strength, abrasion resistance, water absorption, and economic feasibility, which are critical for justifying its widespread adoption as a replacement for conventional OPC-based blocks in real-world scenariosThis study aims to address this gap by developing optimized geopolymer concrete mix designs using fly ash, manufacturing and testing paver blocks in compliance with IS 15658:2006 standards, and evaluating their mechanical and durability properties, including compressive

strength (targeting ≥35 MPa for M35 grade), flexural strength, water absorption, and abrasion resistance, while also comparing their performance with traditional OPC-based blocks and analysing environmental benefits such as carbon footprint reduction and resource conservation. The investigation was motivated by the need to promote sustainable urban infrastructure, utilize industrial waste materials such as fly ash, and reduce the environmental impact of construction activities. However, it has limitations, such as the lack of standardized mix design guidelines, variability in raw material composition, controlled laboratory conditions that may not fully replicate real-world scenarios, and a focus on short-term testing without extensive long-term durability assessments or comprehensive life-cycle cost analyses. The expected outcomes include the development of a sustainable geopolymer mix design, validation of mechanical and durability performance comparable or superior to OPC-based blocks, significant reduction in cement usage and associated emissions, and establishment of a foundation for future research on large-scale production and long-term field applications, ultimately supporting the transition toward greener, more durable, and economically viable construction materials for urban and rural infrastructure. By addressing these aspects, this study seeks to provide performance-based evidence for the feasibility of geopolymer paver blocks, contributing to the broader adoption of low-carbon construction technologies and aligning with global sustainability goals while promoting circular economy principles through productive reuse of industrial by-products

II. MATERIAL AND METHODOLOGY

A.Materials .

1.Cement
2.Fine Aggregate
3.Coarse Aggregate
4.Fly Ash
5.Sodium Silicate (Na2 SiO3)
6.Sodium Hydroxide (NaOH)

B. Methodology

When compared to traditional cement concrete paver blocks, geopolymer concrete paver blocks have demonstrated exceptional compressive strength. According to one study, the compressive strength of geopolymer concrete paver blocks made with fly ash was exceptionally high. This implies that in terms of compressive strength, geopolymer-based paver blocks may be able to perform better than conventional M35 grade cement concrete paver blocks.

a)Compressive Strength

Compressive strength is a crucial property of paver blocks that influences their durability and performance in various applications.It was discovered that the geopolymer paver blocks' compressive strength was adequate and well within the range needed for paving applications. The blocks' strength levels the traditional concrete pavers. This suggests that geopolymer concrete can offer a sustainable substitute for conventional materials while still providing the required load-bearing capacity. Submit your manuscript electronically for review. prepare it in two-column format, including figures and tables(untill it don't fit properly and data is not visible).

b) Experimental Setup and Testing Setup

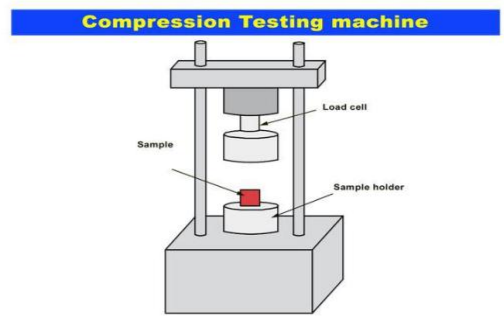

Fig. 1 Experimental Setup

Fig. 2 Testing Setup

c)Casting of Paver Blocks

▪Step 1: Determine Target Strength
- Characteristic Strength (fck): 35 MPa
- Standard Deviation (σ): 5 MPa
- Target Mean Strength (fck'):
= 35 + 1.65×5 = 43.25 MPa

▪Step 2: Binder Content
Total binder = 500 kg/m³

▪Step 3: Alkaline Activator Solution (AAS)
Alkaline Liquid/Fly Ash Ratio (AL/FA):0.45 Na_2SiO_3: NaOH = 67%:33%
NaOH (33% of AAS)
= 0.33 × 225 = 74.25 Kg/m³

Na2SiO3 (67% of AAS)
= 0.67 × 225 = 150.75 Kg/m³

Total Water content

Na_2SiO_3 = 53 ltr/m³
NaOH = 83 ltr/m³

▪Step 4: Aggregates
Total aggregates = 75% of total volume (1650 Kg/m³)
Use FA: CA = 1:1.6
C.A = 1000 Kg/m³
F.A = 650 Kg/m³

▪Step 5: Scale Down to 6 Paver Blocks
Size of mould - 200×100×60 (mm)
Volume of per paver= 0.0012 m3
Volume of 6 paver block = 0.0072 m3 (20% wastage) = 0.009 m3

III. TESTING PROCEDURE

1) Measure the cross-section dimension of the specimen
2)Place paver block assembly on lower cross head of CTM.
3)Fix specimen at centre in CTM.
4)Lower the middle cross head so that load is just touches the specimen.
5)Apply the load at constant rate till the specimen fails, note down the load at failure.
6)Repeat the procedure with remaining specimen.
7)Calculation of compressive strength.

IV. OBJECTIVE

1)To formulate appropriate geopolymer concrete mix designs for the production of paver blocks.
2)To assess the mechanical properties of the geopolymer paver blocks, specifically: Compressive strength and Flexural strength.
3)To evaluate the performance of geopolymer paver blocks in comparison to conventional paver blocks under same testing setting.
4)To study the environmental benefits of geopolymer concrete, particularly in terms of carbon footprint reduction and resource conservation.

V. SPECIFICATION AND RESULT CALCULATION

A. Cement Paver Block.

Paver ID	Dimension (mm)	Concrete Grade	No. of Days	Load in KN	Strength (MPa)	Average Strength
PB-1	240*120* 80	M35	7	770	30.873	
PB-2	240*120* 80	M35	7	690	27.665	*29.00mpa*
PB-3	240*120* 80	M35	7	710	28.467	
PB-4	240*120* 80	M35	14	1100	44.104	*44.63mpa*
PB-5	240*120* 80	M35	14	1090	43.703	
PB-6	240*120* 80	M35	14	1150	46.109	

Table 5.1 Compressive strength of concrete paver block

B. Geopolymer Paver Block

Paver ID	Dimension (mm)	Concrete Grade	No. of Days	Load in KN	Strength (MPa)	Average Strength
PB-1	240*120* 80	M35	7	770	21.049	
PB-2	240*120* 80	M35	7	690	28.066	*25.19MPA*
PB-3	240*120* 80	M35	7	710	26.462	
PB-4	240*120* 80	M35	14	1100	38.090	
PB-5	240*120* 80	M35	14	1090	41.698	*41.16MPA*
PB-6	240*120* 80	M35	14	1150	43.703	

Table 5.2 Compressive strength of Geopolymar Paver block

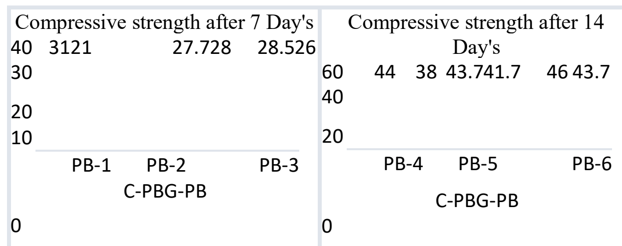

Fig. 5.1 Compressive strength after 7 day's Fig. 5.2 Compressive strength after 28 day's

VII. CONCLUSION

In order to achieve the necessary workability and strength for the construction of paver blocks, suitable geopolymer concrete mix designs were effectively created. The produced geopolymer paver blocks met pavement use performance criteria by exhibiting sufficient compressive and flexural strength. These blocks performed similar to traditional paver blocks in terms of strength and durability when tested under the same circumstances. Furthermore, because geopolymer concrete has a lower carbon footprint and requires less natural resources, its utilisation demonstrated its promise as a sustainable building material. According to the study's findings, geopolymer concrete is economical and it is also an eco-friendly choice because of its sustainable nature, which helps to save resources and lower carbon emissions.

REFERENCES

[1] Davidovits Joseph, “GEOPOLYMERS: Man-Made Geosynthesis and the Resulting Development of Very Early High Strength Cement”, J. Materials Education, 1994, Vol. 16, No.2 & 3, pp. 91-139
[2] Malhotra VM Ramezanianpour AA (1994) “Fly Ash in concrete”, Canada Centre for Mineral and Energy Technology (CANMET), Canada
[3] Davidovits J (1995) “Gloal warming impact on the cement and aggregate industries”, Worid Res Rev 6(2):263-278
[4] Davidovits J (1998) “Geopolymer chemistry and properties”, in: Proceedings of 1st European conference on soft mineralurgy. Geopolymer, vol 88, France, pp 25-48
[5] Malhotra VM (1999) “Making concrete greener with fly ash”, ACI Conc Int 21 (5):61-66
[6] Hardjito D, Wallah SE, Sumjouw DMJ, Rangan BV (2004) “On the development of fly ash based geo polymer concrete”, ACI Mater J 467-472
[7] Kumar V, Mathur M, Sinha SS, Dhatrak S (2005) “Fly Ash: an environmental sarvior”, Fly Ash Utilisation Programme (FAUP), TIFAC, PDST, Fly Ash India, New Delhi, IV, PP 1.1-1.4
[8] Ranganath RV, Mohammed S (2008) “Some optimal values in geo polymer concrete Incorporating fly ash”, Indian Concr J 82:26-34
[9] Ragan BV (2008) “Mix design and production of fly ash based geopolymer concrete”, Indian Concr J 82:7-15
[10] Raijiwala O.B, Patil H. S, (2010) “Geopolymer Concrete A Green Concrete”, 2nd International Conference on Chemical, Biological and Environmental Engineering (ICBEE 2010)
[11] Samuel Demie, Muhd Fadhil Nuruddin, (2011), “Efects of Curing Temperature and Superplasticizer on Workability and Compressive Strength of Self-Compacting Geopolymer Concrete”, University Technology PETRONAS Tronoh, Perak, Malaysia.
[12] S.S. Jamkar, Y.M. Ghugal, and S.V. Patankar, “Effect of fly ash fineness on workability and compressive strength of geopolymer concrete”, The Indian Concrete journal, Vol. 87, No.4, J (2011): 25-28. April 2013, pp. 57-62
[13] Patankar SV, Jamkar SS, Ghugal YM (2012) “Effect of sodium hydroxide on flow and strength of fly ash based geopolymer mortar”, Journal of Structure Eng 39(1):7–12
[14] Anuradha R, Sreevidya V, Venkatasubramani R, Rangan BV (2012) “Modified guidelines for geopolymer concrete mix design using Indian standard”, Asian J Civl Eng (Build Hous) 13 (3):353-364
[15] Subhash V. Patankar, (2014) “Mix Design of Fly Ash Based Geopolymer Concrete”, In: Proceedings of SEC2014, IIT Delhi, Published by Springer India, 1619-1634
[16] Patankar SV, Jamkar SS, Naveed Akhtar Javeed Hasan Mr, (2020) “Effect of Different Curing Systems On Strength Characteristics of Geopolymer Concrete”, International Journal of Advanced Science and Technology · September 2020
[17] Patankar SV, Jamkar SS, Yuwaraj Marotrao Ghugal (2022) “Effect of Water-to-geopolymer Binder Ratio On the Production of Fly Ash Based Geopolymer Concrete”, International Journal of Advanced Technology in Civil Engineering, ISSN: 2231 –5721, Volume-1, Issue-4