

# Suitability of Red mud – Soil liner

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**Abstract**— Red mud is the fine-grained residue left after the extraction of alumina from bauxite ore. At present, in India about 10 million tons of red mud residue are being generated annually posing very serious and alarming environmental problems. This study seeks to evaluate the possibility of red mud application in landfill liners. Landfill liners are provided to prevent the leachate movement into underground water. This paper seeks the use of Red mud – Soil mixture as liner material for the dump yard site. In this study, various percentages of soil and red mud are added and optimum mix is found out. Geotechnical tests include determination of Atterberg limits, compaction test, permeability test, triaxial test and free swell index test. Hydraulic conductivity of soil sample is found to decrease from  $2.16 \times 10^{-4}$  cm/s to  $9.12 \times 10^{-8}$  cm/s by the addition of 50 to 90% red mud respectively. Plasticity index is found to decrease from 25 to 14% when 50% red mud is added which complies with liner requirement. From the above results, it can be concluded that red mud can be effectively utilized as a liner material. Red mud being alkaline in nature, it can be used to prevent acidic contamination of soil.

**Keywords**— Red mud, Hydraulic conductivity, Plasticity

## I. INTRODUCTION

Proper disposal and storage of hazardous waste require their isolation to prevent migration of leachates from the waste into the surrounding areas and to safeguard the soil and water against the possible contamination by infiltration of toxic pollutants from the waste, ultimately protecting the public health. To this aim, mineral liners or “compacted clay liners (CCLs)” are used in waste containment facilities as hydraulic barriers to prevent the flow of liquids. The performance of a liner ultimately depends on its effectiveness to provide a low enough hydraulic conductivity (K), a value less or equal to  $1 \times 10^{-9}$  m/s for hazardous and non-hazardous waste. Strong resistance to chemical attack is also a desirable property of a liner, because CCLs may be attacked by the chemical wastes or leachates they are meant to contain infiltration of hazardous liquids through waste containment barriers can exert contamination and considerable alterations in the geotechnical and hydraulic properties of the liner. Red mud is a by-product of the Bayer process that is used in refining alumina.

The various Aluminium industries in India are at Orissa, Jharkhand, Maharashtra, Madhya Pradesh, Gujarat, Tamil Nadu etc., causing underground water pollution. At present, in India about 10 million tons of red mud residue are being generated annually posing very serious and alarming environmental problems. The sustainable utilization of this by-product helps in the protection of environment. This study seeks to evaluate the possibility of red mud application in liners. Landfill liners are provided to prevent the leachate movement into underground water. H.M.Vijaya et al (2018) assessed the use of red mud produced by alumina refinery industries was reviewed to ascertain its suitability as a construction material. Physical, chemical and geotechnical properties of these waste

materials have been critically reviewed for this purpose; it was observed that the red mud has the potential to be used as a construction material. Shamshad Alam et al (2017) has studied to characterize the coarse fraction (>75 mm) of red mud as an alternate construction material (medium value utilization). Red mud can be used as a sustainable construction material utilizing the industrial waste and conserving natural resources. Josée Duchesne et al (2005) investigated to evaluate the capacity of alkaline residues to inhibit acid mine drainage. The most important indicators of neutralization are pH and the concentrations of metals in solution. The use of alkaline materials as a liner had a positive effect on the reduction of Fe, SO<sub>4</sub>. D. Rubinos et al (2013) studied the geotechnical and hydraulic conductivity (K) characteristics of the RM, as well as the effect of desiccation, were evaluated. Shear strength test revealed high values of friction angle and cohesion for compacted RM. RM could be utilised as a low-permeability barrier to be laid down under engineered landfill sites. Jian He et al (2011) studied that investigates the geopolymerization of red mud and fly ash. The two major industrial wastes, red mud and fly ash, can be reused to produce geopolymers that may replace Portland cement.

## II. MATERIALS

### A. Soil

The soil sample is collected from a dump yard site, Ernakulam, Kerala shown in fig 1, which consists of slightly acidic nature from industrial waste. Table 1 shows the properties of soil collected from the site.

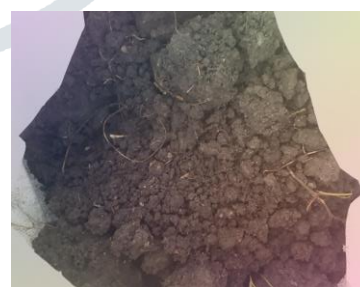


Fig. 1: soil collected from kalamaserry, Ernakulam

TABLE 1: PROPERTIES OF WASTE SOIL AND RED MUD

Property	Local soil
Specific gravity	2
Liquid limit	11.48%
Plastic limit	36.98%
Maximum dry density	1.75g/cm <sup>3</sup>
Optimum moisture content	23.1%
pH	4.8
Coefficient of permeability	$3.05 \times 10^{-3}$ cm/s
Strength	41 kPa

**B. Red Mud**

Red mud is by-product of aluminium industry and is collected from Chennai. Table 2 shows the properties of red mud.



Fig. 2: Red mud

TABLE 2: PROPERTIES OF WASTE SOIL AND RED MUD

Property	Red mud
Specific gravity	3.05
pH	9

**III. METHODS**

Five samples are selected by varying soil, red mud content. A series of laboratory tests include determination of Atterberg limits, compaction parameters, free swell index and triaxial tests was done on each sample and suitable sample needs to be found out. Table 3 shows the sample combination for the tests.

TABLE 3: SAMPLE COMBINATION

Sample	Composition
S1	50% S + 50% RM
S2	40% S + 60% RM
S3	30% S + 70% RM
S4	20% S + 80% RM
S5	10% S + 90% RM

**A. Standard compaction test**

Compaction tests were conducted to achieve the compaction parameters. The maximum dry density and the optimum moisture content were obtained from the peak point of the relation curve. Proper compaction gives uniform mass of soil which does not have voids and thereby increases the density and strength of the soil. Compaction test is carried out according to IS: 2720 (Part 7). The Compaction test were carried out on 5 samples and their OMC and dry densities obtained is given in Table 4.

TABLE 4: COMPACTION CHARACTERISTICS

SAMPLE	COMPOSITION	OMC (%)
S1	50% S + 50% RM	11.36
S2	40% S + 60% RM	18.24
S3	30% S + 70% RM	23.97
S4	20% S + 80% RM	26.2
S5	10% S + 90% RM	29.3

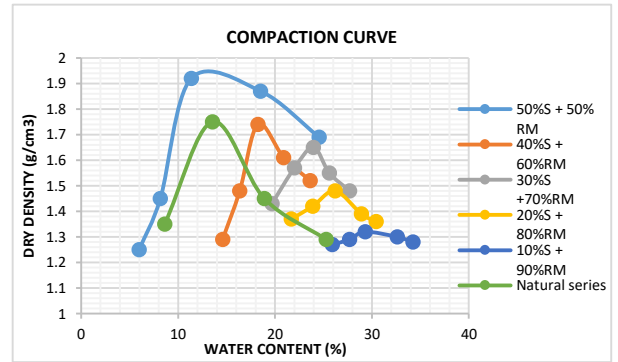


Fig. 3: compaction curve of different sample

From the test results, it is seen that, with increase in percentage of Red mud optimum moisture content increases and maximum dry density decreases. The highest OMC value is obtained for sample S5, which has more red mud content, ie. 29.3%. The sample S5 have the least dry density, ie. 1.32g/cm<sup>3</sup>.

**B. Atterberg limits**

Determination of Atterberg limits is the basic test on the fine grained soil and is used to determine the critical water contents of the cohesive or fine grained soil. This was created by Swedish agriculturist Albert Atterberg and refined later by Arthur Casagrande. It indicates the state of consistency of the soil at the site. From this liquid limit, plastic limit and shrinkage limit can be found out.

Atterberg limits tests were conducted to study the effect of Red mud content on liquid limit, shrinkage limit and plasticity index of the soil. It indicates the state of consistency of the soil at the site. Table 5 shows the Atterberg limits obtained for five samples.

TABLE 5: ATTERBERG LIMITS OF SAMPLES

Sample	Liquid limit (%)	Plasticity index (%)
S1	28	14
S2	34	19
S3	42	24
S4	66	37
S5	81	42

With increasing red mud content of the soil, liquidity of the soil increases, ie. Liquid limit and plastic limit. All other samples other than S5 shows cracking, in figure 3.5 and therefore these samples cannot be used for liner construction. Fig 4 shows the crack obtained for sample 4 (S4). High red mud content in the S5 mix in Fig 5, prevents the formation of cracks.



Fig. 4: Sample 4



Fig. 5: Sample 5

**C. Permeability**

The key parameter for the design and requirement of a liner is its permeability. For a material to be used as a liner, its permeability should be less than 1 x 10<sup>-7</sup> cm/s. To verify the Red mud – Soil mixes as liner materials, the samples were prepared at their maximum dry densities and tested for coefficient of permeability. Table 6 shows the value obtained for permeability test of five samples. Permeability

of Red mud and soil mixtures is determined using falling head permeability test as per IS 2720 part 17.

TABLE 6: PERMEABILITY OF SAMPLES

Sample	Permeability(cm/s)
S1	$2.16 \times 10^{-4}$
S2	$7.72 \times 10^{-5}$
S3	$4.36 \times 10^{-6}$
S4	$5.91 \times 10^{-7}$
S5	$9.12 \times 10^{-8}$

Coefficient of permeability decreases with increase in red mud content. Least value for coefficient of permeability is for sample, S5 i.e.  $9.12 \times 10^{-8}$  cm/s. This is due to the high specific area of red mud which tends to absorb more water which fills the pores in soil structure and lowers the soil porosity and hydraulic conductivity.

#### D. Free swell index

To know the swelling characteristics of Red mud - soil mixes, various percentage combinations of their dry weights were taken, uniformly mixed and 10g of each was poured in distilled water and kerosene.

The free swell index was calculated as below-

$$FSI = (V_w - V_k / V_k) \times 100.$$

TABLE 7: FREE SWELL INDEX OF THE SAMPLES

SAMPLE	FSI
S1	40
S2	65
S3	80
S4	95
S5	105

From the test results it is observed that with increase in percentage of Red mud, free swell index increases.

#### IV. CONCLUSIONS

Coefficient of permeability value decreased from  $3.05 \times 10^{-3}$  to  $9.12 \times 10^{-8}$  cm/s when 90% red mud was added with soil. This agrees with the specification of clay liners (less than or equal to  $10^{-7}$  cm/s). The above combination does not show any crack and hence is suitable for a liner.

As per the liner specification, the plasticity index should be greater than 10% which suits for the above combination. Hence, soil sample with 90% red mud is highly suitable to use as a liner.

#### REFERENCES

- [1] Shamshad Alam, Bijaya Kumar Das and Sarat Kumar Das "Dispersion and Sedimentation Characteristics of Red Mud" ASCE Journal. (2018).
- [2] H.M.Vijaya, T.Samuel Wesley and Prathik Kulkarni, "Assessment of red mud as a construction material: a review" Indian J.Sci.Res. 17(2): 473 – 478 (2018).
- [3] Lianwen Liu, Wei Li, Weiping Song and Mingxin Guo, "Remediation techniques for heavy metal-contaminated soils: Principles and applicability", Science of the Total Environment 633 206–219 (2018).
- [4] Shamshad Alam, Sarat Kumar Das and B. Hanumantha Rao, "Characterization of coarse fraction of red mud as a civil engineering construction material." Journal of Cleaner Production 168 679e691 (2017).
- [5] Aman Jain, Prof. Rajesh Jain, "Evaluation of geotechnical characteristics of red mud lime soil mixture." International Research Journal of Engineering and Technology (IRJET) Volume: 04 Issue: 03 (2017),
- [6] Hui Wu, Qingbo Wen, Liming Hu, Meng Gong, Zili Tang, "Feasibility study on the application of coal gangue as landfill liner material." State Key Laboratory of Hydro-Science and Engineering, Department of Hydraulic Engineering, Tsinghua University, Beijing 100084, PR China (2017).
- [7] D. A. Rubinos, G. Spagnoli, M. T. Barral, "Chemical and environmental compatibility of red mud liners for hazardous waste containment" Islamic Azad University (IAU) (2015).
- [8] D. Rubinos, G. Spagnoli & M.T. Barral, "Assessment of bauxite refining residue (red mud) as a liner for waste disposal facilities" International Journal of Mining, Reclamation and Environment (2013).
- [9] Prof. P.V.V.Satyanarayana, Harshitha.A., Sowmya Priyanka. "Utilization of red soil bentonite mixes as clay liner materials", Lecturer (IIT-IDUPULAPAYA, AP) International Journal of Scientific & Engineering Research, Volume 4, Issue 5, May-2013 ISSN 2229-5518 .
- [10] Yating YANG, Qingbo WEN and Liming HU, " Experimental Study on Application of Industrial Waste in Landfill Liner " GeoCongress 2012 © ASCE (2012).
- [11] Jian He and Guoping Zhang, " Geopolymerization of Red Mud and Fly Ash for Civil Infrastructure Applications " Geo-Frontiers 2011 © ASCE (2011).
- [12] Patil, M.R. Quadri, S.S. Lakshmikantha, H., " Effect of Additives on Geotechnical Properties ". Indian Geotechnical Conference – 2010, GEOTrendz December 16–18, 2010 IGS Mumbai Chapter & IIT Bombay(2010).
- [13] Semra C, oruh, Osman Nuri Ergun, " Use of flyash, phosphogypsum and red mud as a liner material for the disposal of hazardous zinc leach residue waste " Journal of Hazardous Materials 173 468–473 (2010).
- [14] Ekrem Kalkan, " Utilization of red mud as a stabilization material for the preparation of clay liners" Engineering Geology 87 220–229 (2006).
- [15] Josée Duchesne and Isabelle Doye, "Effectiveness of covers and liners made of Red Mud Bauxite and/ or Cement kiln Dust for limiting acid mine drainage". Journal of environmental engineering © asce (2005).