

Study of Red Mud as an Alternative Building Material for Interlocking Block Manufacturing in Construction Industry

Achal Garg^{1*}, Harinder Yadav²

¹ Keppel Offshore and Marine Engineering India Pvt. Ltd, Mumbai, Crystal Palace, Maharashtra, India.

² University of Petroleum and Energy Studies, Dehradun, Energy Acres, Uttarakhand, India.

* Corresponding author. Tel.: +91-9833251070; email: achalgarg_1992@yahoo.com

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Abstract: Before the end of the decade of the 1980's red mud became a major concern in world environmental discussions. Red mud is a solid waste product of the Bayer process, the principal industrial means of refining bauxite in order to provide alumina as raw material for the electrolysis of aluminum by the Hall-Heroult Process. Red mud is composed of a mixture of solid and metallic oxide-bearing impurities, and presents one of the aluminum industry's most important disposal problems. The alumina industry is facing an important problem regarding the settling or separation of red mud during the production process as it not only affects the productivity of alumina but also its purity. Red mud cannot be disposed of easily and in most countries where red mud is produced, it is pumped into holding ponds. The utilization of red mud is of great significance from the point of view of resource conservation & sustainability of the aluminum industry. The direction of the researches undertaken to utilize red mud are based on their chemical, mineralogical and physical properties. There is an effective way of utilizing alumina red mud to make bricks. Only slight modification in the composition of red mud is required which can be done by incorporation of siliceous materials and admixtures. This paper aims at studying the behavior of interlocking blocks manufactured by using red mud for different variables. In this paper, the author is attempting to summarize the potential application of red mud in building materials industry and using the appropriate model of its utilization. The attention is to develop an extensive red mud utilization policy framework for building materials industry in the context of India as it has great potential of reducing the cost of construction material & developing a low cost housing technique considering the preservation of our environment.

Key words: Red mud, construction material, interlocking blocks, industrial waste.

1. Introduction

Though the existence of aluminum was first established in the year 1808, it took almost 46 years to make its production commercially viable. The research work of several years resulted in extracting the aluminum from the ore. Currently it is also the second most used metal in the world after steel. Due to the consistent growth of Indian economy at a rate of 8%, the demand for metals, used for various sectors, is also on the higher side. As a result, the Indian aluminum industry is also growing consistently. The production of aluminum started in India in 1938 when the Aluminum Corporation of India's plant was commissioned.

India is world's fifth largest aluminum producer with an aluminum production competence of around 2.7 million tones, accounting almost 5% of the total aluminum production in the world. India is also a huge reservoir of Bauxite with a Bauxite reserve of 3 billion tones. India lies at the eighth position in the list of leading primary aluminum producers in the world.

Red mud is the by-product of the manufacture of alumina from bauxite by the Bayer process. World production of aluminum is 15 MTPA provided from about 30 MTPA of alumina produced from 50 MTPA of bauxite which give approximately 30 MTPA red mud. The production rates of red mud depend on the origin of the bauxite. From Surinam bauxite, 0.33 tons of red mud is produced per ton of alumina, while the production of red mud from Jamaican bauxite is one ton per ton of Al₂O₃ and from Arkansas bauxite it is two tons per ton of Al₂O₃ [1]. In spite of the efforts to utilize red mud, most of the residue remains unused and the disposal of the discarded red mud is a great environmental problem for two main reasons. The first is the toxicity due to the high pH (caustic soda). The second reason is the volume of the residue. Every ton of alumina produced leaves about 1 ton of solid residue in suspension and 4 tons of slurry.

2. Aluminum Industry at a Glance

The production of aluminum started in India in 1938 when the Aluminum Corporation of India's plant was commissioned. The plant which was set up with a financial and technical collaboration with Alcan, Canada had a capacity of producing 2,500 ton per annum. Hindustan Aluminum Company was set up in Uttar Pradesh in the year 1959; it had a capacity of producing 20,000 ton per annum. In 1965; by 1987, National Aluminum Company was commissioned to produce aluminum. It had a capacity of producing 0.218 million ton. During the 1970s, the government started regulating and controlling the Indian aluminum industry. Restrictions in entry and price distribution controls were quite common in the Indian aluminum sector. However, in 1989, the order was removed as the government decontrolling was revoked. With de-licensing of industry in 1991, the liberal import of technologies and capital goods was started. The liberalization resulted in a growth rate of 12% of the industry, comparing to the growth rate of 6% during the 1980. India saw a significant growth in aluminum production in the past ten years. Due to the growing demand from the construction, electrical, automobiles and packaging industry, the production of aluminum also hiked up. The most commercially mined aluminum ore is bauxite, as it has the highest content of the base metal.

The primary aluminum production process consists of three stages. First is mining of bauxite, followed by refining of bauxite to alumina and finally smelting of alumina to aluminum. India's share in world aluminum capacity rests at about 3%. The aluminum production process can be categorized into upstream and downstream activities. The upstream process involves mining and refining while the downstream process involves smelting and casting & fabricating. Downstream-fabricated products consist of rods, sheets, extrusions and foils. Power is amongst the largest cost component in manufacturing of aluminum, as the production involves electrolysis. Consequently, manufacturers are located near cheap and abundant sources of electricity such as hydroelectric power plants. Alternatively, they could set up captive power plants. Indian manufacturers are the lowest cost producers of the base metal due to access to captive power, cheap labour and proximity to abundant supply of raw material, i.e., bauxite.

The per capita consumption of aluminum in India continues to remain abysmally low at 1.2 kg as against nearly 15 to 18 kg in the western world and 10 kg in China. This offers significant upside potential. The key consumer industries in India are power, transportation, consumer durables, packaging and construction. Of this, power is the biggest consumer (about 48% of total) followed by infrastructure (20%) and transportation (about 10% to 15%). The metal has a long working life due to its propensity for recycling. Recycled metal requires significantly less amounts of energy for manufacturing of primary aluminum. Just

to put things in perspective, the recycling of aluminum scrap requires 5% of the energy required for primary smelting, which is astoundingly lower [2], considering that power is such a high cost component.

3. Red Mud Disposal

Bauxite is a heterogeneous material composed mainly of aluminum hydroxide minerals. The principal impurities common to nearly all known deposits of bauxite are aluminum silicates (clays), iron and titanium oxides. The quantity of impurities varies from one deposit to another as does the proportion of tri-hydrates to monohydrates. Bauxite deposits are essentially old soil and occur in a variety of geological and geomorphic situations. These deposits are products of the erosion of lateritic-bauxite deposits, are transported to the area, and are then overlain on the eroded surface of alumina-silicate rocks. The most important reserves of bauxite are Guinea, Australia, Brazil, Vietnam, India, and Jamaica. Although a large number of methods to produce alumina have been developed on a laboratory scale, most of the commercial production of alumina is obtained by the Bayer process or a modified version. Patented by Karl Bayer in 1888, this process consists of leaching bauxite with caustic soda at elevated temperatures and pressure. The products of this reaction are a solution of sodium aluminate and an insoluble red mud residue which is removed by decantation and filtration. The pure sodium aluminate solution is then cooled and seeded with crystals of alumina hydrate. Although retains some characteristics of the mother bauxite, red mud is somewhat different because of the chemical and physical treatments. The alumina industry is facing an important problem regarding the settling/separation of red mud during the production process. The settling/separation of red mud not only affect the productivity of alumina but also its purity. Quick-settling red mud permits an effortless filtration process for producing high purity alumina. The red mud slurry is usually discharged into sealed or unsealed artificial or natural areas. The impoundment areas include deep ponds, tailing dams and dykes, stacking and 5% slope mud stacking [3] by solar drying. Most of the storage areas are lined with impervious earth or plastic liners, but the possibility of seepage or leakage still exists. The environmental impact of red mud disposal could come from the seepage of the alkaline solution into the ground water which may result in contamination affecting industrial, domestic and agricultural water suppliers. It could also come from the vast area of land used for mud disposal, or from dust pollution generated from the dried surface of the pond.

4. Utilization of Red Mud in Manufacturing of Building Materials

The directions of the researches undertaken to utilize red mud are based on their chemical, mineralogical and physical properties. Red mud contains alumina, iron and titanium oxide and it is thermodynamically possible to recover the metals. Red mud can be added to blast furnace as poor iron ore or reduced to titanium recovered by chlorination. Titanium can also be obtained by precipitation of hydroxide and aluminum as sulphate. Other processes allow minor elements such as V, Zr, and Mo to be extracted. The reduction process to recover iron produces a slag which can be used in cement directly or, after recovery of soda and alumina [4] by a leaching process. Until recently, none of these processes were economically feasible. The production of absorbents to remove sulphur dioxide from industrial effluents has been proposed as an application for red mud. Ceramic materials can be made from the mud, but the quantity of this utilization is limited. Red mud is used as filler in mortars based on bitumen and other resins. A filler was developed for use in bituminous road construction and in plastics and a road surface of 6,00,000 m² with 2500 tons of red mud filler [5] have been constructed. Red mud is also used in rubber and plastic products, as an artificial aggregate in concrete and bricks or, by addition to raw mix of cement to modify its properties particularly, its color. The production of cements by addition of lime, fly ash, gypsum has also been proposed. Red mud has been recommended as an additive to cement to improve its strength and

modify its setting behavior.

Red mud is used in two ways, either in the production of ordinary Portland cement as a source of iron oxide or alumina, or in the raw mix of special cements. Red mud is a good source of Fe₂O₃ for cement raw mix, but modifies somewhat the microstructure of the clinker. Using red mud for the production of bricks is a simple and economical method to utilize this waste material. There are two basic processes. The first requires that the red mud be pressed into blocks and fired at high temperatures. The second process mixes the red mud with binders and makes use of either hydraulic hardening, or firing at low temperatures. The addition of red mud to concrete leads to modification of the properties. The addition of red mud, replacing 30% of sand exhibits higher strengths than concrete with quartz aggregates for in built-in piles and have a better durability [6] than standard concrete in defined conditions. Addition of slag to red mud and firing improves the crushing strengths of the aggregates and decreases the sintering temperature [7]. A great demand exists in the construction industry for lightweight aggregates which have density less than 0.88 g/cm³.

5. Results and Discussions

The average chemical composition of red mud and fly ash in percentage weight used for the study is shown in Table 1. A three component raw materials consisting of red mud, fly ash and stone dust were mixed in a high speed mixer. The homogenized mass was made into slurry with water, cement and foaming agents and molded in to blocks of different size and shape in an interlocking block manufacturing machine. The red mud blocks are then cured for 7 days to achieve the maximum strength. An ideal composition range of 30-50% red mud, 20-40% fly ash and 10-20% stone dust with 5-10% cement and 0.25-1% foaming agents in red mud interlocking blocks were derived from experimental trials. The compressive strength of interlocking block is determined in order to verify whether it conforms to IS specifications and whether it will be able to develop the required compressive strength against maximum loading.

Table 1. Average Chemical Composition of Red mud in Percentage Weight Used for the Study

S. No.	Major Constituents	Red mud (%)	Fly ash (%)
1.	Fe ₂ O ₃	35-70	3-7
2.	Al ₂ O ₃	10-20	17-35
3.	SiO ₂	3-7	40-60
4.	TiO ₂	2-6	0.5-2
5.	Na ₂ O	2-5	-
6.	CaO	0.5-4	-
7.	Loss on Ignition (LOI)	6-10	-

The interlocking blocks made of red mud have tongue and groove profile to form interlocking masonry and the interlocking shear key makes masonry earthquake resistant. These interlocking blocks facilitate speedier, cost-effective and greener construction requiring no post construction works. These blocks can be manufactured on the construction site itself, avoiding multiple handling and transportation and compatible for both load bearing and in-fill applications. These interlocking blocks and masonry are compatible for green buildings also and provides greater flexibility to alter density and compressive strength to suit the project requirements. These blocks have exposed brick finish requiring optional plaster and the beveled edge blocks ease handling and smooth flow of rain water on wall face.

6. Industrialization Opportunities in Manufacturing of Interlocking Blocks

Burnt bricks are the most popular building materials in India. Even with the advent of alternate technologies and materials, bricks will continue to remain as the most preferred choice for wall construction. Brick industry all over the country is currently based on decentralized production activity

using energy intensive, resource depleting and highly polluting technologies. The initial demonstration kilns were constructed and operated by lead agencies under controlled conditions so that the technology absorption and adaptation could be implemented. This caution was necessary, as premature mutilation of technology by private entrepreneurs in other countries had adversely affected the success of the technology transfer process. In India currently more than 14,000 crore bricks are produced per year with increasing growth. The per capita consumption of bricks in the country is around 150 bricks. The industry employs more than 60 lakhs of people which is seasonal. It consumes more than 24 million tons of coal which is approximately 8% of the total coal consumed in India. Additionally it also uses 5-10 million tons of biomass leading to large scale deforestation. In spite of such large scale operation it is classified under the unorganized sector. The brick sector especially small scale brick entrepreneurs are confronted with environmental regulation and face numerous challenges for its survival; such as high air pollution, environmental degradation and the problem of environmental compliance and inadequate engagement between regulatory agencies and brick associations.

There is a growing demand for the interlocking blocks and with the increasing pace of industrialization it is going to increase since these blocks are the major materials for infrastructural development. The need of the hour is to adopt a cluster development approach of hydraulic pressed interlocking block manufacturing establishment through successful demonstration of waste material utilization. This will not only help in making available infrastructural materials but also reduce environmental pollution by utilizing the waste materials being generated. Intimate relation between Department of Industry, building material associations, manufacturers, financial institutions, waste producing industries and technology promoters are necessary in providing technical support and facilitate solutions for optimizing the scale of production and make the production process user friendly.

7. Conclusion

It is envisaged that the utilization of red-mud bricks in urban housing and construction activities will lead to substantial reduction in the total weight of walls and partitions in multi-storied buildings, thus reducing the foundation costs and total building costs. The presence of all through tiny air filled cells provides excellent acoustic performance and they are highly suitable for partition walls, floor screens and panel material. The low thermal conductivity of red-mud bricks provides low thermal exchange between inner and outer atmospheric conditions. Hence, it helps in reducing the energy consumption. The lightness and irregular porous structure in the material increases resistance against earthquake and causing less chance of loss/damage to human lives. The utilization of red mud is of great significance from the point of view of resource conservation and sustainability of the aluminum industry. However, the reuse of red mud for any application should have four criteria of volume, performance, cost and risk.

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Mr. Achal Garg (corresponding author) is currently working as a Structural Engineer at Keppel Offshore & Marine Engineering, Mumbai. He has attained his Bachelor degree in Civil Engineering from University of Petroleum and Energy Studies and continuing studies in operations management. He worked on various projects of low cost housing and alternative building materials focusing on the needs of developing construction industry. He has published 12 research papers in leading national & International Journals. He is also associated with People's Empowerment & Development Society, Uttar Pradesh and IGET, Pune. He is a member of American Society of Civil Engineers, society of Petroleum Engineers, Society of Exploration Geophysicists, International Association of Engineers, and International Safety Quality Environment Management Association.



Mr. Harinder Yadav is the co-author, who is currently pursuing civil engineering with specialization in infrastructure development from University of Petroleum and Energy Studies. He has published 10 research papers in leading national and International journals. He has special interest in building construction materials, climate change and project management. He is associated with Global Shapers Hub. Having a work experience with youth organization, he believes that further advanced training in an international setting will enable him to make truly unique contributions in this field.