# Performance of Red Soil - Bentonite as a Landfill Liner

Sharon Grace Xavier
Dept. Of Civil Engineering
Marian Engineering College
Trivandrum. India

Soorya S R
Dept. Of Civil Engineering
Marian Engineering College
Trivandrum. India

Kannan K
Dept. Of Civil Engineering
Marian Engineering College
Trivandrum. India

***Abstract*— One of the main problem in the geo environment is the generation of large quantities of waste from industries, which requires efficient disposal facilities. Landfills plays a vital role in the whole waste containment or disposal process. This study is associated with the laboratory investigation of naturally available red soil incorporated with montmorillonite based clay soil bentonite, as a permeable reactive barrier in the landfill. Various proportions of Bentonite is used, varying from 3% to 18% by weight of the red soil. Different tests are conducted like Atterberg limits, Compaction, Unconfined Compression and Permeability to determine the suitable mixture of Red soil – Bentonite mixture. Dosage of 15% bentonite yields satisfactory results for usage as a liner.**

***Keywords*— Bentonite, Landfill liner, Red soil**

## I. INTRODUCTION

Large quantities of wastes are being produced by industrial activities. These wastes are in different forms like solids, liquids and gas and thus it turns out as pollutants. These wastes can be hazardous and non-hazardous based on the safety level. Landfill is the most frequently used disposal method for solid wastes because of its efficiency and low cost in construction. Landfill plays an important role in waste disposal or treatment process. Clay is the most vital component of soil liners because the clay fraction of the soil assures low hydraulic conductivity. Mainly bentonite based materials are used as landfill lining. For any liner material to be used, it should have the following properties:

1.A low permeability of generally 10-7 cm/sec is required.
2.Durability and resistance to weathering is the quality of the material to withstand the forces of alternating wet/dry and freeze/thaw cycle.
3.Constructability, which means the material, should be reasonably feasible in terms of placement and compaction under field conditions.
4.Compatibility with leachate: the liner material must maintain its strength and low permeability even after prolonged contact with leachate.

Even though soil liners has many limitations, they are widely used because of their low cost, large attenuation capacity, universal availability and resistance to puncture and damage. Because of the availability of good quality clays and cheap labour CCLs are more popular in the developing countries. Landfill engineering is adequate to ensure a leachate retention time of 50 years. Engineered waste landfills with liner systems having low permeable materials (less than $10^{-7}$ cm/s) has to be used to avoid uncontrolled release and migration of hazardous contaminants into the environment.

This paper describes about the suitability of locally available Red Soil and Bentonite mixture as a landfill liner material.

## II. MATERIALS USED

### *A. Sodium Bentonite*

The commercially available sodium bentonite were used for the study. It was collected from KINFRA Kazhakoottam, TVM. A Small amount of nearly 20gm of the sample was sealed in a polythene bag for determining the natural moisture content.

Fig 1. Sodium Bentonite

### *B. Red Soil*

Locally available Red soil was collected from Neyyattinkara, TVM for the study.

Fig 2. Red Soil

## III. METHODOLOGY

### *A. Preparation of Red Soil - Bentonite Liner*

Atterbergs limit (IS 2720 Part5-1985), Compaction tests (IS 2720 Part7-1980), Unconfined Compression Strength tests (IS 2720 Part 10-1991) and Permeability tests (IS 2720 Part 17-1986) were conducted to obtain the red soil - bentonite mix for landfill liner. Bentonite used for the study was kept in a moisture controlled environment. Various proportions of Bentonite (3%, 6%, 9%, 12%, 15%, 18%) were added with the red soil.

*B. Atterberg Limits*

Liquid limit, plastic limit, plasticity index and shrinkage limit of the red soil and bentonite mixed in various percentage were determined as per IS 2720 Part5-1985.

*C. Compaction Characteristics*

The test to determine the maximum dry density and optimum moisture content were done in air dried soil sample using standard proctor according to IS 2720 Part 7-1980 with various percentage of bentonite content.

*D. Unconfined Compressive Strength*

The unconfined compressive strength of the mixture was determined as per IS 2720 Part 10-1991 with various percentage of bentonite content.

*E. Hydraulic Conductivity*

Hydraulic conductivity of the red soil with various percentages of bentonite were determined as per IS 2720 Part17-1986.

## IV. RESULT AND DISCUSSION

*A. Initial Properties of Sodium Bentonite*

Initial properties of Sodium Bentonite were determined as per relevant IS method and the same is tabulated in Table I.

TABLE I. PROPERTIES OF SODIUM BENTONITE

| Soil Properties | Values |
|---|---|
| Specific gravity | 2.69 |
| Optimum moisture content (%) | 12 |
| Liquid limit (%) | 329 |
| Plastic limit (%) | 40.6 |
| Plasticity index (%) | 288.4 |
| Shrinkage limit (%) | 13.7 |
| Free swell (ml/2g) | 30-35 |
| UCC strength (kN/m$^2$) | 102.36 |
| IS designation | CH |

*B. Initial Properties of Red Soil*

Properties of the collected Red Soil is listed in Table II.

TABLE II. PROPERTIES OF RED SOIL

| Soil Properties | Values |
|---|---|
| Gravel (%) | 0.0 |
| Sand (%) | 52 |
| Fines (%) | 48 |
| Liquid limit (%) | 26 |
| Plastic limit (%) | 14 |
| Plasticity index (%) | 12 |
| Specific gravity | 2.63 |
| IS designation | CL |
| Maximum Dry Density (kN/m$^3$) | 20.7 |
| Optimum Moisture Content (%) | 10.2 |
| Hydraulic Conductivity (cm/s) | 4.4*10$^{-5}$ |

*C. Effect of Bentonite on Atterbergs Limits of Red Soil – Bentonite Mixture*

Atterberg limits were conducted to evaluate the effect of bentonite on liquid limit, plastic limit, plasticity index and shrinkage limit of the soil. Summary of the test result is tabulated in Table III.

TABLE III. VARIATION ON ATTERBERG LIMITS

| Bentonite Content (%) | WL | WP | IP |
|---|---|---|---|
| 3 | 28 | 16.7 | 8.3 |
| 6 | 33 | 16.8 | 16.2 |
| 9 | 42 | 17 | 25 |
| 12 | 53 | 25.3 | 27.7 |
| 15 | 69 | 26.2 | 42.8 |
| 18 | 75 | 26.5 | 48.5 |

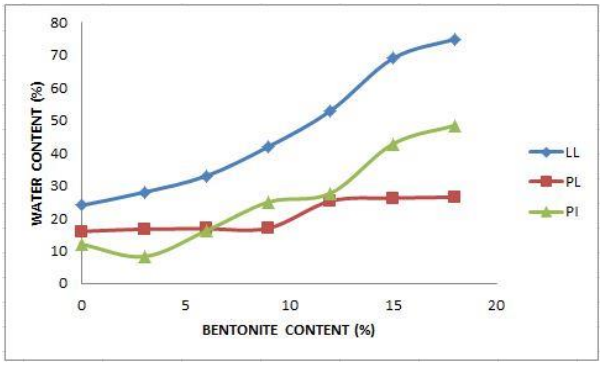


Fig 3. Variation Graph of Atterberg limits

An increasing trend of the consistency limits of the red soil – bentonite mixture with increase in bentonite can be seen from Fig 3. As the bentonite content increases from 3% to 18% , liquid limit increases from 28 to 75% and also similarly plastic limit and plasticity index do increase with respect to the bentonite content.

*D. Effect of Bentonite on Compaction Characteristics of Red Soil – Bentonite Mixture*

The compaction characteristics of the red soil with different proportions of bentonite is been evaluated and the results for optimum moisture content and maximum dry density is presented in Table IV.

TABLE IV. VARIATION ON COMPACTION CHARACTERISTICS

| Bentonite Content (%) | MDD (kN/m$^3$) | OMC (%) |
|---|---|---|
| 3 | 18.57 | 10.8 |
| 6 | 18.42 | 11.5 |
| 9 | 18.12 | 12.5 |
| 12 | 18.00 | 13.6 |
| 15 | 17.63 | 15.0 |
| 18 | 17.54 | 15.7 |

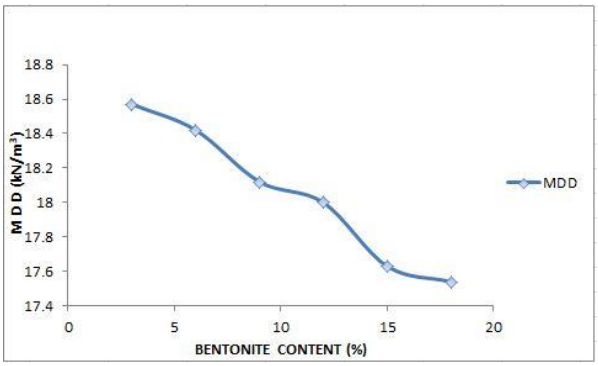


Fig 4. Variation Graph of Maximum Dry Density

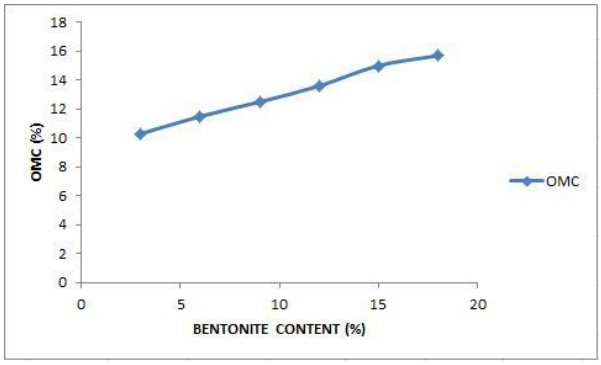

Fig 5. Variation Graph of Optimum Moisture Content

As shown in Fig 4 and Fig 5, when more bentonite is added the MDD decreased and OMC increased respectively. When bentonite is mixed with red soil, more water is required in compaction in order to achieve maximum dry density. When additional water is added, dry unit weight of the compacted red soil – bentonite mixture drastically decreased particularly at high bentonite contents. The bentonite swelled further when more bentonite is added and this stage the additional water and swelled bentonite which was lighter than soil occupied more space in the compaction mould resulting in decreasing of dry unit weight of the mixtures.

*E. Effect of Bentonite on Unconfined Compressive Strength of Red Soil – Bentonite Mixture*

The bentonite quantity in the sample was each time increased by 3% and then tested for its strength. The unconfined compressive strength of the mixtures are shown in Table V.

TABLE V. VARIATION ON UCS

| Bentonite Content (%) | UCS (kN/m$^2$) |
|---|---|
| 3 | 51.2 |
| 6 | 62.3 |
| 9 | 79.2 |
| 12 | 85.2 |
| 15 | 107 |
| 18 | 84.25 |

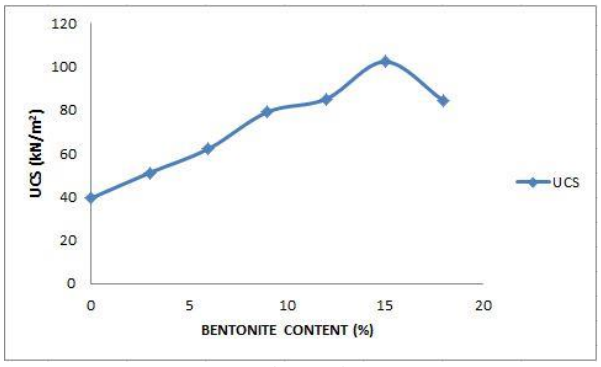

Fig 6. Variation Graph of Unconfined Compressive Strength

From the Fig 6 its seen that UCS value increased from 51.192 kN/m$^2$ at 3% bentonite to 102.36 kN/m$^2$ at 15% bentonite mix. The increase in strength can be explained by the change of soil structure due to the presence of bentonite content. When bentonite is added, soil structure becomes flocculated due to reduction in interparticle repulsion. Bentonite content of 15% gives the maximum UCC strength and is considered as the optimum mix for liner.

*F. Effect of Bentonite on Hydraulic Conductivity of Red Soil – Bentonite Mixture*

The permeability test was performed on the red soil and bentonite mix of different proportions and the result is tabulated in Table VI.

TABLE VI. VARIATION ON HYDRAULIC CONDUCTIVITY

| Bentonite Content (%) | Permeability (cm/s) |
|---|---|
| 3 | $3.56*10^{-6}$ |
| 6 | $3.42*10^{-7}$ |
| 9 | $2.09*10^{-7}$ |
| 12 | $1.53*10^{-7}$ |
| 15 | $2.02*10^{-8}$ |
| 18 | $1.87*10^{-8}$ |

Results reveals that hydraulic conductivity of the mix decreases with increase in bentonite content. Hydraulic conductivity must be less than $1*10^{-7}$cm/s for the liner material. For bentonite addition of 6% and more is seen as adequate for using as a liner. The high specific surface of bentonite and fine bentonite particles resulted in adsorption of large number of hydrated cations and water molecules and contributed to decrease in hydraulic conductivity in the red soil – bentonite mixture.

## CONCLUSIONS

1. When the percentage of Bentonite increases, consistency properties such as liquid limit, plastic limit and plasticity index are increasing.
2. As the Bentonite content increases, the MDD value decreases and OMC value increases.
3. As Bentonite increases and the Red soils Bentonite mixes exhibit good strength at higher percentages of Bentonite.
4. Bentonite content from 6% can be used as a liner material as it achieves the hydraulic conductivity of a liner.
5. From the test data it is identified that a dosage of 15% Bentonite yields satisfactory results for the use of these mixes as liner materials.

## REFERENCES

[1] Albright. W, (1995) Physical and hydraulic characteristics of Bentonite amended soil from area 5 Nevada test site, Master publication # 45197, 1 – 66.
[2] Kenney, T.C., Veen, W.A.V., Swallow, M.A., and Sungaila, M.A.,(1992), Hydraulic conductivity of compacted bentonite-sand mixtures,Canadian Geotechnical Journal, 29(3), 364-374.
[3] Sivapullaiah and Lakshmikantha H et.al. (2003) "geotechnical properties of Indian red earth", *Jr. of geotechnology and geological engineering*, 399-415.
[4] Watabe, Y., Yamada, K., and Saitoh, K., (2011), Hydraulic conductivity and compressibility of mixtures of Nagoya clay with sand or bentonite, Géotechnique, 61(3), 211-219.
[5] Sheela Evangiline .Y, et.al. (2012) "Assessment of bentonite and laterite mixture as clay liner material". *IGC 2012*, Vol II, 834-837.
[6] Fan, R., Du, Y., Liu, S., and Chen, Z., (2014), "Compressibility and hydraulic conductivity of sand/clay-bentonite backfills", *Geoenvironmental engineering*, 21-30.
[7] Oluwapelumi, ojuri. O, 2015. Geotechnical Characterization of some clayey soils for use as landfill liner, Journal of Applied Science and Environmental Management (JASEM), Vol. 19 (2) June, 211-217.
[8] Gopinath, R., Poopathi, R., Vasanthavigar, M., Arun, R., Mahadevan, M., (2018), "Stabilized Red Soil—An Efficient Liner System For Landfills Containing Hazardous Materials", *Environmental Monitoring Assessment*, 190
[9] Krishna, R.V., Reddy, H.K.P., (2021), "Optimizing the liners thickness to design a landfill", *Materials Today: Proceedings*, 43 , pp. 2331–2336