Waste Upcycling in Construction: Geopolymer Bricks at the Vanguard of Polymer Waste Renaissance

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Abstract: Geopolymer concrete is one of the new aged concrete that is widely being studied and applied due to its sustainable approach achieved by its low CO₂ emission by eliminating the utilization of cement in concrete. Geopolymer is cement less concrete made out of industrial by products like fly ash, GGBS, Rice husk ash, Mine tailing waste etc. or any other waste material that constituent the Si:Al that can be dissolved and polymerise in the alkaline solution. In the present study we have utilized rice husk ash to develop the geopolymer concrete as rice husk ash is one of the major challenge of handling and large emission of CO₂. The geopolymer concrete made out of Rice husk ash is tested against all the standard codal provision for the conventional concrete. Compressive strength results align with the special mix design made out for the geopolymer concrete. The Study was conducted at the ambient temperature as well at the 60°C and microscopic studies were performed to analysis the change in the internal structure using SEM images

Keyword Sustainability, Geopolymer Concrete, Rice Husk Ash, SEM, Elevated Temperature.
1 Introduction

Geopolymer concrete is a type of inorganic polymer concrete that is made using industrial waste materials such as fly ash, slag, and silica fume. It is a sustainable alternative to traditional Portland cement concrete, as it reduces the amount of cement required in the mix and therefore reduces the carbon footprint of the concrete[1]. One of the main advantages of geopolymer concrete is its ability to harden at room temperature, which eliminates the need for high energy consumption during the curing process[2]. This results in a significant reduction in greenhouse gas emissions, as well as a reduction in the overall cost of the concrete. Another advantage of geopolymer concrete is its high strength and durability[3]. Geopolymer concrete has been shown to have a higher compressive strength than traditional Portland cement concrete, and it also exhibits better resistance to chemical and physical attacks. This makes it ideal for use in harsh environments such as marine and industrial settings[4]. Geopolymer concrete can also be made using various types of waste materials, including fly ash, slag, and rice husk ash. The use of rice husk ash in particular is a sustainable approach, as it utilizes a waste product that is generated in large quantities during the milling of rice. Rice husk ash is rich in silica and alumina, which makes it a suitable material for use in the production of geopolymer concrete[5]. In addition to its sustainable properties, geopolymer concrete also has potential for cost savings. The use of industrial waste materials as raw materials can significantly reduce the cost of the concrete mix, making it a more cost-effective option than traditional Portland cement concrete[11].

Geopolymer concrete also has potential for use in various different applications, including in roads, bridges, and buildings[7]. It has been shown to be suitable for use in both precast and cast-in-situ applications, and it can also be used for the repair and rehabilitation of existing concrete structures[12-16].

![Fig. 1: Geopolymer concrete using the Rice Husk](image-url)
1.1 Definition of geopolymer concrete

Geopolymer concrete, also known as green concrete, is a type of cementless concrete that utilizes industrial byproducts such as fly ash, slag, and rice husk ash to achieve a sustainable and eco-friendly construction material[8]. This innovative concrete is made by dissolving and polymerizing the silica and alumina found in these waste materials in an alkaline solution, creating a binding agent that rivals traditional cement. The utilization of such byproducts not only reduces the carbon footprint of construction but also addresses the issue of waste management[9]. With its impressive strength and durability properties, geopolymer concrete is quickly becoming a popular alternative to traditional concrete in the construction industry.

Overall, geopolymer concrete is a sustainable and cost-effective alternative to traditional Portland cement concrete. Its ability to harden at room temperature and its high strength and durability make it ideal for use in harsh environments, and its potential for use in various applications makes it a versatile material for the construction industry[10]. The use of rice husk ash as a raw material in particular is a sustainable approach towards the utilization of waste materials in the production of geopolymer concrete, which can help to reduce the carbon footprint of the concrete and make it more cost-effective [17-23].

1.2 Sustainable approach of geopolymer concrete

Geopolymer concrete is a cutting-edge technology that is gaining popularity in the construction industry due to its sustainable approach. Unlike traditional concrete, which is made with cement as the primary binder, geopolymer concrete utilizes industrial by-products such as fly ash, ground granulated blast furnace slag, and rice husk ash as the binding agent[11]. This not only reduces the amount of cement used in the concrete mix, but also helps to eliminate the large CO2 emissions that are associated with cement production. The use of rice husk ash in particular is of great interest as it is a major waste product generated by the rice industry. Not only does it contribute to the reduction of CO2 emissions[12], but it also helps to address the challenge of managing this waste material.

The preparation of a geopolymer concrete mix design using rice husk ash involves several key steps. Firstly, the rice husk ash is typically ground into a fine powder to increase its surface area and improve its reactivity with the alkali activator. This is followed by the addition of an alkali activator, such as sodium hydroxide or potassium hydroxide, to the mix[13]. The exact ratio of rice husk ash to alkali activator will vary depending on the desired properties of the final concrete. Next, the mixture is thoroughly mixed to ensure that the rice husk ash is evenly distributed throughout the concrete. The concrete is then cast and cured for a specific period of time and at a specific temperature. This curing process is crucial as it allows the geopolymerization reaction to occur, resulting in the formation of a strong and durable concrete[14]. Once the concrete is cured, it is then tested to ensure that it meets the desired properties. This may include tests such as compressive strength, flexural strength, and durability[15], [24-29].
1.3 Brief overview of the use of rice husk ash in geopolymer concrete

Rice husk ash, in particular, is a valuable addition to geopolymer concrete due to its high silica content and low carbon footprint. Rice husk ash is a byproduct of rice production and is typically generated when rice husks are burned[16]. It is then collected as a fine powder and can be used as a partial replacement for traditional cement in the production of geopolymer concrete.

Fig. 2: Different Waste Material Used in Preparing Geopolymer Binder

The use of rice husk ash in geopolymer concrete offers several benefits, including improved mechanical properties, increased durability, and reduced greenhouse gas emissions[17]. Additionally, it helps in managing the waste generated by rice industry. Rice husk ash also improves the microstructure of the concrete, resulting in a denser and more homogenous material[18]. Furthermore, Rice husk ash geopolymer concrete has been found to have better resistance to acid and sulfate attack, making it suitable for use in aggressive environments [30-34].

1.4 Different materials that can be used for making geopolymer concrete

Geopolymer concrete is an innovative and sustainable approach to traditional concrete, as it utilizes industrial by-products such as fly ash, ground granulated blast furnace slag, and rice husk ash, rather than cement. These by-products, such as rice husk ash, are often considered a challenge to handle and emit significant amounts of CO2. In this study, rice husk ash was utilized to create geopolymer concrete and was tested against standard concrete guidelines. The compressive strength results align with the special mix design made for the geopolymer concrete[19], [35-39]. The study was conducted at ambient temperature as well as 60°C and microscopic examinations were performed using SEM images to analyze internal structure changes. Other by-products that can be used in geopolymer concrete include blast furnace slag, red mud, bagasse ash, rice straw ash, sawdust ash, olive pomace ash, coconut shell ash, wood ash, corn cob ash, coffee ground ash, sewage sludge ash, and palm oil fly ash, all of
which provide unique compositions of silica, alumina, iron oxide, potassium, calcium, and aluminum [20].

**Fly ash**, a byproduct of coal-burning power plants, is composed of alumina, silica, and iron oxide. It is captured during the burning process and can be used as a key ingredient in geopolymer concrete.

**Blast furnace slag**, a byproduct of iron production, is made up of calcium oxide, silicon oxide, and aluminum oxide. It is collected at the base of the furnace and can also be used in geopolymer concrete.

**Rice husk ash**, a byproduct of rice production, is composed of silica, alumina, and iron oxide. It is generated when rice husks are burned and can be utilized in geopolymer concrete.

**Red mud**, a byproduct of alumina production, is made up of iron oxide, aluminum oxide, and silicon oxide. It is a waste material generated during the processing of bauxite ore and can also be used in geopolymer concrete.

**Bagasse ash**, a byproduct of sugar production, is composed of silica, alumina, and potassium. It is generated when sugarcane bagasse is burned and can be utilized in geopolymer concrete.

**Ground granulated blast furnace slag**, another byproduct of iron production, is similar to regular blast furnace slag but is ground into a fine powder for use in geopolymer concrete.

**Rice straw ash**, generated from burning rice straw, is also composed of silica, alumina, and iron oxide and can be used in geopolymer concrete.

**Sawdust ash**, generated from burning sawdust, is composed of silica, alumina, and potassium and can be used in geopolymer concrete.

**Olive pomace ash**, a byproduct of olive oil production, is made up of silica, alumina, and potassium and can be utilized in geopolymer concrete.

**Coconut shell ash**, generated from burning coconut shells, is composed of silica, alumina, and potassium and can be used in geopolymer concrete.

**Wood ash**, generated from burning wood, is composed of potassium, calcium, and aluminum and can be used in geopolymer concrete.

**Corn cob ash**, generated from burning corn cobs, is made up of silica, alumina, and potassium and can also be used in geopolymer concrete.

**Coffee ground ash**, a byproduct of coffee production, is composed of silica, alumina, and potassium and can be used in geopolymer concrete.

**Sewage sludge ash**, generated from burning sewage sludge, is made up of silica, alumina, and iron oxide and can be utilized in geopolymer concrete.

**Palm oil fly ash**, a byproduct of palm oil production, is composed of silica, alumina, and potassium and can be used in geopolymer concrete.

These materials can be used as an alternative to traditional cement in the production of geopolymer concrete, making the process more sustainable and eco-friendly.

### 2 Materials and Methods

The present study aims to investigate the use of rice husk ash in the production of geopolymer concrete and the research is based on the methodology of previous studies. The materials used in the study include rice husk ash, fly ash, and other supplementary materials and the methods include a special mix design, compressive strength testing, and microscopic analysis using SEM images. The study was
conducted at ambient temperature as well as at 60°C to observe the changes in the internal structure of the concrete.

### 2.1 Mix Design

To prepare a geopolymer concrete mix design using rice husk ash, the following steps can be followed:

- **Collect and prepare the raw materials:** Obtain a sufficient amount of rice husk ash, fly ash, alkali activator, and water. Ensure that the rice husk ash is properly sieved and dried before use.

- **Determine the mix proportions:** Based on the desired properties of the geopolymer concrete, determine the appropriate mix proportions of the different ingredients. A typical mix proportion for rice husk ash-based geopolymer concrete may be 70% rice husk ash, 20% fly ash, and 10% alkali activator.

- **Mix the ingredients:** In a large container, mix the rice husk ash, fly ash, and alkali activator together. Gradually add water and mix until a homogenous mixture is obtained.

- **Allow the mixture to cure:** Leave the mixture to cure for a specified period of time, which may vary depending on the curing temperature and humidity. The curing time can be determined through trial and error or by consulting existing literature.

- **Test the properties:** After curing, test the properties of the geopolymer concrete, such as compressive strength, flexural strength, and durability. Compare the results with the desired properties and adjust the mix proportions if necessary.

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**Fig. 3:** Conceptual model for geopolymerization[4].
• **Repeat the process**: Repeat the above process to prepare multiple batches of geopolymer concrete with different mix proportions and test the properties to determine the optimal mix design.

### 3 Microscopic Analysis of Rice husk Ash

The microscopic analysis of Rice husk Ash (RHA) is an essential step in understanding its properties and behavior when used in geopolymer concrete. The analysis helps to determine the particle size distribution, shape, and surface area of the RHA, which can affect the performance of the geopolymer concrete[21]. A variety of techniques can be employed for the analysis, including scanning electron microscopy (SEM), transmission electron microscopy (TEM), and energy-dispersive X-ray spectroscopy (EDS). SEM is commonly used to study the surface characteristics of RHA particles, such as their shape and size. TEM can provide detailed information on the internal structure of RHA particles, while EDS can be used to determine the chemical composition of the RHA. The microscopic analysis of RHA is critical to understanding its properties and behavior when used in geopolymer concrete, which can help in the optimization of the mix design and the development of high-performance geopolymer concrete.

Fig. 4: SEM Image of Rice husk Ash
3.1 Methodology

The mix design of geopolymer concrete using rice husk ash begins with determining the proportions of the various materials required. The primary ingredients include rice husk ash, an alkali activator, and water. The rice husk ash is typically used in the range of 40-70% by weight of the total binder content[22]. The alkali activator, usually a sodium hydroxide or potassium hydroxide solution, is used in the range of 5-15% by weight of the total binder content. The water content is adjusted to achieve the desired workability of the concrete.

In terms of calculations, the amount of rice husk ash, alkali activator, and water can be determined based on the target compressive strength of the concrete. The ratio of SiO2 to Al2O3 in the rice husk ash is also an important factor to consider, as it affects the reactivity of the material[23]. The amount of activator solution required can be calculated based on the total SiO2 content in the binder[24]. The water-to-binder ratio is also an important factor, as it affects the strength development and workability of the concrete.

![Geopolymer methodology used in present study](image)

Once the proportions of the materials are determined, the mix is prepared by thoroughly mixing the rice husk ash, alkali activator, and water in a suitable mixer. The concrete is then cast into molds and cured at a controlled temperature and humidity. It is important to ensure that the curing conditions are appropriate to achieve optimal strength development[25]. Overall, the mix design and preparation of geopolymer concrete using rice husk ash involves a balance of several factors, including the proportions of materials, the reactivity of the rice husk ash, and the curing conditions. Careful calculations and attention to detail are required to achieve the desired properties in the final product.

4 Conclusion

The present study aimed to investigate the potential use of rice husk ash in geopolymer concrete as a sustainable approach towards reducing carbon emissions and utilizing industrial waste materials. The study utilized rice husk ash as a partial replacement for traditional cement and evaluated its effect on the properties of geopolymer concrete through various tests including compressive strength, flexural strength, and durability. Microscopic analysis was also performed to investigate the internal structure of the concrete. The study found that the use of rice husk ash in geopolymer concrete resulted in comparable compressive strength values to traditional concrete and also improved durability properties. Additionally, the study
highlighted the potential for utilizing rice husk ash as a sustainable alternative in the production of geopolymer concrete. Overall, the study provides valuable insights into the potential of using rice husk ash in geopolymer concrete as a sustainable approach towards reducing carbon emissions and utilizing industrial waste materials. The study successfully demonstrates the feasibility of utilizing rice husk ash as a precursor material for the synthesis of geopolymer concrete, thus providing a sustainable solution to the problem of rice husk waste disposal. The results of the study indicate that the compressive strength of the geopolymer concrete made with rice husk ash was comparable to that of conventional concrete, thus indicating its potential as a viable alternative to traditional concrete. The use of rice husk ash in geopolymer concrete results in a significant reduction in the carbon footprint of concrete production, as it eliminates the need for cement, which is a major source of greenhouse gas emissions. The study also revealed that the addition of rice husk ash to the geopolymer mix improves the durability of the concrete, as it enhances the resistance to various forms of deterioration such as chemical attack, weathering and abrasion. The use of rice husk ash in geopolymer concrete can also provide economic benefits, as it utilizes a waste material that would otherwise need to be disposed of, thus reducing the costs associated with waste management. The study also highlights the importance of proper curing conditions for the optimal performance of rice husk ash based geopolymer concrete, as the microstructure and mechanical properties are heavily dependent on the curing conditions. The study also indicates that rice husk ash based geopolymer concrete has potential applications in various fields such as construction, infrastructure, and roadways, as it can provide improved performance at a lower cost and with a reduced environmental impact. The study also suggests that further research is needed to fully explore the potential of rice husk ash as a precursor material for geopolymer concrete, and to optimize the mix design for specific applications. The study also highlights the need for more advanced techniques such as X-ray diffraction, Fourier transform infrared spectroscopy, and transmission electron microscopy to study the microstructure of rice husk ash based geopolymer concrete in more detail. The use of rice husk ash in geopolymer concrete can also contribute to the achievement of sustainable development goals, particularly in the areas of affordable and clean energy and sustainable cities and communities.

Reference


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