EVALUATION OF CHARACTERISTIC PROPERTIES OF RED MUD FOR POSSIBLE USE AS A GEOTECHNICAL MATERIAL IN CIVIL CONSTRUCTION

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ABSTRACT

Red mud is a byproduct produced in the process of extraction of alumina from bauxite. The process is called Bayers Process. It insoluble product and is generated after bauxite digestion with sodium hydroxide at elevated temperature and pressure. This paper describes the characteristic properties of Red Mud and possible use as a geotechnical material. Basics properties like Specific gravity, Particle size distribution, Atter Berg's limit, OMC and MDD are determined. Engineering properties like shear strength, permeability and CBR values are also determined in conformity with the Indian Standard Code and test results are discussed in geotechnical point of view. It revealed that the behavior of red mud is likely as clay soil with considerably high strength compared to conventional clay soil.

KEY WORDS: *Red mud, Bayer's process, Bauxite residue.*

I. INTRODUCTION

Industrialization and urbanization are the two world wide phenomena. Though these are the necessity of the society and are mostly inevitable, one has to look into their negative impacts on the global environment and social life. The major ill effect of these global processes is the production of large quantities of industrial wastes and the problems related with their safe management and disposal. Second problem is the scarcity of land, materials and resources for ongoing developmental activities, including infrastructure.

Red Mud is produced during the process for alumina production. Depending on the raw material processed, 1–2.5 tons of red mud is generated per ton of alumina produced [1]. In India, about 4.71 million tons/annum of red mud is produced which is 6.25% of world's total digestion with sodium hydroxide at elevated temperature and pressure [2]. It is a mixture of compounds originally present in the parent mineral bauxite and of compounds formed or introduced during the Bayer cycle. It is disposed as slurry having a solid concentration in the range of 10-30%, pH in the range of 10-13 and high ionic strength.

Considerable research and development work for the storage, disposal and utilization of red mud is being carried out all over the world [3]. This article provides an overview of the basic characteristics of red mud. The main ways of comprehensive utilization are also summarized. It describes the progress of experimental research and comprehensive utilization. The aim is to provide some valuable information to further address the comprehensive utilization of red mud.

II. ORGANIZATION OF MANUSCRIPT

The present work is divided into two main two stages. i) Experimental work and ii) Utilization of red mud as a geotechnical construction material. In experimental works, it is further divided into two parts; first, tests determining index properties, second, tests determining the engineering properties. In second stage of the work, it is described the possible utilization of red mud as a geotechnical material.

III. MATERIAL: RED MUD

The red mud is one of the major solid wastes coming from Bayer process of alumina production. For the present work it was collected from HINDALCO, At Renukoot, Uttar Pradesh. The conventional method of disposal of red mud in ponds has often adverse environmental impacts as during monsoons, the waste may be carried by run-off to the surface water courses and as a result of leaching may cause contamination of ground water: Further disposal of large quantities of Red mud dumped, poses increasing problems of storage occupying a lot of space.

IV. CHARACTERISTIC PROPERTIES OF RED MUD

Index Properties:

Specific gravity of the red mud has been carried out as per the IS: 2720 (Part II) 1980. The experiment was performed from both pycnometer method and density bottle. The specific gravity of the red mud was found to be 3.04.

Particle Size distribution of the red mud was carried out as per the IS: 1498 – 1970 As the materials consists near about 90 percent silt and clay, wet sieve analysis is carried out. The particles passing through 75 micron was collected and allowed to Hydrometer analysis to determine the particle size variation. About 87.32% percentage of the total mass was passed through the 75 micron sieve. Fig:1 shows the graph plot between the particle diameter and the percentage finer.

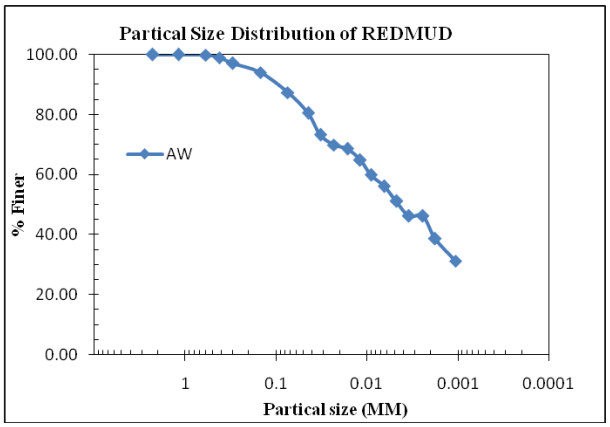

Fig-1: Graph showing particle size distribution with % finer

Standard Proctor test was carried out to determine the maximum dry density and optimum moisture content of the red mud. The test is carried out as per the IS: 2720 (Part VII) Light compaction was adopted. The variation of water content and the corresponding water content variation is shown in thefig:2

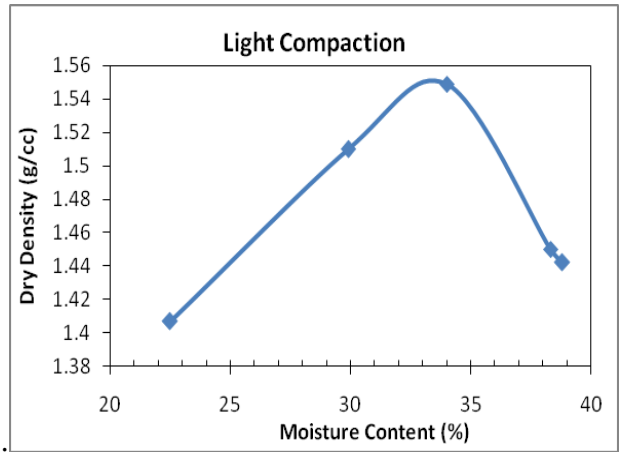

Fig-2: Graph showing water content and dry density.

Atter Berg's limits of the red mud was determined as per the IS: 2720 (Part V). Corresponding liquid limit, Plastic limit and plasticity index is shown in the table: 1

Table: 1. Strength and physical parameters of red mud

S.NO	Tests		Values
1	Maximum dry Density (g/cc)		1.53
2	Optimum moisture Content (%)		33.5
3	Specific Gravity		3.04
4	Liquid Limit (%)		45.5
5	Plastic Limit (%)		32.3
6	Classification		ML
7	Cohesion (kg/cm^2)		0.123
8	Angle of internal friction(in Degree's)		26.8
9	CBR (%)	Soaked	4.2
		Unsoaked	7.8

Chemical and Mineral Compositions of Red Mud

Red mud is mainly composed of fine particles of mud. Its composition, property and phase vary with the origin of the bauxite and the alumina production process, and will change over time when stocked. Chemical analysis shows that red mud contains silicium, aluminium, iron, calcium, titanium, sodium as well as an array of minor elements namely K, Cr, V, Ba, Cu, Mn, Pb, Zn, P, F, S, As, and etc. Tables 2 and 3 list the chemical and mineral compositions of red mud that are produced by the Bayer process [4].

Table 2. Typical composition of red mud

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%

Mineralogical Phases:
Mineralogical phases of red mud are listed below [5]
Hematite Fe_2O_3
Goethite FeO(OH)
Gibbsite $AlOH_3$
Diaspore AlO(OH)
Quartz SiO_2
Cancrinite $(NaAlSiO_4)6CaCO_3$
Kaolinite $Al_2O_3\,2SiO_2\,2H_20$
Calcilte [CaCO3]

Engineering Properties.

Permeability test is carried out as per the IS: 2720 (Part XVII). The coefficient of permeability of the red mud specimen is found out using falling head method. Coefficient of permeability was found to be 5.786e-7cm/s.

Triaxial Compression Test is best suited for Clayey soil. The sample of size 38mm dia. x 76mm height. After applying confining pressure (e.g. 0.5, 1.0 or 1.5 kg/cm2) deviator stress is applied till failure. Having minimum two readings Mohr's stress circles are plotted. A line tangent to the Mohr's circles is failure envelope and shear parameters: Cohesion and Angle of Internal Friction. Results are shown in the table 1

Unconfined Compressive strength: The samples of sizes 38 mm diameter and height of 76 mm were prepared by static compaction method to achieve maximum dry density at their optimum moisture contents. Unconfined compressive strength tests were conducted at a strain rate of 1.25 mm/min. The results obtained are tabulated in table 1

California Bearing ratio test: The sample of nearly 4.5 to 5 kg was compacted in a mould of volume 2250cc with 5 layers and 56 blows were given for each layer. For soaked CBR value, the different sample of identical size is prepared and kept soaking for 4 days with the surcharge. This test was conducted as per IS: 2720 (Part XXXI). The test results are entered in the table 1

V. COMPREHENSIVE UTILIZATION OF RED MUD IN CONSTRUCTION

A. Red mud in cement replacement

Dicalcium silicate in red mud is also one of the main phases in cement clinker, and red mud can play the role of crystallization in the production of cement clinker. Fly ash is mainly composed of SiO_2 and Al_2O_3, thus can be used to absorb the water contained in the red mud and improve the reactive silica content of the cement. Scientists conducted a series of studies into the production of cement using red mud, fly ash, lime and gypsum as raw materials. 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 [6]

B. Concrete industry

Red mud from Birac Alumina Industry, Serbia was tested as a pigment for use in the building material industry for standard concrete mixtures. Red mud was added as a pigment in various proportions (dried, not ground, ground, calcinated) to concrete mixes of standard test blocks (ground limestone, cement and water) [7]. 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. Compressive strengths from 14.83 to 27.77 MPa of the blocks that contained red mud between 1 and 32% were considered satisfactory. The reported tests have shown that neutralized, dried, calcined and ground red mud is usable as pigment in the building materials industry. Red oxide pigment containing about 70 % iron oxide was prepared from NALCO red mud by [8] after hot water leaching filtration, drying and sieving.

C. Red mud in the brick industry

D. Dodoo- Arhin, et al [9] 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. The red mud-clay composites have been formulated as 80%-20%, 70%-30%, 60%-40%, 50%-50% and fired at sintering temperatures of 800ºC, 900ºC and 1100ºC. Generally, mechanical strengths (modulus of rupture) increased with higher sintering temperature. The results obtained for various characterization analyses such as bulk densities of 1.59 g/cm3 and 1.51 g/cm3 compare very well with literature and hold potential in bauxite residue eco-friendly application for low-cost recyclable constructional materials. Considering the physical and mechanical properties of the fabricated brick samples, the batch formulation which contained 50% each of the red mud and Tetegbu clay is considered the best combination with optimal properties for the construction bricks application and it could be employed in lighter weight structural applications.

VI. UTILIZATION OF RED MUD AS FILLING MATERIAL

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 [10] 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 [11].

B. Mining

Yang et al. [12], 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 by the Institute of Changsha Mining Research, in cooperation with the Shandong Aluminum Company. They mixed red mud, fly ash, lime and water in a ratio of 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. This technology is a new way not only for the use of red mud, but also for non-cement cemented filling, successfully resolving the problem of mining methods in the Hutian bauxite stop. 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 [13].

VII. RECOVERY OF COMPONENTS FROM RED MUD

Red mud primarily contains elemental compositions such as Fe_2O_3, Al_2O_3, SiO_2, CaO, Na_2O and K_2O. Besides, it also contains other compositions, such as Li_2O, V_2O_5, TiO_2 and ZrO_2. For instance, the content of TiO in red mud produced in India can be as much as 24%. Because of the huge amount of red mud, value elements like Ga, Sc, Nb, Li, V, Rb, Ti and Zr are valuable and abundant secondary resources. Therefore, it is of great significance to recover metals, especially rare earth elements, from red mud.

Due to the characteristics of a high iron content, extensive research into the recovery of iron from Bayer process red mud have been carried out by scientists all over the world. The recycling process of iron from red mud can be divided into roasting magnetic recovery, the reducing smelting method, the direct magnetic separation method and the leaching extraction method, according to the different ways of iron separation. Researchers in Russia, Hungary, America and Japan have carried out iron production experiments from red mud. Researchers from the University of Central South have made steel directly with iron recovered from red mud [14]. The Chinese Metallurgical Research Institute has enhanced the iron recovery rate to 86% through making a sponge by red mud-magnetic separation technology. Sun et al. [15] researched magnetic separation of iron from Bayer red mud and determined the process parameters of the magnetic roasting-magnetic selecting method to recover concentrated iron ore.

VIII. SUMMARY AND CONCLUSION

- Specific gravity of the red mud is 3.04 which is very high compared to the soil solids. So the density of red mud will be more and so the strength is more.
- From the fig 1 graph showing particle size distribution mud indicated grains are fine and it is well graded. So the soil can be used as an embankment material, backfill material etc.
- From the Atter berg's limits it is concluded that the plasticity Index of the red mud is13.2. So, according to the IS classification based on plasticity A-line, the soil falls under ML. Means it is silt with low compressibility.
- The maximum dry density and optimum moisture content of the red mud is 1.53gm/cc and 33.5% Respectively
- Co-efficient of permeability of red mud is 5.786e-7cm/s which shows that permeability is very low. Low permeable materials can be used for construction of earthen dams, road embankments etc.
- The cohesive strength and the angle of shear resistance obtained from the triaxial test are $0.123 kg/cm^2$ and 26.8^0. The strength value of the red mud is higher than the conventional clay material.
- CBR value of the red mud in soaked condition is 4.2% which is greater than the 3%, so we can use the red mud as a road material in village side.
- 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.

- A wide variety of potential uses of red mud have been reviewed, yet there is no economically viable and environmentally acceptable solution for the utilization of large volumes of red mud.
- There is urgent need to undertake research and development for studying the metal speciation and the changes associated with red mud reuse in the construction purposes and during the wet storage of red mud in ponds.

IX. SCOPE FOR FUTURE WORK

In the present work, all the tests are worked on the unstabilized red mud. After these tests, it is concluded that, the red mud can be used as a geotechnical material for varies purposes. In future, one can also work with the red mud by stabilizing by adding lime, fly ash, gypsum.

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