

A Comprehensive Review on Red Mud as Construction Material and Its Utilization for Environmental Advantage

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Abstract

There are materials that can help to decrease pollution and disposal difficulties when utilized effectively in civil engineering applications. Red mud, a by-product of converting bauxite into aluminum, collects and occupies an increasing amount of deforested area because of its high alkalinity. With little chance of being used, an estimated 116 tons of red mud are created each year globally, posing a major risk of contamination and pollution. The companies responsible for the waste are left with the most environmental duties arising by this waste of bauxite production. Even though studies indicate that it is possible to use this solid waste in the formulation of ceramic goods, this analysis investigates red mud's potential as a sustainable building material. Red mud is a by-product of aluminum refining process. Because of its availability and the growing demand for sustainable alternatives in the building sector, red mud has attracted attention in recent years. Physical properties, chemical properties, and environmental consequences are examined, as well as some of the potential benefits and drawbacks of using it in construction. The potential of this red mud generated by alumina refinery businesses as a construction material was assessed by analyzing its physical, chemical, and other civil engineering properties. It is the fine-grained residue that is left behind following the extraction of alumina by bauxite. India produces over one crore tons of red mud residues every year, which poses serious and alarming environmental problems. In order to significantly reduce pollution, this red mud may be neutralized. Once neutralized, red mud can be used as an additive and raw material in construction projects.

Keywords: Red mud, road sublayers, materials construction, cement constitution, waste utilization, material properties

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INTRODUCTION

A by-product of bauxite ore for the extraction of alumina by Bayer's method is called red mud. It is caustic in nature and has detrimental influence on nature. It is frequently regarded as a waste substance that presents disposal issues. However, in an effort to lessen red mud's negative environmental effects and provide this waste product some additional value, researchers have been looking at methods to use it for the variety, including as building materials. In study papers on construction materials, scientists usually evaluate the viability for addition of this mud to different building materials, including asphalt, concrete, and bricks.

The following are some topics that these reviews often touch on. It is crucial to remember that red mud construction materials are still being researched, and there may have been new advances.

The building sector is under growing pressure to implement sustainable practices, which is driving research into substitute materials. One such substance that has potential uses in building is red mud, which is extracted from the Bayer process of the manufacturing of alumina. This section gives a summary for production of red mud worldwide and explains why it is being considered for use as a building material (Figure 1) [1–7].

Chemical Composition and Physical Properties

This section examines the different elements and compounds that make up red mud's chemical composition. The physical characteristics are also looked at, including porosity, density, and particle size. Comprehending these characteristics is essential in determining the material's appropriateness for various building uses [8–12].

Mechanical and Thermal Properties

Red mud's mechanical and thermal characteristics must be thoroughly examined in order to assess the material's structural performance. In order to provide light on the structural integrity and thermal behavior of red mud-based materials, this section analyzes research that look at their compressive strength, tensile strength, and thermal conductivity [13, 14].

A strong alkaline solid waste known as bauxite residue is released during the industrial alumina manufacturing process [1]. Rich iron (III) oxides, which makes about 20% to 40% of the bulk of bauxite residue, give it its red color [2]. Red mud is its popular moniker, and this feature explains why [3]. About 1.5 tons of red mud are released for every 1 ton of alumina produced [4]. Based on available data, the total amount of red mud in the world's stock was close to 4 billion tons in 2015 [5], and production increased by around 150 million tons annually [6, 7]. More than 0.6 billion tons of red mud are stored in China, of which 88 million tons are released annually [8].

Construction Applications

The various uses of red mud in construction are examined in this section, including its usage in bricks, concrete, and road building. The viability and effectiveness of red mud-based products in practical settings are demonstrated via case studies and experimental findings.

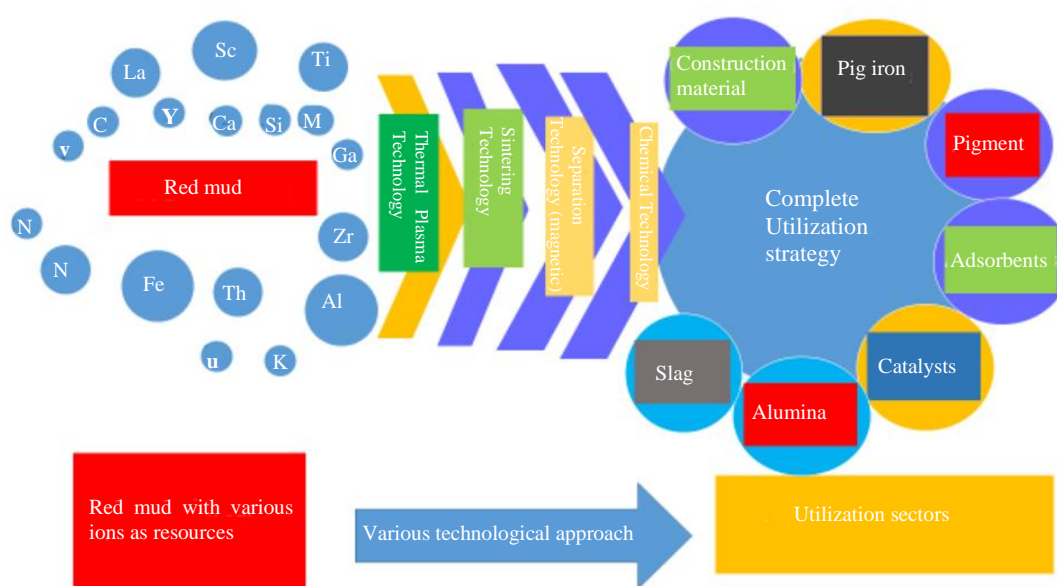


Figure 1. Significance of red mud.

Environmental Impact and Sustainability

This section evaluates the carbon footprint, energy consumption, and waste reduction possibilities of red mud construction as it relates to the environment. The overall sustainability of red mud-based alternatives is demonstrated through comparisons with conventional building materials.

Challenges and Future Directions

This section addresses the obstacles that come with using red mud in construction, including possible pollutant leaching, regulatory concerns, and unpredictability in red mud qualities. It is suggested that additional research and development be done in order to overcome these obstacles and improve red mud's usefulness as a building material.

The potential of red mud, a by-product of aluminum processing, as a sustainable building material is investigated in this review study. Because of its availability and the growing demand for sustainable alternatives in the building sector, red mud has attracted attention in recent years. The study explores the chemical makeup, physical characteristics, and environmental effects of red mud, emphasizing both the advantages and disadvantages of using it in building.

Advantages of Red Mud

- There is betterment of environment.
- Red mud is used for improving the soil quality.
- Saving in energy requirements in the production of ordinary Portland cement (OPC).
- Economic advantage.

Applications

- Red mud is applied as supplement to the source of silica, alumina, and calcium that improves the setting time, quality characteristics, and separation of slag.
- Red mud consists of kaolin, which is used for the preparation of low-cost ceramic tiles for floors.
- Red mud has low cost as compared to cement.
- Raw material in cement production.
- It is applied in brick manufacturing.
- It is applied as a corrosion inhibitor.

LITERATURE REVIEW

The dry and fly ash specimens' intercept of cohesiveness and angle of shearing resistance. He stated that the dry specimen is the primary cause of the 100% loss of cohesiveness, and the resistive shearing angle remains unchanged. Their research also focused on substituting ash in ratios of 5%, 10%, 15%, and 20% for cement. Their experiment, conducted without the use of admixtures, found that a 10% ash concentration yields more strength than other ratios. A higher ash percentage results in a lower strength and a higher water need. They also carried out an experiment to determine the rheological characteristics of concrete. Every property was acknowledged to have met the requirements for 50% and 55% of replacement.

Singh et al. [9] researched the substitution of cement with ash in ratios of 5%, 10%, 15%, and 20% without the use of admixtures. They found that the 10% ash content provides more strength than the other ratios. A higher ash percentage results in a lower strength and a higher water need. Their study covers all of the hardening characteristics as well as the adaptable and flexible strength of HVFAC using prisms and cubes with replacement rates of 35%, 50%, and 75%. As a result, they found that there were an average of 12 cost overruns for every 50 replacements.

Akarsh [10] investigated the possibility of red mud replacing cement. On the other hand, because of storage issues, garbage has an impact on the globe. Cement was pushed 40% of the cement's weight into the red soil to address this problem. Similar to clay concrete's compressive, tensile, and ductile

strengths, the proprietary concrete was assessed. This study demonstrates how adding clay to concrete improves its qualities.

McLaren et al. [11] showed ash to have a somewhat lower precise gravity than soils. When used as different filler materials, the ash fills' decreased density might be a big benefit. These days, fillers are frequently used in the spongy wall sand ridges, especially in cases when inspiration is poor.

The red mud might be used in geoenvironmental engineering projects by stabilizing it with gypsum and lime. Different amounts of lime (2%, 4%, 6%, and 8%) are mixed with gypsum (1% and 2%) to make a load of dried red mud. In order to observe the effects of long-term curing at temperature, thirteen samples were made and stored for 1, 3, or 7 days. The UCS test and CBR (wet and unsoaked) tests were run. They were able to do this by increasing the wet and unsoaked CBR by 939.62% and 302.36%, respectively, by adding 6% lime and a little amount of gypsum to red mud. Moreover, UCS increases by 193.71%, 494.41%, and 668.05% at the 1, 3, and 7-day cure periods.

Parlikar et al. [12] have come to the conclusion that there is no method for using large amounts of clay that is both ecologically sound and commercially feasible. Research and study on metal speciation are desperately needed, as are any improvements pertaining to the reuse of red mud for building purposes and through wet pond storage.

Rout et al. [13] have investigated the properties of clay using finite element analysis and laboratory testing in order to prepare it for usage as a subgrade in pavement building. The necessary geotechnical characteristics were looked at for this objective. Engineering properties and index properties are established. In order to assess red mud's stability as a subgrade material, model footing tests were also carried out in laboratories. The Mohr-Coulomb model is used for finite element analysis using PLAXIS, and as a consequence, the outcomes of the laboratory model tests and finite element analysis are contrasted. Based on numerical and experimental research, they came to the conclusion that red mud is the industrial waste generated when aluminum is extracted from bauxite. Every year, over 75 million tons of red mud are generated.

UCS, CBR, and compaction strength at addition of cement kiln dust exhibited a better value up to eight and further addition does not play a critical part in boosting strength. It was concluded with stabilizing red mud and cement kiln dust approximately (2%, 4%, 6%, 8%, 10%, 12%).

The possibility that the increased weight of neutralized red mud and finer mud particles, which fill the spaces in the cement and perhaps raise the combination's density, are also responsible for the reduction in the first setting time at 5% and 10%. Because of a decrease in mixture density, neutralized clay cement might expand by up to 10% of the initial setting time. The impact of substituting neutral clay for cement in planned mix concrete of grade M50 has been investigated. According to traditional economic theory, neutral clay concrete has a value of 15% replacement, whereas ordinary concrete has a value of about 13.7. There is a nominal decrease in compressive strength.

The characteristics of concrete that has solidified. The test findings demonstrate how the amount of red mud affects the material's compressive strength and splitting durability, leading to the conclusion that a 25% weight replacement of cement is the ideal amount. We shall have strength sufficient to match the strength of controlled concrete by this replacement.

Process of Red Mud

The majority waste produced by the Bayer process is called red mud, which is created when a reaction occurs between sodium hydroxide and bauxite ores. This procedure involves separating alumina from

undesirable elements such as iron, calcium, titanium, silica, etc. Here, bauxite is burned in conjunction with caustic soda to a pressure of around 30 atm, which forms sodium aluminate.

Research Gap

As was previously said, research is crucial in this. Until the replacement with cement, cement mortars, fly ash, and ground granulated blast furnace slag (GGBS) is thoroughly investigated. Red mud has been the subject of investigations on its mechanical, physical, and durability characteristics.

Research Significance

When comparing self-compaction concrete (SCC) to conventional vibrated concrete, SCC often performs better. Red mud may be added to SCC to boost these qualities, producing high strength red mud self-compacting concrete (HSRMSCC). It is possible to increase strength characteristics like flexural strength, split tensile strength, and compressive strength. The effect of red mud on the structures are significant, and much research has been done on the mechanical and physical durability features of high strength self-compacting concrete.

CONCLUSION

Currently, a particular technology is used in research on the application of red mud in low value-added building materials, road construction materials, and other disciplines. This technology is utilized in practice and yields specific results. An essential technique that makes the use of construction materials and road building materials practical is red mud de-alkalization, which directly affects the product's quality. In the realm of environmental remediation, red mud may also be utilized as a restorative material to cure inorganic and organic contaminants in waste liquid or soil. The previously proposed red mud treatment scheme has several benefits over the valuable components of extracting high value-added products from red mud, including low cost, easy method, and high industrial feasibility.

The outcomes for this replacement process are almost equal to those of the control concrete, and the ideal amount of cement replacement by weight is determined to be 25%. It has been observed that the concrete's durability and compressive strength decline with increasing red mud and ash concentration. Red mud-prepared concrete has an attractive look and is appropriate for decorative applications. According to the literature evaluations mentioned above, the ideal proportion of red mud ranges from 5% to 20%. Concrete's compressive strength, split tensile strength, and flexural strength have all improved up to this percentage replacement when red mud has been partially substituted for cement.

1. Red mud is a mixture of calcium, aluminum, and silica from bauxite ore.
2. Red mud's physical, mechanical, and durability qualities suggest that only a limited fraction of its output is used for building materials and for construction purposes.
3. Mixing super plasticizers may affect the workability of the concrete with the increasing the amount of red mud.
4. The free water in the concrete mix is decreased by every tiny part of red mud. Red mud holds onto water better.
5. The amount of this decreases as base layer of road increases linearly.
6. In cement mortars, the red mud acts as a reactive ingredient.
7. Because of the hydraulic nature of red mud, its presence quickens the hydration process.

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