

Design of Amended Soil Liner

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Abstract— Landfills are highly engineered waste containment systems, designed to minimize the impact of solid waste on the environment and human health. In modern landfills, the waste is contained by liner and cover system. The greatest threat to ground water posed by modern landfills is leachate. Leachate consists of water and water soluble compounds in the refuse that accumulate as water moves through the landfill. Barrier layer in liner system are used to prevent the flow of leachate out of landfill. These are normally constructed with very low permeability clay. When low permeability clay is not available locally, in-situ soils may be mixed with medium to high plasticity imported clay, or commercial clays such as bentonite to achieve the required low hydraulic conductivity. Such liners are called amended soil liners. In this work, two amended soil liners are designed one clay soil from Kuttanad region, fine sand and bentonite and the other with Kaolinite, fine sand and bentonite.

Index Terms— Bentonite, Clay Liner, Kaolinite, Kuttanad Soil, Landfill, Leachate, Permeability

1 INTRODUCTION

WASTE disposal has become one of the most serious modern environmental problems in developed and developing countries all over the world. One of the preferred methods of dealing with this kind of environmental problem is to dispose off the waste in sanitary landfills. The most important problem in designing and maintaining a landfill is management of the leachate. Leachate is generated when water percolates through the waste in the landfill.

Landfill liners should be designed to prevent leachate from migrating to the surrounding environment. Low permeability compacted clays are used to form landfill liners. Locally available natural clays are used as liner material. If the local soil does not possess the property of low permeability, additives in the form of natural clays or commercially available clays may be mixed with local soils to form amended soil liners.

Various types of soil deposits are found in Kerala. Southern region of the state has deposits of kaolinite at Thonnakkal region of Thiruvananthapuram district and middle region has high plasticity soils at Kuttanad of Allappuzha district. Laterite is common at all places of the state. Studies are already done on the acceptance of laterite as part of amended soil liner. Hence, in this report, two amended soil liners are designed one with Kuttanad soil, bentonite and fine sand and the other with Kaolinite, bentonite and fine sand.

2 LITERATURE REVIEW

To prevent the leakage of leachate from the landfill, liners are designed. This is done using very low permeable clay like bentonite. Local soil is sometimes mixed with bentonite to form amended clay liners. There are various specifications for a soil to be used for liner. All authors specify a minimum hydraulic conductivity of 1×10^{-7} cm/s [1], [2].

Landfill liner can be prepared by using locally available soil if it

satisfies certain conditions, the most important condition being a low hydraulic conductivity of less than 1×10^{-7} cm/s. Since the determination of plasticity index is too time consuming, the primary design can be done such that the resultant mix should have a minimum of 20 to 30% fines and the percentage gravel should not exceed 30% [1], [2], [3]. The maximum particle size is restricted to 25- 50mm. the plasticity index should be between 12 and 30%. This design can be adopted once it is found that the mix has minimum shear strength of 200 kPa, volumetric strain is less than 4%. To form amended clay liners, well graded soil has to be mixed with 5 to 10 % bentonite whereas uniformly graded soil has to be mixed with 10 to 15 % bentonite. Medium to high plasticity clays (15 to 25 %) can be added to local clays if bentonite is not available. 20% of bentonite is suitable for amended clay liners [4].

3 EXPERIMENTAL PROGRAMME

3.1 Design of Liner

The main requirement of amended clay liner includes a minimum hydraulic conductivity of 1×10^{-7} cm/s. For a soil to have such a low value of permeability it should contain a minimum of 20- 30% fines and the plasticity index should be a minimum of 7- 10%. The properties of soils used for the preparation of liner are given in table 1.

3.1.1 Materials

i. Kuttanad Soil

Kuttanad soil is obtained from Kuttanad region in Allappuzha district of Kerala. These are dark brown colored medium sensitive alluvial deposits. The dominant mineral constituents in this clay are kaolinite and illite. They are characterized by high compressibility, low shear strength and high percentage of organic matter.

ii. Bentonite

Bentonite is naturally occurring clay with high swelling capacity, high ion exchange capacity and very low water permeability. The term bentonite represents either calcium montmorillonite or sodium montmorillonite. The bentonite used in this study is calcium montmorillonite.

iii. Kaolinite

Kaolinite is white clay obtained from Thonnakkal region of Trivandrum of Kerala. It is low expansive clay. It is clay with very little percentage of fine sand.

iv. Aditive

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Fine sand was used as additive for satisfying two purposes. First, Kuttanad clay and kaolinite alone could not produce the required amount of sand size particle as per literature. Second, sand was required to reduce the amount of shrinkage cracks.

TABLE I
PROPERTIES OF BENTONITE, KUTTANAD SOIL AND KAOLINITE

Property	Value		
	Bentonite	Kaolinite	Kuttanad soil
Specific Gravity	2.6	2.43	2.36
Free Swell (ml/ 2g)	17	2	4
Liquid Limit (%)	265	55	112
Plastic limit (%)	53.23	29.3	62.32
Percentage Clay (%)	66	44	30
Percentage Silt (%)	34	49	54
Percentage Fine Sand (%)	-	7	9
Percentage Medium Sand (%)	-	-	5
Percentage Coarse Sand (%)	-	-	2

3.1.2 Mix Design

In the study, two liners were developed. The first liner, Liner 1 contained bentonite, Kuttanad soil and fine sand. The second liner, Liner 2 was made by mixing bentonite, kaolinite and fine sand. To develop the mix, the percentage of bentonite was fixed to be 10%. Various trial mixes were then tried and finally a mix was obtained such that the resultant particle size distribution has the percentage of clay, silt and sand within the specifications given by various authors. Table 2 and 3 give the composition of liners designed.

TABLE II
COMPOSITION OF LINER 1

Quantity of	100 g Bentonite	650 g Kaolinite	250 g Fine sand	Total: 1000 g
Clay (g)	66	209.69	0	275.69
Silt (g)	34	377	0	411
Sand (g)	0	62.92	250	312.92

TABLE III
COMPOSITION OF LINER 2

Quantity of	100 g Bentonite	650 g Kaolinite	250 g Fine sand	Total: 1000 g
Clay (g)	66	286	0	352
Silt (g)	34	318.5	0	352.5

Sand (g)	0	45.5	250	295.5
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3.1 Check for design and Characterisation of amended soils

The check for design is done by finding whether the plasticity indices of the liners developed are within the limits.

3.2.1. Liner 1

The plasticity index of liner 1 was obtained as 29.23%. Since the value is greater than 12% and less than 30%, the mix design can be adopted. The properties of the liner 1 are summarized in table 4.

TABLE IV
PROPERTIES OF LINER 1

Property	Value
Liquid Limit (%)	57.7
Plastic Limit (%)	28.47
Maximum Dry density (g/cc)	1.584
Optimum Moisture Content (%)	20.5

3.2.1. Liner 2

For liner 2, the liquid limit and plastic limits were determined as 55.57 and 25.04% respectively resulting in a plasticity index of 29.54%. Since the value is greater than 12% and less than 30%, the mix design can be adopted. The properties of the liner 1 are summarized in table 5.

TABLE V
PROPERTIES OF LINER 2

Property	Value
Liquid Limit (%)	55.57
Plastic Limit (%)	25.04
Maximum Dry density (g/cc)	1.4
Optimum Moisture Content (%)	27

The composition and plasticity indices of the two liners satisfy the requirements for having low permeability. So the two mixes can be used as amended soils.

4 CONCLUSION

Landfill liners are constructed with very low permeability clay. Local soils are mixed with medium to high plasticity clays like bentonite to form amended soil liners. Two amended soil liners are designed one with soil from Kuttanad region, fine sand and bentonite and the other with Kaolinite, fine sand and bentonite. The designs have been checked and the properties of the liner were determined.

5 REFERENCES

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