# Circular Economy Enabler: Enhancing High-Performance Bricks through Geopolymerization of Plastic Waste

*Md. Zia ul* Haq[1], *Hemant* Sood[1], *Rajesh* kumar[2], *Saurav Dixit*[3], *T.* Srinivas[4], *Suniana* Ahuja[5], *B* lingam[6], *Kaushal Kumar*[7]

[1]Department of civil engineering NITTTR CHANDIGARH, Sector 26, Chandigarh
[2]Department of civil engineering NITTTR CHANDIGARH, Sector 26, Chandigarh
[3](a) Division of Research & Innovation, Uttaranchal University, Dehradun, India, sauravarambol@gmail.com ; (b) Peter the Great St. Petersburg Polytechnic University, Saint Petersburg, 195251, Russian Federation, diksit_s@spbstu.ru (c) Department of Management Science and Engineering, Khalifa University of Science and Technology, 127788, Abu Dhabi, United Arab Emirates, saurav.dixit@ku.ac.ae
[4]Department of Civil Engineering, GRIET, Bachupally, Hyderabad, Telangana
[5]Lovely Professional University, Phagwara Punjab, 144001, India
[6]KG Reddy College of Engineering & Technology
[7]K R Mangalam University, Gurgaon, 122103, India

**Abstract:** This article investigates the merging of geopolymerization and plastic waste usage, imagining high-performance brick production that couples innovation with sustainability, in an effort to transform the environmental effect of the building sector. This idea is supported by the circular economy, which diverts resources from waste streams into a closed-loop paradigm. By creating inorganic polymers from aluminosilicate-rich sources, the chemical process of geopolymerization provides a paradigm change in the production of materials. This procedure is improved even more by the addition of plastic trash, which combats plastic pollution and improves brick qualities. In order to create a more resilient and environmentally conscientious construction industry in the future, this paper outlines the process's complexities, advantages, and difficulties while arguing for a harmonic fusion of circular economy concepts, technical innovation, and environmental stewardship.

**Keywords:** Circular economy, geopolymerization, plastic waste, high-performance bricks, sustainability

# 1 Introduction

The idea of the circular economy is at the vanguard of this transformation towards sustainability that is taking place in the world's economic environment[1–4]. The circular economy offers an appealing alternative in the construction sector, which has historically used a linear model of resource extraction, manufacturing, and disposal. By placing a higher priority on resource efficiency, recycling, and waste reduction, it aims to rethink the industry's practices and match them with more general environmental objectives[5–7].

## 1.1 Relevance of the Circular Economy to the Construction Industry

The construction industry is well known for its high levels of resource, energy, and trash consumption. The tenets of the circular economy directly address these difficulties. The circular economy offers a fresh perspective through which the construction industry may shift to a more sustainable paradigm by placing an emphasis on material reuse, lowering the demand for virgin resources, and supporting responsible waste management[8–11].

## 1.2 Geopolymerization: A Paradigm Shift in Material Production

The idea of geopolymerization represents a considerable improvement in the manufacture of sustainable materials. Using an inventive chemical procedure, aluminosilicate substances like fly ash, slag, or clay are converted into inorganic polymers [12–15]. When compared to conventional cement-based production, geopolymerization has the potential to use less energy and emit fewer greenhouse gases. It has the potential to change how the building industry sources and produces materials.

### *1.2.1 Potential Benefits of Geopolymerization*

Numerous advantages of geopolymerization are compatible with the objectives of sustainable building. These advantages include greater durability, less environmental impact, and improved mechanical qualities. Additionally, geopolymer-based materials can enhance structural performance in terms of overall structural performance, fire resistance, and thermal insulation. The creation of high-performance building goods requires such characteristics[16–20].

## 1.3 Plastic Waste Challenge and Environmental Impact

Nevertheless the construction sector, like many others, is confronted with a huge environmental problem: plastic waste[21–26]. The over use of plastics has led to widespread contamination that has an adverse effect on human health, marine life, and ecosystems. These problems are made worse by conventional disposal techniques

like landfilling and incineration. The issue of plastic waste has become urgently critical for enterprises everywhere.

### 1.4 Purpose of the Paper

In light of this, the purpose of this research is to examine a unique strategy that combines the circular economy, geopolymerization, and plastic waste management concepts in the context of building. The main goal is to investigate the viability and benefits of using geopolymerization to improve the qualities of high-performance bricks. This improvement is made possible by using plastic waste, which not only keeps plastic out of landfills but may also improve the sustainability of building materials as a whole. In summary, this study aims to add to the continuing conversation about environmentally friendly building methods. The goal of this article is to offer insights that can direct the creation and adoption of circular economy-driven solutions in the construction industry by examining the technical viability, environmental consequences, and possible economic advantages of this creative approach. In the end, this investigation has the potential to transform building materials, promote a more sustainable business, and tackle the urgent problem of plastic waste.

## 2 Geopolymerization and Plastic Waste

### 2.1 Explanation of Geopolymerization

Inorganic polymers can be produced from materials rich in aluminosilicates through the transformational chemical process known as geopolymerization. Using alkaline solutions, usually sodium or potassium silicate, to activate these materials, a three-dimensional network of interconnected molecules is formed. The resultant geopolymer materials can have exceptional mechanical toughness, longevity, and chemical resistance. Geopolymerization offers a sustainable substitute for conventional cement-based products in the building sector. The procedure uses less energy and produces noticeably less carbon dioxide emissions. Geopolymer materials may also be customized to have certain qualities, making them adaptable for a variety of building applications.

### 2.2 Significance of Plastic Waste in Geopolymerization

An appealing route for the manufacturing of sustainable materials is opened up by the incorporation of plastic waste into the geopolymerization procedure. Plastic garbage, which is frequently non-biodegradable and harmful to the environment, may be recycled to help produce strong building materials. The construction industry can simultaneously solve two urgent problems: decreasing plastic pollution and improving the sustainability of building materials—by utilizing plastic trash as a resource. Since plastics may increase flexibility, impact resistance, and reduce weight, their usage in geopolymerization has the potential to enhance the material's qualities. This makes it possible to develop high-performance building materials with enhanced properties and little environmental effect.

### 2.3 Plastic Waste Types Suitable for Geopolymerization

Not every kind of plastic waste can be geopolymerized. great-density polyethylene (HDPE) and polyethylene terephthalate (PET), two plastics with great heat stability, are more likely to function well during the procedure. These polymers are capable of withstanding the high temperatures needed for the geopolymerization process' curing without deteriorating or emitting toxic gases[27–30].

Given the wide variety of plastic polymers available, a careful sorting procedure is necessary. Only appropriate plastic trash is chosen for inclusion in the geopolymerization mixture thanks to proper sorting. To preserve the quality and performance of the resultant geopolymer-based building materials, contaminants like non-plastic materials or plastics with incompatible qualities must be carefully eliminated [31–37].

### 2.4 Considerations for Sorting and Preparation

There are various procedures involved in efficiently preparing plastic waste for geopolymerization. To begin with, plastic trash should be sorted to distinguish between various plastic kinds depending on their qualities and thermal stability. The next step is shredding, which reduces the sorted plastic trash into tiny pieces. Shredding increases the surface area of the plastic, which increases its reactivity during the geopolymerization process.

The size and form of the plastic particles should also be taken into account. Particle size uniformity can encourage homogeneous mixing within the geopolymerization mixture, resulting in materials with consistent characteristics in the finished product. To improve the compatibility of plastic waste with the other elements of the geopolymerization mixture, additional additives or treatments can be required.

Finally, the use of plastic waste in geopolymerization offers a fresh chance to improve the sustainability of building materials. The construction industry can support the principles of the circular economy while creating high-performance materials with minimal environmental impact by carefully choosing appropriate plastic waste types, implementing thorough sorting and preparation processes, and incorporating plastic waste into the geopolymerization process.

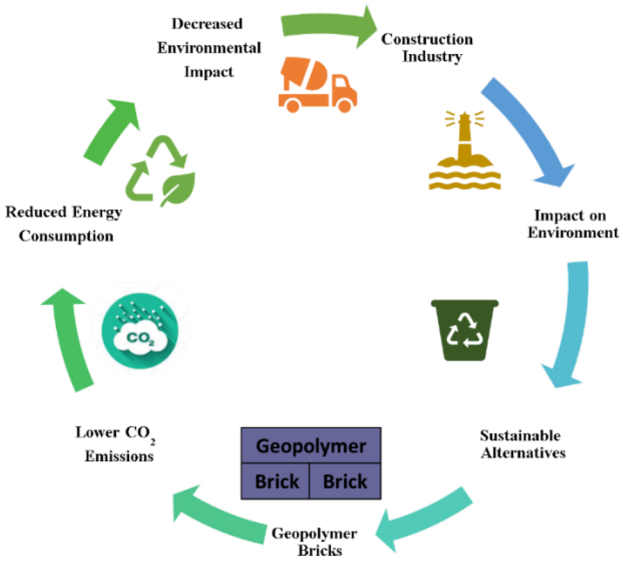


**Fig1.** Circular Sustainable approach of geopolymer brick production

# 3 Production of High-Performance Bricks

## 3.1 Components of the Geopolymerization Mixture

The production of high-performance bricks through geopolymerization involves a precise combination of components:

- **Plastic Waste:** Pre-sorted and prepared plastic waste, selected based on its compatibility and thermal stability.
- **Aluminosilicate-Rich Materials:** These include fly ash, slag, or clay, which serve as the primary source of aluminosilicates required for the geopolymerization reaction.
- **Alkaline Activator:** Sodium or potassium silicate solutions, which provide the alkaline environment necessary for the geopolymerization process.
- **Additives:** These could include reinforcing fibers, mineral aggregates, or chemical modifiers to enhance specific properties of the resulting geopolymer-based material.

## 3.2 Process of Mixing, Molding, and Curing

The production process involves a series of steps:

- **Mixing:** To create a homogeneous mixture, the pre-sorted plastic trash, aluminosilicate-rich components, and alkaline activator are completely combined. To achieve effective integration, the plastic debris is dispersed uniformly throughout the mixture in shred form.

- **Molding:** Using conventional brick-making methods, the geopolymerization material is subsequently formed into brick forms. Molds are meticulously prepared to provide uniform dimensions and shapes.
- **Curing:** The manufactured bricks are dried under carefully regulated circumstances. Alkaline activator initiates the geopolymerization process during curing. The components are joined by the process of polymerization, which forges powerful chemical bonds that solidify the mixture and produce a high-performance material.

### 3.3 Properties Improved by Geopolymerization

Geopolymer-based bricks exhibit improved properties compared to conventional bricks:

- **Strength:** The chemical bonds formed during geopolymerization lead to higher compressive and flexural strengths. This results in bricks that can withstand greater loads and stresses.
- **Insulation:** Geopolymer materials often possess better thermal insulation properties compared to traditional bricks. This can contribute to energy-efficient buildings by reducing heat transfer through walls.
- **Durability:** The chemical resistance of geopolymer materials makes them highly durable, particularly in harsh environments or exposure to aggressive chemicals.
- **Fire Resistance:** Geopolymer-based bricks generally exhibit excellent fire resistance due to the inorganic nature of the polymer matrix.
- **Environmental Benefits:** The incorporation of plastic waste enhances the environmental profile of these bricks by reducing the demand for virgin materials and diverting plastic waste from landfills.

The resulting high-performance bricks offer a more environmentally friendly and adaptable alternative to traditional building materials by utilizing the advantages of geopolymerization and combining plastic waste. The carefully planned mixture, together with meticulous processing and curing, results in bricks that have a variety of desired features, advancing environmentally friendly and effective building techniques.

## 4 Benefits and Challenges

### 4.1 Benefits of the Proposed Approach

The integration of geopolymerization and plastic waste in the production of high-performance bricks offers a range of benefits:

- **Plastic Waste Diversion:** By repurposing plastic waste as a valuable resource in construction materials, the approach contributes to reducing the accumulation of plastic waste in landfills and oceans, addressing a significant environmental challenge.
- **Resource Efficiency:** Geopolymerization consumes fewer natural resources compared to traditional cement production methods. The

incorporation of plastic waste further extends the efficient use of materials.

- **Reduced Carbon Emissions:** Geopolymerization generates significantly lower carbon emissions compared to conventional cement production, aligning with climate change mitigation efforts.
- **Enhanced Brick Properties:** The incorporation of plastic waste can potentially improve the mechanical, thermal, and fire-resistant properties of bricks, resulting in materials that surpass the performance of conventional alternatives.
- **Economic and Environmental Advantages of Circular Economy Integration:** The proposed approach exemplifies circular economy principles by repurposing plastic waste as a resource, thereby reducing the need for virgin materials. This can lead to cost savings and reduced environmental impact in the long term.

### 4.2 Challenges to Address

However, this innovative approach also presents challenges that require careful consideration:

- **Quality Control:** Ensuring consistent quality across batches of geopolymer-based bricks is essential for construction applications. Variability in plastic waste properties and mixing conditions could impact the final product's performance.
- **Process Optimization:** The geopolymerization process needs optimization to achieve desired material properties consistently. Adjustments to factors such as curing time, temperature, and mixing ratios may be necessary.
- **Environmental Considerations:** While using plastic waste is beneficial, potential concerns related to the release of microplastics or other pollutants during the lifecycle of the bricks should be evaluated and mitigated.
- **Market Acceptance:** Introducing innovative construction materials into the market can face resistance due to established practices and perceptions. Convincing stakeholders about the viability and benefits of geopolymer-based bricks may require education and demonstration.

Collaboration between scholars, business leaders, legislators, and other stakeholders is necessary to address these issues. The building industry can fully realize the benefits of geopolymerization with plastic waste integration and contribute to a more sustainable built environment by creating strategies and solutions to overcome these barriers.

In conclusion, there is a lot of potential for sustainability and performance improvement with the suggested strategy. Despite the substantial advantages, the difficulties highlight the demand for a thorough and diverse approach to research, development, and implementation. The construction sector may utilize the benefits of the circular economy, technological advancement, and ethical waste management via coordinated efforts to open the door for a more robust and sustainable future.

# 5 Conclusion

In the journey towards a more sustainable and environmentally conscious construction industry, the intersection of geopolymerization and plastic waste utilization offers a promising avenue. This paper has delved into the intricacies of this innovative approach, revealing both its potential benefits and the challenges that lie ahead.

## 5.1 Recap of Key Points

We examined the circular economy's significance to building throughout this study, highlighting the necessity of resource efficiency and waste minimization. Because geopolymerization can produce robust and long-lasting inorganic polymers, it has emerged as a transformational technique that can reshape the manufacturing of materials. We solved the urgent problem of plastic pollution while releasing improved qualities for high-performance bricks by mixing plastic trash into this procedure.

## 5.2 Significance of the Circular Economy Approach

The construction sector will greatly benefit from the circular economy strategy proposed here. It exemplifies the transition from a closed-loop system of linear resource consumption to one in which waste is used as a resource and sustainability becomes the primary concern. By rethinking building in this way, we can reduce our influence on the environment, make the best use of our resources, and promote a healthier world.

## 5.3 Call to Action

A definite call to action appears as we come to the end of this investigation. There is no denying the promise of geopolymer-based high-performance bricks. Realizing this promise, however, necessitates teamwork across several sectors. First, further study is necessary to improve the geopolymerization process and ensure its consistency in quality and performance. To overcome obstacles and discover new opportunities, this calls for cooperation between scientists, engineers, and business professionals. Second, innovation and progress need to coexist. This idea has to gain support from producers, decision-makers, and investors if it is to be successfully incorporated into the mainstream building industry. This calls for a setting that encourages testing, scaling up, and piloting. Finally, achieving measurable benefits requires execution. These high-performance bricks should be embraced by building businesses, designers, and architects as a practical substitute. They help create greener structures, less plastic waste, and a more sustainable future by doing this. The combination of geopolymerization and the incorporation of plastic waste, in conclusion, reflects the spirit of development and sustainability that the times need. We can open the door for a construction business that not only produces structures but also develops a better society by utilizing the potential advantages, overcoming difficulties, and jointly adopting this strategy. The road has started, and the goal is a future that is sustainable.

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