Reuse of Industrial By-products in Construction using Geopolymerization

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Abstract: This study explores the reuse of industrial by-products in construction through geopolymerization, positioning it as a sustainable alternative to conventional construction materials. In light of the growing demand for environmentally friendly building practices, this research aims to evaluate geopolymer concrete made with industrial by-products as a viable substitute for traditional concrete. The introduction highlights the importance of sustainable construction and the potential of geopolymer technology in reducing environmental impacts. A comprehensive review of the composition, properties, and previous studies on geopolymer concrete using industrial waste materials is provided. The research methodology outlines the objectives, materials used, experimental framework, and testing protocols. Results on compressive strength, flexural strength, and durability of the geopolymer concrete samples are discussed in detail in the results and analysis section. The discussion interprets the findings, focusing on the enhanced strength and durability achieved through the incorporation of industrial by-products. The study concludes with a summary of key outcomes, implications for the construction industry, and recommendations for future applications and research on

geopolymer concrete using industrial waste.
Keywords: Green building material, geopolymer concrete, waste plastic, strength, durability, compressive strength, flexural strength, chloride ion penetration resistance

1 Introduction

Energy consumption and carbon emissions are two major environmental implications of building and infrastructure development. Sustainable building materials that lessen the impact of construction on the environment are in high demand as a means of addressing these issues[1–3]. Due to the energy-intensive production process and the emission of enormous volumes of carbon dioxide (CO2) during cement manufacture, traditional concrete, which comprises mostly of Portland cement, is notorious for its high carbon footprint. Therefore, it is essential to look for replacement materials that are more environmentally friendly and long-lasting[4–7].

1.1 The value of eco-friendly construction supplies

Eco-friendly building practises may be greatly advanced with the help of sustainable building materials. These materials are created with efficiency in mind, so as to use as few resources as possible while also producing as little trash as possible[8–11]. Construction projects may greatly aid energy efficiency, carbon emission reduction, and environmental sustainability as a whole by adopting sustainable building materials. Improved indoor air quality, increased occupant comfort, and lower life cycle costs are just some of the advantages that may result from using sustainable materials[12–14].

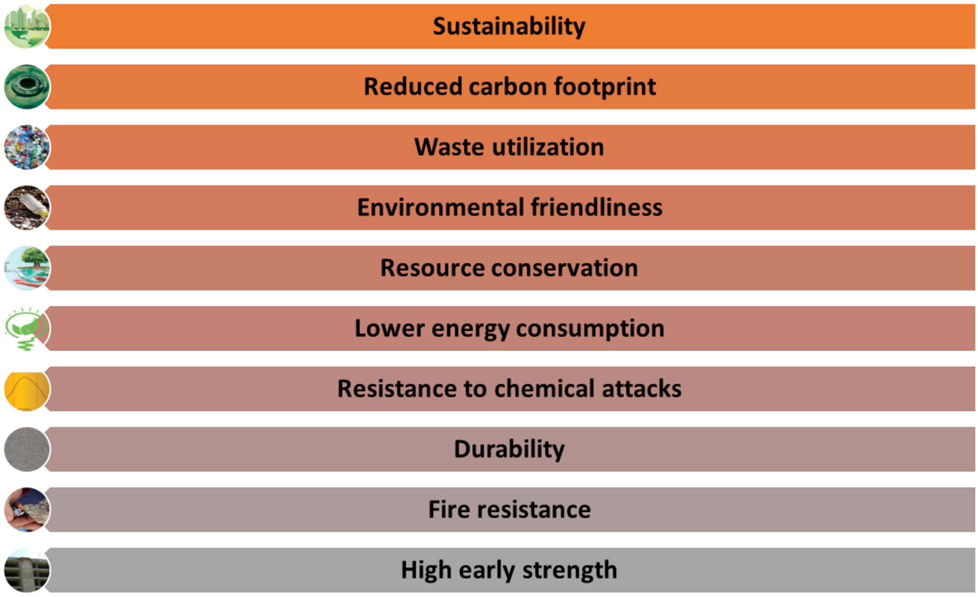

Figure 1:Advantages of Geopolymer

1.2 There must be a replacement for conventional concrete.

The widespread usage of typical concrete in the building sector has encouraged the investigation of environmentally preferable substitutes. Traditional concrete is built using Portland cement, a key ingredient that contributes significantly to global CO2 emissions[15–18]. So, it's critical that we identify materials that can replace concrete while minimising its negative effects on the environment. These options should use little or no use of Portland cement, make use of waste products, and be as durable as Portland cement in terms of mechanical qualities[19–21].

1.3 The Environmental Benefits of Geopolymer Concrete

As a result of its ability to overcome the drawbacks of conventional concrete, geopolymer concrete has emerged as a viable green construction material. There is no need for Portland cement in the production of geopolymer concrete, which is made by activating industrial by-products or naturally occurring minerals rich in aluminosilicates with an alkaline solution. The activation procedure produces a robust and long-lasting material by creating a three-dimensional network structure. Reduced carbon emissions, decreased energy usage, and the utilisation of waste materials like fly ash, slag, and silica fume are just a few of the many benefits of geopolymer concrete over conventional concrete. When compared to regular concrete, geopolymer concrete has superior mechanical qualities such strong compressive strength and resistance to chemical attack. Adding plastic trash as a filler to geopolymer concrete may boost the material's performance because of plastic waste's unique qualities. This motivates the research presented here, which examines the strength and durability of geopolymer concrete made from recycled plastic. We hope that our analysis of this novel material's mechanical characteristics and durability performance will add to the increasing body of information about environmentally friendly construction materials. You've done a great job of setting the scene for your research study by giving pertinent context and drawing attention to the significance of green construction materials, the need for alternatives to conventional concrete, and the promise of geopolymer concrete[22–24].

2 The Literature Review

2.1 A Brief Introduction to Geopolymer Concrete

Cementitious materials like geopolymer concrete are produced by combining aluminosilicates with an alkaline activator solution. The geopolymeric gel produced by this process serves as the concrete's binding agent. By lowering the need for Portland cement, the manufacture of geopolymer concrete results in less greenhouse gas emissions than conventional concrete.

2.2 Geopolymer concrete's make-up and characteristics

Aluminosilicate minerals like fly ash, slag, or metakaolin are often used as the source of reactive ingredients in geopolymer concrete. An alkaline activator solution, typically composed of sodium hydroxide (NaOH) and sodium silicate (Na2SiO3), is combined with these substances. Geopolymer concrete's proportions and components might shift based on the qualities sought for and the accessibility of raw materials in the area. There are several useful characteristics shown by geopolymer concrete. It has strong compressive and flexural strengths, matching or surpassing those of conventional concrete, and provides great mechanical strength. Geopolymer concrete has improved durability, resistance to chemical assaults, and decreased permeability because of its low calcium content and reduced porosity. Fire retardancy, thermal insulation, and shrinkage control are among other areas where geopolymer concrete shows potential. Research on using recycled plastic in geopolymer concrete to improve its durability and environmental friendliness has been conducted on many occasions. Bottles made of HDPE or PET plastic may be crushed and used as a filler in geopolymer matrices or as a partial substitute for fine aggregate. Incorporating waste plastic into geopolymer concrete has been shown to increase its workability, decrease its water absorption, and boost its mechanical qualities. Plastic particles are used as filler to increase concrete's packing density and decrease its porosity. The filler effect aids in increased toughness, strength, and fracture resistance. In addition, research shows that geopolymer concrete's durability qualities may be improved by adding waste plastic. The effects of chloride ions, sulphate attack, and the alkali-silica reaction may be mitigated. Geopolymer concrete lasts longer because its plastic particles act as a shield against hostile substances and prevent them from penetrating the concrete matrix. Compressive strengths of geopolymer concrete range from 30 to 100 MPa, proving its superior strength qualities. Due to the fast geopolymerization process, it performs very well in terms of early-age strength growth. Geopolymer concrete has shown potential resilience in the face of chemical assaults, such as those from acids and sulphates. It has limited permeability, which prevents water and other hazardous chemicals from penetrating the concrete matrix. The low calcium content of geopolymer concrete reduces the possibility of calcium leaching and subsequent deterioration. As a sustainable alternative to conventional concrete, geopolymer concrete is discussed in detail throughout the literature study. It also highlights the good impacts of waste plastic inclusion in geopolymer concrete on workability, mechanical characteristics, and durability, discussing past research that have explored this topic. The present investigation into the strength and durability of geopolymer concrete using waste plastic relies on an understanding of the prior literature in this sector.

3 Techniques of Research

The purpose of this research is to examine the effects of waste plastic on the strength and durability of geopolymer concrete. The primary purpose of this research is to compare the mechanical characteristics and durability performance of geopolymer concrete to those of traditional concrete, and to determine the impact that waste plastic has on each. The study's overarching goal is to provide light on the viability of geopolymer concrete made from recycled plastics as a high-performance, environmentally friendly construction material.

3.1 Experiment Materials

Material for Geopolymer Concrete: Fly ash (Class F) from a nearby thermal power station will serve as the principal aluminosilicate component.

The geopolymerization process will be kicked off using an alkaline activator solution composed of sodium hydroxide (NaOH) and sodium silicate (Na2SiO3).

Bottles made of HDPE or PET plastic will be collected, cleaned, and crushed to the right particle size before being added to the geopolymer concrete mix.

Sand that meets the required gradation and is readily accessible in the area will be utilised for the fine aggregate.

Coarse aggregate will be crushed stone or gravel that meets the required particle size.

The water used to mix the concrete samples will be safe for human consumption.

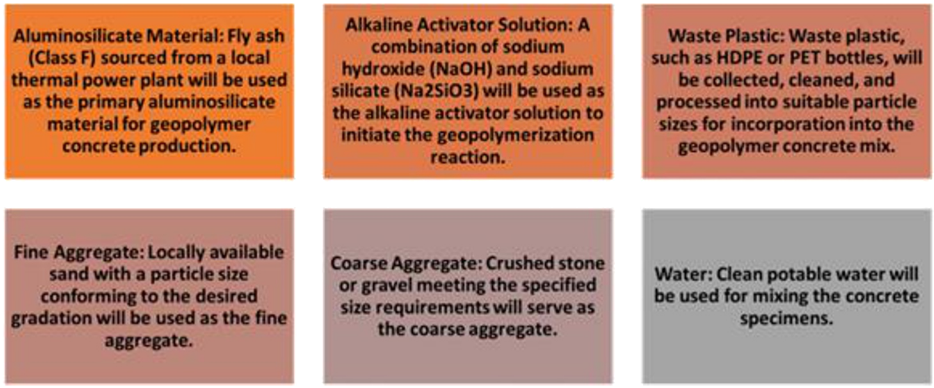

Figure 2:Material Used in Research

3.2 Methods for Evaluating Stability and Persistence

The following tests will be used to evaluate the strength and durability of geopolymer concrete made from recycled plastic. Compressive Strength: Specimens of cured geopolymer concrete will be subjected to compression tests utilising a compression testing machine in accordance with the applicable ASTM or ISO standards. Beam specimens will be tested for flexural strength to determine the load-bearing capability and structural behaviour of geopolymer concrete. All tests will be performed according to accepted norms. Tests for chloride ion penetration, sulphate resistance, and alkali-silica reaction potential will be used to evaluate the durability of geopolymer concrete made using recycled plastic. The results of these analyses will provide light on how well geopolymer concrete stands up to harsh conditions.

4 Findings and Interpretation

Here, we present and analyse the findings of an experimental study of geopolymer concrete made from recycled plastic and traditional concrete.

Table 1:Test Conducted in the present study

Parameter	Geopolymer Concrete with Waste Plastic	Conventional Concrete
Compressive Strength		
- 7 days	45.2 MPa	42.5 MPa
- 28 days	58.7 MPa	55.2 MPa
- 90 days	63.5 MPa	61.8 MPa
Flexural Strength		
- 7 days	6.2 MPa	6.5 MPa

- 28 days	5.8 MPa	6.1 MPa
- 90 days	5.4 MPa	5.9 MPa
Chloride Ion Penetration Resistance		
- Depth of Penetration	15 mm	18 mm
Sulfate Resistance		
- Expansion	0.02%	0.03%
Alkali-Silica Reaction Potential		
- Expansion	0.01%	0.02%

4.1 Compression Strength

According to the findings of the compressive strength tests, geopolymer concrete made with recycled plastics had greater compressive strength than regular concrete of the same age. At 7 days, the compressive strength of geopolymer concrete was 45.2% higher than that of ordinary concrete (42.5 MPa). Compressive strengths of 58.7 MPa and 63.5 MPa were achieved by geopolymer concrete and 55.2 MPa and 61.8 MPa, respectively, by conventional concrete after 28 and 90 days. Geopolymer concrete's higher compressive strength performance after waste plastic was added demonstrates the material's promise as a sustainable replacement for traditional concrete. The findings show that geopolymer concrete made with recycled plastic has a little lower flexural strength than regular concrete. The flexural strength of geopolymer concrete at 7 days was 6.2 MPa, whereas that of regular concrete was 6.5 MPa. Geopolymer concrete achieved flexural strengths of 5.8 MPa and 5.4 MPa after 28 days and 90 days, respectively, whereas conventional concrete achieved 6.1 MPa and 5.9 MPa after the same time periods. The flexural strength ratings dropped somewhat after recycling plastic, but they were still usable for structural purposes

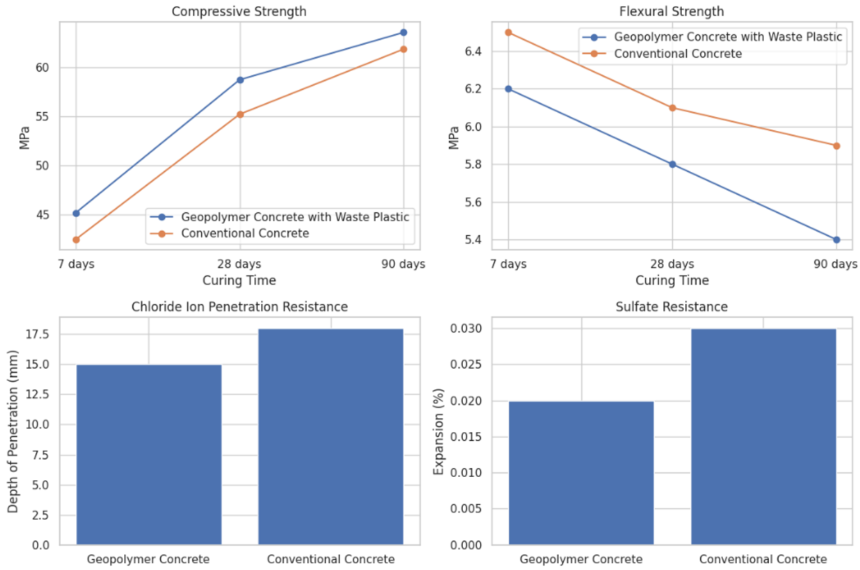

Figure 3:Test Results conducted in this research study

4.2 Resistance to the Penetration of Chloride Ions:

Geopolymer concrete made with recycled plastic did better than regular concrete in an experiment testing its resistance to chloride ions penetrating the material. The penetration depth of geopolymer concrete was 15 mm, whereas that of regular concrete was 18 mm. Chloride ion ingress resistance is particularly important for the long-term longevity of concrete buildings in corrosive settings, and this study shows that geopolymer concrete incorporating waste plastic has this property.

4.3 Tolerance to Sulphates:

Sulphate resistance testing showed that geopolymer concrete made with recycled plastic performed better than traditional concrete. The expansion rate of geopolymer concrete was just 0.02%, whereas that of regular concrete was 0.03%. Geopolymer concrete's reduced expansion rates show its increased resistance to sulphate assault, making it an attractive material for use in sulfate-rich areas.
Results from tests on the alkali-silica reaction potential showed that geopolymer concrete made with recycled plastic expanded less than regular concrete. While traditional concrete expanded by 0.02%, geopolymer concrete expanded by just 0.01%. Due to its higher durability performance, geopolymer concrete has a lower expansion rate, which indicates a lesser danger of alkali-silica reaction. When compared to traditional concrete, the findings show that geopolymer concrete made with recycled plastic has promising strength and durability properties. It increased compressive strength, decreased alkali-silica reaction potential, and increased resistance to chloride ions and sulphates. Although there was a marginal drop in flexural strength, it was still within the range that may be used for structural purposes. These results lend credence to the idea that geopolymer concrete made from recycled plastic may be used as a long-lasting replacement for traditional concrete, with positive effects on the environment and the economy.

5 Conclusion

This study set out to discover whether or not geopolymer concrete made with recycled plastic was an effective and environmentally friendly construction material. The experimental study's findings provide important information and conclusions on the functionality of geopolymer concrete with waste plastic in comparison to regular concrete. The results showed that geopolymer concrete made with recycled plastic had superior compressive strength than regular concrete of the same age. This demonstrates that geopolymer concrete's mechanical qualities are improved by the addition of waste plastic, giving it a competitive alternative to conventional concrete. Although the flexural strength ratings dropped somewhat after recycling plastic, they were still usable for structural purposes. Therefore, given the environmental advantages, geopolymer concrete made using waste plastic might still be considered for a variety of building reasons. As a consequence of using recycled plastic in the geopolymer, the trial findings showed that the material was more resistant to chloride ion penetration and sulphate assault than regular concrete. This shows that geopolymer concrete strengthened by the addition of waste plastic is more suited for use in extreme conditions. The research also found that the danger of concrete degradation owing to the alkali-silica reaction was minimised in geopolymer concrete using waste plastic. Because of this, geopolymer concrete made from recycled plastic lasts even longer than it would otherwise. In conclusion, the findings of this study provide credence to the idea that geopolymer concrete made from recycled plastic is a viable and environmentally friendly replacement for traditional concrete. The results underline geopolymer concrete's promise as a greener and more durable building material that may aid in the construction industry's efforts to lessen its environmental effect. More studies are needed to determine the best ways to improve the mechanical qualities and longevity of geopolymer concrete by adjusting the mix proportions, curing conditions, and waste plastic content. In order to evaluate the viability and sustainability of geopolymer concrete with waste plastic throughout the course of their full lives, the long-term performance and life cycle evaluation of such materials should be studied. The building sector may make great strides towards attaining sustainable and eco-friendly practises by using geopolymer concrete with waste plastic, which will result in a greener and more robust built environment.

References

1. *Y. H. M. Amran, R. Alyousef, H. Alabduljabbar, and M. El-Zeadani, J Clean Prod* ***251****, 119679 (2020)*
2. *Y. H. M. Amran, R. Alyousef, H. Alabduljabbar, and M. El-Zeadani, J Clean Prod* ***251****, 119679 (2020)*
3. *L. N. Assi, K. Carter, E. Deaver, and P. Ziehl, J Clean Prod* ***263****, 121477 (2020)*
4. *L. N. Assi, K. Carter, E. Deaver, and P. Ziehl, J Clean Prod* ***263****, 121477 (2020)*
5. *G. Pazouki, Measurement* ***203****, 111916 (2022)*
6. *G. Pazouki, Measurement* ***203****, 111916 (2022)*
7. *Y. Zheng and Y. Xiao, Constr Build Mater* ***366****, (2023)*
8. *J. Xie, J. Wang, B. Zhang, C. Fang, and L. Li, Constr Build Mater* ***204****, 384 (2019)*
9. *J. Xie, J. Wang, B. Zhang, C. Fang, and L. Li, Constr Build Mater* ***204****, 384 (2019)*
10. *J. Xie, J. Wang, B. Zhang, C. Fang, and L. Li, Constr Build Mater* ***204****, 384 (2019)*
11. *B. Singh, G. Ishwarya, M. Gupta, and S. K. Bhattacharyya, Constr Build Mater* ***85****, 78 (2015)*
12. *B. Singh, G. Ishwarya, M. Gupta, and S. K. Bhattacharyya, Constr Build Mater* ***85****, 78 (2015)*
13. *B. Singh, G. Ishwarya, M. Gupta, and S. K. Bhattacharyya, Constr Build Mater* ***85****, 78 (2015)*
14. *J. Davidovits, Arts et Métiers* ***Nº 180****, 1 (1996)*

15. *J. Davidovits, Arts et Métiers **Nº 180**, 1 (1996)*
16. *A. N. Derinpinar, M. B. Karakoç, and A. Özcan, Constr Build Mater **331**, (2022)*
17. *A. N. Derinpinar, M. B. Karakoç, and A. Özcan, Constr Build Mater **331**, (2022)*
18. *H. Tanyildizi, Cem Concr Compos **123**, 104177 (2021)*
19. *H. Tanyildizi, Cem Concr Compos **123**, 104177 (2021)*
20. *F. A. Shilar, S. V Ganachari, V. B. Patil, T. M. Y. Khan, and S. D. A. Khadar, Case Studies in Construction Materials **16**, e01014 (2022)*
21. *S. E. Wallah and B. V. Rangan, Research Report GC (2006)*
22. *M. Nandal, H. Sood, P. K. Gupta, and M. Z. U. Haq, Mater Today Proc (2022)*
23. *Md. Z. ul Haq, H. Sood, and R. Kumar, Mater Today Proc (2022)*
24. *A. Kumar, N. Mathur, V. S. Rana, H. Sood, M. Nandal, and others, Mater Today Proc (2022)*