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Kuttanad Clay Amended Laterite as a Landfill Liner for Waste Disposal Facilities

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Abstract: ***In a developing nation like India, large amount of waste is generated due to human activities. Human health is severely affected by increasing amount of municipal solid waste. One way of disposing the waste is landfilling. An engineered landfill system should contain a bottom liner, a side liner and a cover system. A landfill liner is a low permeable barrier with hydraulic conductivity less than $1x10^{-7}$ cm/sec. Landfill liner prevents the migration of leachate into ground water. Traditionally these barriers are constructed using locally available clayey soil. The soil locally available in the landfill site cannot be used as a liner material because of its higher hydraulic conductivity. This study makes an attempt to produce a liner by mixing locally available laterite soil and clay from nearby area. Kuttanad clay is used as an additive to the local laterite soil. The amendment of local laterite soil with Kuttanad clay is carried out for reducing the hydraulic conductivity of the laterite soil to the desirable level. The use of laterite soil can improve the shear strength of the liner compared to using clay as a liner material. In this paper different conditions to be satisfied for a liner are checked by laboratory experiments. The final mix is selected based on the hydraulic conductivity of the liner mix.***

Keywords: Landfill, Clay, Hydraulic conductivity.

1. Introduction

Disposal of waste such as open dumping leads to the pollution of air, water, and land. Municipal solid waste in India increases rapidly in few decades because of the rapid population and economic growth of the country. The waste will generate leachate. This may percolate to the ground water and may cause contamination of ground water and underlying water bodies. The waste disposal technology includes from open pits to engineered design approach. Large amount of waste is openly dumped without considering the environmental considerations. Because of the increasing ground water contamination environmentally sound waste disposal and containment structure have an important role. For effective disposal of waste some scientific methods are needed. An engineered landfill is an effective method of disposal of waste without causing pollution to the living environment. In a landfilling structure the bottom liner play an important role because the migration of chemicals from the contained waste to the ground water depends on the hydraulic conductivity of the liner material. The liner material also should satisfy some conditions such as activity, plasticity index, coarse fraction and percentage fines. Natural, synthetic and some combination of some natural and synthetic materials can be used as the liner materials. Natural clays and some byproducts can also use as the liner material. The natural clays can be replaced by certain geomaterials such as sand – bentonite mixtures, foundry sand, fly ash, wood ash and fly ash amended tire rubber. Significant money savings can be attained by using certain alternative materials. Cost effectiveness can be achieved by using locally available materials. But these locally available materials may not be suitable because of their higher hydraulic conductivity. For reducing hydraulic conductivity these local soil has to be treated with some low permeable materials. Bentonite, lime, fly ash were used as the treating materials. In this study an attempt is made by producing liner by using two natural materials. The locally available laterite soil is treated with the kuttanad clay in order to reduce the hydraulic conductivity and thereby making it suitable for liner construction.

1.1. Literature review

Landfill liners are constructed based on some standards obtained from extensive research. The liner material can be classified as unsuitable, marginal and suitable. Plasticity index between 6 and 12 are classified as marginal and the materials which have plasticity index above 12 are classified as acceptable [1]. For controlling and retarding the migration of leachate from the landfill, the liner should have hydraulic conductivity less than $1x10^{-7}$ cm/sec [2]. For attaining hydraulic conductivity of $1x 10^{-7}$cm/sec the percentage fines should be more than 30%, activity should be greater than 0.3, liquid limit should be greater than 20 and the percentage of clay should be greater than 15% 3].Natural soil which is compacted to its desired density can be used as bottom liner in waste containment landfill. Locally available materials which can provide low hydraulic conductivity can be used as landfill liners. Crushed shale was used as landfill liner which is a local material in northern Oman [4]. In Turkey, the locally available material sepiolite can be used as a liner material which can provide considerable cost savings and which provide high unconfined compressive strength with low hydraulic conductivity [5]. Cost effectiveness can be achieved by using some byproducts such as red mud and the addition of which to the clay liners can improve the compressive strength of clay [6]. Some synthetic materials can be used as landfill liner if there is an unavailability of natural material. Some recycled materials such as fly ash can also be used for construction of liner [7]. Compacted mixtures of bentonite and sand can be used as an alternative. Bentonite has very low permeability suitable for liner material. If local soil is mixed with bentonite is used as a liner considerable cost savings along with low permeability can be achieved [8].

1.2. Methodology

In the first step of the study the literatures about the liner were studied. In this phase few papers about the liner, selection of liner, suitability of different materials as liner etc. were studied and reviews were prepared related to the paper. Based on the literatures and other studies certain objectives were selected considering the scope of the study. In the seconed phase of the project the samples were collected and definite mix proportions were selected based on the reviewed literatures. Mix proportions were selected based on percentage of fines and percentage of sand. Selected mix proportions were M1, M2, M3, M4 and M5 for the laterite with Kuttanad clay. In the third phase of the study laboratory tests were conducted on the mixes for the determination of plasticity index, shear strength, and hydraulic conductivity and results are interpreted. In the fourth phase the result is interpreted and a final mix has to be selected for both laterite - kuttanad clay.

2. Materials and Methods

The materials used for the study are local laterite soil and the clay soil. The laterite soil is collected from the local area in Ernakulum district and the clay soil is collected from kuttanad area in Alappuzha district in Kerala. The samples were taken from a depth of 1m. The laterite soil passing through 4.75mm sieve is used for the study. The properties of laterite soil is shown in Table 1 and the particle size distribution curve of laterite soil is shown in Fig.1.The index and engineering properties of the kuttanad clay is shown in Table 2. The particle size distribution of the kuttanad clay is shown in Fig.2 The experimental programs conducted were hydrometer analysis, Atterberg limits. Compaction test, unconfined compression test, Permeability test. The tests were conducted on the liner mixes which contain laterite amended with 10%, 13%, 16%, 19% and 20% kuttanad clay.

Table 1: Engineering properties of laterite

Properties	*Values*
Specific gravity	2.73
Liquid limit	43%
Plastic limit	22.3%
Plasticity Index`	20.7
Percentage of Clay size particles	16%
Percentage of Silt size particles	23.1%
Percentage of Sand size particles	60.9%
Optimum moisture content	19.8%
Maximum dry density	1.95g/cm^3
Unconfined Compressive Strength	117.68kPa

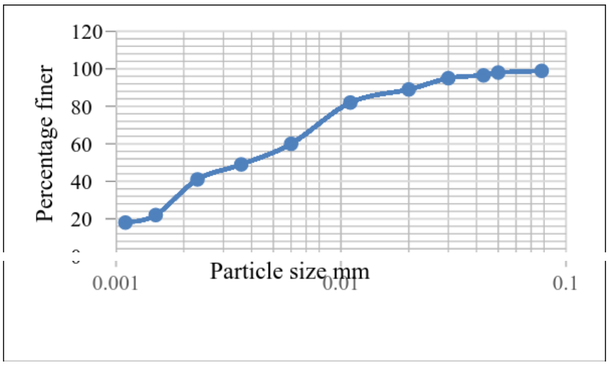

Figure 1: Particle size distribution of laterite

Table 2: Engineering properties of kuttanad clay

Properties	*Values*
Specific gravity	2.45
Liquid limit	91%
Plastic limit	33%
Plasticity Index`	58
% of Clay size particles	68%
% of Silt size particles	21.7%
% of Sand size particles	10.3%
Optimum moisture content	28%
Maximum dry density	1.65g/cm^3
Unconfined Compressive Strength	23.68kPa

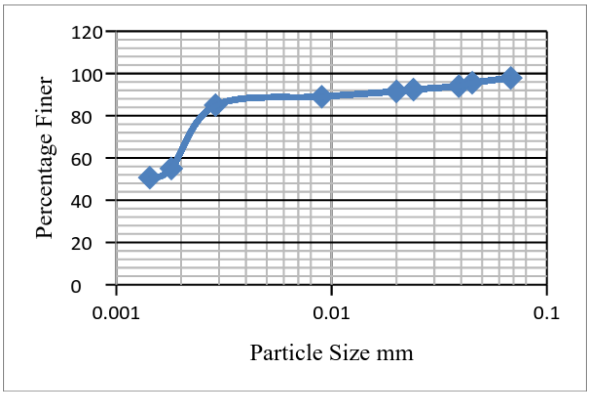

Figure 2: Particle size distribution of kuttanad clay

Table 3: Selected mixes

Sl No	*Mix*	*% of laterite*	*% of kuttanad clay*
1	M1	46	22.5
2	M2	49.6	24.8
3	M3	54.9	27.4
4	M4	57.5	28.9
5	M5	59.8	29.6

3. Result and Discussion

3.1. Determination of liquid limit, plastic limit and plasticity index of liner mixes

Table 4: Liquid limit, plastic limit and plasticity index test result

Sl No	*Mix*	*Liquid Limit %*	*Plastic Limit %*	*Plasticity Index*
1	M1	46	22.5	23.5
2	M2	49.6	24.8	24.8
3	M3	54.9	27.4	27.5
4	M4	57.5	28.9	28.6
5	M5	59.8	29.6	30.2

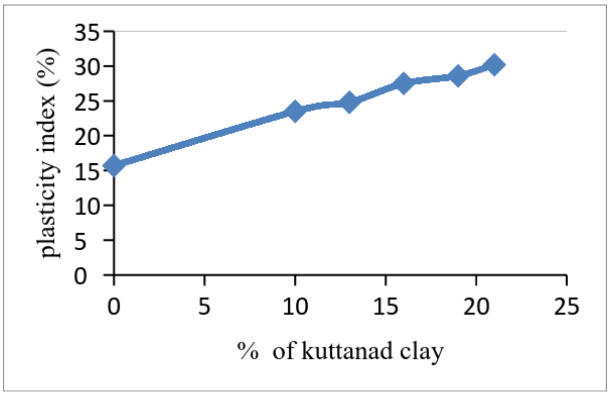

Figure 3: Variation of plasticity index with clay content

From figure 3 Plasticity index value increases with increase in clay content. As percentage of Kuttanad clay increases the availability of clay particles in the given soil matrix increases the plasticity characteristics by taking more water to deform and filling up of the voids by these clay particles make the mix impervious. The plasticity index value is between 12 and 65%, indicates that the blended soil can be easily compacted on field and it only generate a lesser number of desiccation cracks because the plasticity index less than 65%.

3.2. Determination of optimum moisture content ana maximum dry density

Table 5: Compaction test results

Sl No	*Mix*	*% of Laterite*	*% of clay*	*O MC (%)*	*MDD g/cm³*
1	M1	90	10	20.1	1.92
2	M2	87	13	21.2	1.89
3	M3	84	16	22.3	1.82
4	M4	81	19	22.9	1.76
5	M5	79	21	23.6	1.73

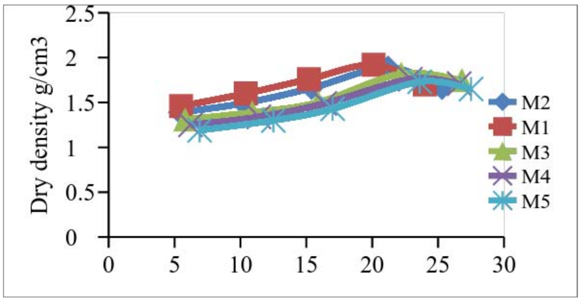

Figure 4: OMC and MDD graph of selected mixes

Figure indicates that with increase in percentage of Kuttanad clay decreases maximum dry densities. Decrease in dry densities is due to formation of flocculent structure by occupying fewer solids in a given volume.

The decrease in maximum dry unit weight with increase in clay content may be attributed to high swelling characteristics of clay that forms a gel called as diffused double layer around soil particles. The increase in optimum moisture contents is due to increase in percentage of clay content in a given mix and continued with increases the percentage of Kuttanad clay, they require more water to coat the soil particles to slide one over the other.

3.3. Unconfined compressive strength of the mixes

Table 6: UCC test results

Sl No	*Mix*	*UCS (kPa)*	*Cohesion (kPa)*
1	M1	115.08	56.04
2	M2	105.96	53.46
3	M3	103.64	51.82
4	M4	101.35	50.65
5	M5	99.87	49.9

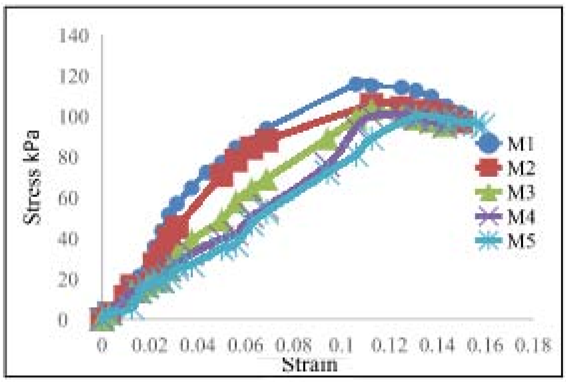

Figure 5: Variation of UCS with addition of kuttanad clay

The unconfined compressive strength of laterite decreased with increase in the clay content. Unconfined compressive strength of of laterite amended with different percentage of kuttanad clay is summarized in table 6 From the Figure 5 indicates that with an increase in clay content from 0 to 21% decreases the unconfined compressive strength from 117.75 kPa to 99.87 kPa.

3.4. Activity of selected mixes

Table 7: Activity of selected mixes

Mix	*Percentage of Kuttanad Clay*	*Activity*
M1	10	1.15
M2	13	1.16
M3	16	1.21
M4	19	1.22
M5	21	1.24

As per the criteria of a liner mix the activity value of the liner mix should not be less than 0.3 and in no case the hydraulic conductivity of 1x 10^{-7} cm/s can be achieved using the clay with an activity less than 0.14. From the Table 7 values the activity of each mixes were greater than 0.3. Hence it is satisfied.

3.3. Determination of Hydraulic conductivity Table

Table 8: Hydraulic conductivity of mixes

Mix	*Percentage of Kuttanad Clay*	*Hydraulic Conductivity (cm/sec)*
Laterite	0	$9.19X10^{-5}$
M1	10	$1.96X10^{-6}$
M2	13	$6.13X10^{-7}$
M3	16	$2.17X10^{-7}$
M4	19	$8.51X10^{-8}$
M5	21	$4.32X10^{-8}$

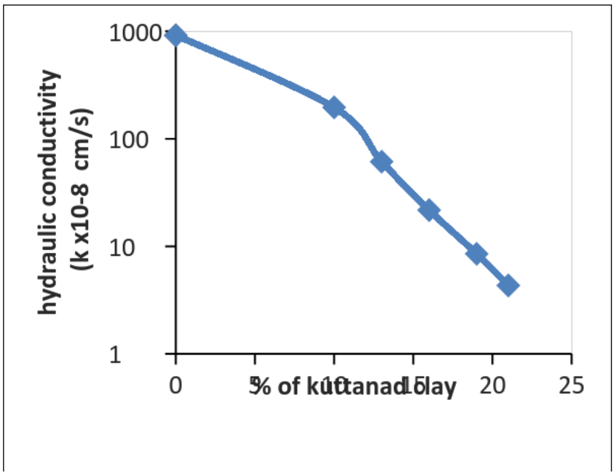

Figure 6: Variation of UCS with addition of kuttanad clay

From the Figure 6 it is identified that increase in the percentage of Kuttanad clay decreases the coefficient of permeability in the given laterite- clay mix. The local laterite soil has higher coarse fraction, addition of clay reduce the hydraulic conductivity by filling the voids in the mix. Filling of the voids by the fines make them impervious by reducing void ratio and hydraulic conductivity comes to 10^{-7} cm/sec and also obtained further lower values.

4. Conclusion

Five mixes were selected such that the conditions of gradation were satisfied. Plasticity index of three mixes were within the acceptable range of greater than 12. Unconfined compressive strength of the mixes reduced from 115.75kPa to 99kPa addition of Kuttanad clay from 10 to 21%. Optimum moisture content is increased from 19.8% to 23.6% and maximum dry density reduces from 1.95 g/cm^3 to 1.7 g/cm^3 by the addition of Kuttanad clay from 10% to 21% to the laterite Activity is found to be greater than 0.3 for all mixes selected. Hence it satisfies the suitability criteria of liner.

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