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ASSESSMENT OF RED MUD AS A CONSTRUCTION MATERIAL: A REVIEW

[1] H.M.Vijaya, [2]T.Samuel Wesly, [3]Prathik Kulkarni
[1,2] Department of Civil Engg, Aurora's Scientific, Technological & Research Academy, Bandlaguda, Hyderabad
[3]Department of Civil Engineering, Pondicherry Engineering College, Puducherry

Abstract-The establishment of many industries results in the large amount of by-products in the form of solid, semi-solid, and liquid as industrial waste materials may be either toxic or nontoxic in nature results, a large damage to the environment. In India, vast network of existing industries spread across the country and many more to come in future, generates millions of tonnes of variety of by-product materials. The pollution and disposal problems can be minimised to greater extent by properly utilising these materials in civil engineering applications. In this review paper, assessment of red mud produced by aluminarefinery industries was reviewed to ascertain its suitability as a construction material from physical, chemical and other civil engineering properties. Red mud is the fine-grained residue left after alumina extracted from the bauxite ore. At present, in India about 10 million tonnes of red mud residue are being generated annually posing very serious and alarming environmental problems. Neutralization of this red mud would be very much use full and reduces the pollution largely and this neutralised red mud could be further used for the construction as admixture and as raw material. Physical, chemical and geotechnical properties of these waste materials have been critically reviewed for this purpose; it is observed that the red mud has the potential to be used as a construction material.

Keywords: Red mud; Waste utilization, Material properties; Construction materials

I. Introduction

Shortage of borrow materials and concern about the use of top soils often demand widespread utilization of industrial wastes/by-products and for sustainable development of infrastructure. The major ill effect of industrialisation is the generation of large volume of by-products or wastes, and these wastes cause an environmental pollution problem in the surrounding disposal area. As such, Red mud is red colour industrial waste slurry insoluble water produced during the alumina production [1].

Out of the total red mud, India contributes about 4% of total world's production, present about 10 million tons of red mud is generated annually [2, 3].

Due to filtration, treatment and disposal of red mud causes the disposal of red mud becomes uneconomical also requires large area for its disposal/dumping of the waste. Closed cycle disposal system,direct disposal system, dry disposal method are the three types of methods adopted in India for the disposal of red mud [4, 5].

Dumping red mud into secured large inland artificial ponds is closed cycle disposal type and is most commonly used and economical. Red mud is directly dumped into seawater and seawater dilutes neutralizes the causticity of the red mud and the iron oxide released into sea water helps the marine life algae, corals and other crawling life system grow at a faster rate. Many of the shore based alumina refineries in the world are continuing with this form of red mud disposal system despite occasional agitations by the environmentalists. Dry disposal method in which the wet slurry undergoes several Stages of filtration and water is separated from it. After that, the dry mud is disposed of as pyramids or dumped at the pond side. The dry mud is covered by cotton soil and requires regular water sprinkling to prevent the metallic dust from polluting the air, livestock and crops around.

Reddy and Rao (2016) [1]-Theutilisation of industrial wastes in infrastructure is essential for developing countries like India for sustainable development.

Power et al. (2011) [2]-Each year, about 120 million tons of red mud is discharged all over the world.

Rai et al. 2012 [3]-About 1.2-1.4 tons of red mud is generated per each ton of alumina produced.

Hind et al. (1999)[4] It is the most improved solution for disposal of red mud. Red mud is very toxic in nature Chemical analysis shows that red mud contains silicon, aluminium, iron, calcium, titanium, sodium as well as an array of minor elements.

II. Physical and Geotechnical Characteristics of Red Mud

About 0.8-2.5 tonne of red mud is generated per tonne of alumina production. In India, it is estimated that more than 10 million tonnes of red mud are being generated per annum from several numbers of aluminium plants [3]. Red mud is highly alkaline in nature with pH ranging from 10.5

[1]Corresponding Author

to 13 because of excessive caustic soda (NaOH) content, which is added during the Bayer's process.

- **Parekh and Goldberger (1976)** [5]Red mud is a residual waste generated during the extraction of alumina from bauxite by Buyer's process.
- **Li (1998) and Rout et al. (2013**) [6, 7] usually, red mud is disposed of into encapsulating facilities in the form of slurry containing about 15 to 40% solids.
- **Gray and Somogyi(1974) andSomogyi and Gray (1977)** [8, 9]

  -Interestingly, in the absence of either quartz or clay minerals, red mud exhibits compression and plastic behaviour similar to that of clay soils and frictional behaviour closer to sandy soils, and many of its geotechnical properties matches with the clayey tailings.
- **Parekh and Goldberger (1976)** [5]Red mud mostly contains fine particles in the range from sand to silt size, but completely free from either quartz or clay mineral constituents. However, geotechnical properties like compaction, consolidation, settlement, shear strength, permeability, etc., are strongly influenced by chemical and mineralogical characteristics of the waste. The properties of red mud are given in Table: 1.

TABLE I**.** Physical and geotechnical properties of Indian red mud's [1, 7, 10, 11]

Property	Typical Values	
Source of material	HINDALCO, Renukoot	NALCO, Damanjodi
Appearance	Fine material	Fine material
Colour	Red	Red
Odour	Slightly pungent, earthy odour	Slightly pungent, earthy odour
pH	10.2-11.0	10.5-11.5
Liquid limit (%)	40-45	21-45
Plastic Limit (%)	30-35	16-35
OMC (%)	28-34	30-34
MDD (g/cc)	1.45-1.64	1.45-1.60
Grain size distribution (%) Sand Silt	10-14	2-10 45-75
Clay	43-57 32-29	22-35
Free swell index (%)	No swell	No swell
Specific gravity	2.85 - 2.97	2.85-3.05
Co-efficient of Permeability (cm/sec)	$2\text{-}30*10^{-6}$	$2\text{-}10*10^{-6}$

Specific gravity of the red mud will be very high due to the iron materials minerals present in it. Geotechnical properties like compaction, consolidation, shear strength, permeability, etc., are strongly influenced by chemical and mineralogical characteristics of the waste and source of bauxite [5]. The usage of the red mud mainly depends on the physical characteristics like mainly its strength, specific gravity, maximum dry density, optimum moisture content etc., strength can be known by compaction process and unconfined compressive strength tests. Different chemicals with ratios can be added to find out the strength as the material consists of the different type of minerals and their properties differ.

III. Chemical and Mineralogical Characteristics

Many types of minerals present in the red mud the chemical properties will differ with the amount of chemicals present and their chemical composition. The chemical composition mainly depends on the method of extraction, mineralogical origin their efficiency and method of disposal. The hydroxyl groups on the surface of red mud particles surface generated from bauxites of various mineralogical compositions are the responsible for its zeta potential, flocculation, dispersion.

- The pH in the range of 10.5 to 13, high ionic strength, red mud contains silica, aluminium, iron, calcium, titanium, sodium as well as of minor elements namely K, Cr, V, Ba, Cu, Mn, Pb, Zn, P, F, S, As, and etc [4].
- The zeta potential increases (higher positive) with the decrease of pH. The higher negative potential is due to high value of pH [12, 13].

  Tables 2 list the chemical compositions of red mud that are produced by the Bayer process.

TABLE II. Typical composition of red mud [3, 13]

Composition	Percentage
Fe_2O_3	30-60%
Al_2O_3	10-20%

SiO_2	3-50%
Na_2O	2-10%
CaO	2-8%
TiO_2	Trace-25%
Zeta Potential	+23 to -45 mV
pH	10.2-13
Mineralogical Phases	Hematite, Goethite, Gibbsite, Diaspore, Perovskite, Rutile, Sodalite, Quartz, Cancrinite, Calcilte

IV. Utilization of Red Mud as a Construction Material

A. Utilization of red mud in cement production

During the past decades, many researchers to develop various economic ways for the utilization of red mud have done extensive work. One of the economic ways is using red mud in cement production, which is also an efficient method for large-scale recycling of red mud. Liu and Zhang [14] used red mud mainly in three ways for the production of cement they are preparation of cement clinkers, production of composite cements as well as alkali-activated cements.Use of red mud cement not only reduces the energy consumption of cement production, but also improves the early strength of cement and resistance to sulfate attack [14].

B. Utilization of red mud in the concrete and brick industry

Red mud was added as a pigment in various proportions (dried, not ground, ground, calcinated) and the idea to use red mud as pigment was based on extremely fine particles of red mud (upon sieving: 0.147 mm up to 4 wt%, 0.058 mm up to 25 wt% and the majority smaller than 10 microns) and a characteristic red colour[15]. Red oxide pigment containing about 70 % iron oxide was prepared from NALCO red mud by after hot water leaching filtration, drying and sieving [15]. Arhin, et al [16] have been investigated bauxite red mud-Tetegbu clay composites for their applicability in the ceramic brick construction industry as a means of recycling the bauxite waste. The initial raw samples were characterized by X-ray diffraction (XRD) and thermo gravimetric (TG) analysis.

C. Utilization of red mud as a road base material

High-grade road base material using red mud from the sintering process is promising, that may lead to large-scale consumption of red mud. Qi [17] suggest using red mud as road material. Based on the work of Qi, a 15 m wide and 4 km long highway using red mud as a base material was constructed in Zibo, Shandong. A relevant department had tested the sub grade stability and the strength of road and concluded that the red mud base road meets the strength requirements of the highway [18].

Rao et al. (2012) [19] Experimental study on the behaviour of red mud with GGBS adding 5% increment from 5 to 30%. UCS, Spilt tensile test, CBR were conducted at 1, 3, 7, and 28 days curing periods, found that 25%GGBS has shown higher values compared to other percentages and at 28 curing periods a CBR value of CBR i.e., 35% was obtained as it satisfy the sub base, base course requirement and also used as sub grade material for high traffic volume roads. Similar studies have been carried out by Satyanarayana et al. (2012) [20], stabilized red mud with lime in the increment of with 2% to 12% and corresponding UCS, Split tensile strength, CBR were conducted at 1, 3, 7, and 28 days curing periods. Observed that 10% lime has shown higher values compared to other percentages. At 28 days it has shown maximum values than other curing periods for all percentages of lime. The CBR value obtained for 10% lime at 28 days is 25% so that it can be used as sub grade and sub base material in road construction.

D.Utilization of red mud as an embankment material

The Highway Engineering Laboratory of the Aristotle University of Thessaloniki studied a pilot project to utilise red mud in the construction of a road embankment and is constructed in three sections. Section I consisting of natural soil and in the red mud with partial in section II, the last section III is constructed with red mud in combination with 4% fly ash. The results of the investigation have demonstrated that the performance of the red mud as embankment material is satisfying the requirements and also observed that no signs of rutting or disintegration appeared on the surface [21]. Ghosh P.K. (2009) [22] carried out a feasibility study of red mud and Pond ash for construction of Embankment. Shows, the 10% of fly ash shows improvement in compaction, direct shear and triaxial tests results, from study concluded that, the mix is having 90%-10% is suitable for embankment.

E.Utilization of red mud as a filling material in mining

Yang et al. (1996) [23], from the Institute of Changsha Mining Research, have studied the properties, preparation and pump pressure transmission process of red mud paste binder backfill material. Based on this study, a new technology named “pumped red mud paste cemented filling mining” has been developed with a mixed ratio of red mud, fly ash, lime and water as 2:1:0.5:2.43, and then pumped the mixture into the mine to prevent ground subsidence during bauxite mining. The tested 28- day strength can reach to 3.24 MPa. Underground exploitation practice on the bauxite has proved that cemented filling technology is reliable and can effectively reduce the filling costs, increase

the safety factor of the stop and increase the comprehensive benefits of mining [24].

V.Conclusion

A review on physical, chemical, and geotechnical characteristics of red mud wastes as a construction material in civil engineering has been discussed above. Red mud, could become a potential construction material, based on the critical review the following general conclusions have been drawn:

- Red mud having least plasticity it can be an advantage in practical utilization such as road material and could become alternate as a substitution to natural materials.
- Lime, other waste and/or in combination with cement, can be used to stabilize the red mud. Red mud can be used in subgrade and subbase layers after stabilisation.
- Utilization of red mud in embankment construction has been demonstrated successfully, though needs to be treated for its high pH value.
- By seeing all these properties of the red mud we can utilize the red as geotechnical material like Backfill material, road sub-grade material embankment material. Red mud is further stabilized to enhance the more strength with lime, gypsum, fly ash etc
- Utilization of red mud is established in brick manufacturing, partial cement refilling, in concrete industry and stabilization process.

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