# Development of Polymer Composite from Bauxite Residue and Plastic Waste for Sustainable Utilization

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## Abstract

The increasing accumulation of bauxite residue (BR), a by-product of alumina extraction from bauxite ore at Hindalco Industries Limited presents significant storage and environmental challenges. Simultaneously, plastic waste management remains a critical issue for municipalities. This study investigates the potential of utilizing BR and plastic waste to develop Bauxite Residue Waste Plastic Composite (BR-WPC) bricks as a sustainable construction material. The feasibility of using BR with plastic waste was explored in collaboration with the Indian Institute of Technology, Bombay (IITB). The physicochemical, thermal, and toxicity characteristics of BR-WPC bricks were analysed to assess their environmental viability. Additionally, unconfined compressive strength (UCS) tests were conducted to evaluate their structural performance.

Composite samples were prepared with varying BR content (15 %, 20 %, 25 %, 30 %, 40 %, and 50 %) to determine the optimal mix for strength and durability. The study emphasized the minimal leaching potential of these composites, ensuring environmental safety. The water absorption study indicated their hydrophobic nature, i.e., water-resistant properties, making them suitable for use in extreme weather conditions. The UCS test findings showed that compressive strength was around 15 MPa which surpassed the strength standard for Class I bricks (10.5 MPa) as per IS 1077:1992, suggesting that BR-WPC bricks offer a viable solution for sustainable construction while contributing to both industrial waste management and circular economy initiatives.

**Keywords:** Bauxite residue, Plastic waste, Polymer composite bricks, Unconfined compressive strength, Sustainable construction.

## 1. Introduction

Urbanization and industrialization have significantly contributed to economic growth but have also led to the excessive exploitation of natural resources, resulting in substantial amounts of industrial and municipal waste. Among these, Bauxite Residue (BR), a by-product of alumina extraction from bauxite, presents severe environmental and storage challenges due to its alkalinity and potential metal leaching. The specific generation of BR per tonne of alumina from the plants (more than 95 %) which use the Bayer process ranges between 1 and 1.5 metric tonne globally. The Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016 (HOWM Rules 2016) notified by the Govt. of India under the Environment (Protection) 29 Act, 1986, exempts Red Mud from the scheduled category of hazardous waste and instead classifies it as a "High Volume Low Effect Waste" [1]. Similarly, plastic waste accumulation in landfills poses a major problem for municipalities. Traditional waste disposal methods such as landfilling, dumping, and stockpiling are no longer sustainable due to limited space, environmental concerns, and resource depletion.

This study explores an innovative approach to address these challenges by developing bauxite residue–plastic composites using BR as a filler in polymer matrices. Past research has shown the potential of industrial waste as fillers in polymer composites to enhance mechanical properties and durability while preventing harmful leaching [2]. However, limited studies have investigated BR in combination with plastic waste for sustainable applications [3].

The present work focuses on the physicochemical, mechanical, and thermal properties of BR-WPC with varying BR content (15–50 %). Additionally, unconfined compressive strength (UCS) tests and leaching assessments are conducted to ensure the environmental viability of the developed BR-WPC. By transforming industrial and municipal waste into a valuable construction material, this study aligns with sustainable development goals and promotes a circular economy approach to waste management.

## 2. Materials and Methods

### 2.1 Materials

The primary materials used in the study include bauxite residue (BR) and waste plastic. BR, a byproduct of aluminium production, is rich in iron oxide, making it a potential candidate for composite materials. The sample of the BR was collected from the filter feed unit of Hindalco Industries Limited, Belagavi (Karnataka), India. The main chemical composition of the bauxite residue is $Fe_2O_3$, $Al_2O_3$, $SiO_2$, and CaO followed by $Na_2O$, MgO and $K_2O$. Waste plastic, including polyethylene (PE) and polypropylene (PP), was also sourced from the same plant.

### 2.2 Preparation of BR-WPC Bricks

The preparation involved blending BR with different proportions of waste plastic i.e., 15–50 %, followed by moulding and curing processes. Field-scale demonstration of the technology to manufacture recycled polymer composites consists of a pilot plant comprising of a shredder, a mixer cum preheater, and an extruder to obtain the fresh binder filler composite to shred the plastic waste, mix and preheat plastic waste and red mud mixture, and melt the mixture followed by pressing in moulds at the end, respectively. The temperature required for melting depends on the plastics added.

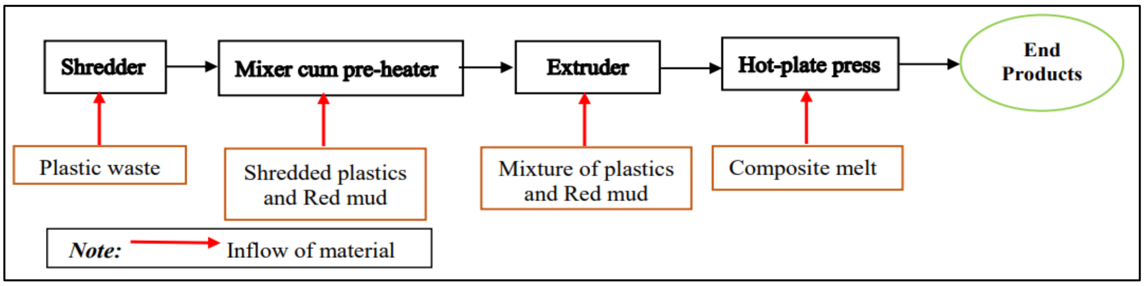


**Figure 1. Flowchart of the BR-WPC production process.**

### 2.3 Testing Methods

#### 2.3.1 Physical Properties

The compressive strength of BR-WPC bricks was observed to be higher than that of conventional clay bricks, making them suitable for load-bearing applications. Figure 9 indicates compressive strength test set-up and Figure 10 shows the results of UCS test.

The UCS of BR-WPC containing 15 %, 20 %, 25 %, and 40 % red mud exceeds 10.5 MPa, thereby meeting the requirement for Class I bricks as per IS 1077:1992 [10]. Notably, the UCS of BR-WPC with 30 % red mud content surpasses the standard for Class II bricks. These findings indicate that BR-WPC exhibits superior compressive strength compared to conventional bricks.

## 4. Conclusion

The study demonstrates that BR-WPC bricks, developed using varying proportions of red mud and waste plastic, exhibit promising physical, chemical, and mechanical properties. The low water absorption confirms the effectiveness of the adopted methodology for making bricks. Long-term batch leaching tests (up to 120 days) reveal significantly lower values of pH, EC, TDS, and salinity in BR-WPC bricks compared to raw red mud, indicating improved chemical stability. ICP-AES analysis confirms that most heavy metals are either undetectable or within permissible limits making this as a non-leachable product. Unconfined compressive strength tests further show that BR-WPC bricks surpass conventional burnt clay bricks in strength, highlighting their potential as a sustainable alternative in construction applications.

The primary objective of this study is the large-scale utilization of bauxite BR accumulated within industrial premises. To achieve this, efforts have been made to develop mechanically and chemically stable materials by converting BR into synthetic aggregates. These aggregates offer significant advantages in terms of bulk utilization, ease of transportation, and long-term durability. Additionally, BR can be employed in the production of paver blocks, which are suitable for direct application in road construction. Furthermore, high-strength composite bricks incorporating BR demonstrating compressive strength sufficient can support the movement of heavy vehicles.

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