International Journal of Scientific Engineering and Research (IJSER)
www.ijser.in
ISSN (Online): 2347-3878, Impact Factor (2015): 3.791

Study on Amended Soil Liner with Additive

Karthika S Nair[1], Dipty Sarin Issac[2]

[1]PG Student, Department of Civil Engineering, Saintgits College of Engineering, Pathamuttom, Kottayam, Kerala, India

[2]Faculty, Department of Civil Engineering, Saintgits College of Engineering, Pathamuttom, Kottayam, Kerala, India

Abstract: ***Landfill is a primary method for the disposal of waste. The waste is contained by a liner and a cover system. Liner system has great importance in preventing contact between waste and environment. But the use of high tech liner system like GCL results a substantial increase in the cost of waste disposal. Hence the usage of compacted clay liner is a common and efficient method of practice. Landfill liner can also be prepared using locally available soil .The locally available soil can be mixed with medium to high plastic clay or commercially available clay like bentonite form amended soil liner. The resultant liner mix should possess a permeability of less than 1×10^{-7} cm/s. Several researchers have carried out investigations for efficient and economic liners. This study makes an attempt to produce a liner using locally available lateritic soil, bentonite, and additive. Lateritic soil is mixed with bentonite in different percentages from 0 to 60%. Then the optimum combination of bentonite-laterite mix for liner application determined based on permeability. From the optimum mix bentonite replaced by fly ash upto 50% and studied the variation in properties such as consistency limits, dry density, OMC, permeability and UCC strength of each mix with the addition of fly ash.***

Keywords: Landfill, liner, locally available soil, bentonite, fly ash.

1. Introduction

The generation of municipal solid waste increases with increase in economic growth and rapid urbanization. It has a potential impact on human health and sustainable development of cities. Open dumping, incineration, and land filling are the traditional methods used for waste management. The open dumping creates a direct contact with environment, and which leads to environmental as well as health problems. Hence compared to the open dumping and incineration methods, landfill is more efficient and economical way of waste disposal. Landfill comprises of liner system, cover system, leachate collection system, gas collection system, surface water drainage system and environmental monitoring system. In which low permeable liner system is the integral part of the landfill, which minimize leachate percolation into surrounding. There are certain specification should be satisfied for a material to be used as a liner. In which the most important condition is lowest permeability of less than 1×10^{-7} cm/s. For attaining the lowest permeability, liner material should contain a minimum of 20-30% fines and less than 30% gravel. Maximum size of the particle in the liner mix limited to a range of 25-50 mm. The liquid limit should be greater than 30% and plasticity index should be greater than 15%. Also the percentage of clay should be greater than 25%. But the selection of liner material depends mainly on the waste type and landfill operations. The material selected should be compatible with contaminants. The leachate generated from waste should not degrade liner material. The commonly used liners are CCL, GCL and composite liners. But the usage of high-tech liner system like GCL may becomes uneconomical due its import from elsewhere. Similarly, if clay is not locally available for CCL application, then the cost of project comes to an intolerable level. Therefore it is of paramount importance to research new materials for landfill liner, with long term efficient waste containment properties. The amended soil liner is an economic alternative to use as liner. The locally available soil mixed with medium to high plastic clay or bentonite form amended soil liner. Bentonite is suitable clay for amendment, because of its low permeability and better retention capacity. But near disposal sites, its application may be extremely costly due to limited availability. Hence it is necessary to find alternative for bentonite. Fly ash is a waste product from coal industry. Usage of fly ash in amended soil liner is an economical and eco-friendly solution. In this work an attempt made to produce amended soil liner with an additive. Amended soil prepared using locally available lateritic soil and bentonite clay. From the optimum combination of amendment, bentonite replaced with fly ash producing liner mix.

With this in view, the present study examine the suitability of fly ash as an alternative for bentonite in amended soil liner material. Also the study aims to maximize the usage of fly ash for the liner application.

2. Literature review

Landfill liners constructed using very low permeable materials. For liner application permeability of locally available lateritic soil can be reduced through addition of bentonite [1]. The presence of lateritic soil in the liner material helps to absorb heavy metals from contaminated water there by it can act as a good sorbent [2]. For the usage of natural clay in liner application it should be amended with bentonite. Amendment with bentonite provide sustainable membrane behaviour, hence it can used over wide range of salt concentration [3]. Bentonite-sand mixtures can also used as liner material. Results show that the effect of organic and inorganic fluid on bentonite sand mixture is less compared to bentonite alone [4]. The usage of fly ash in liner application is found to be suitable. From GCL bentonite can replace by fly ash upto 40 %, and the resulting product possess a permeability of less than 1×10^{-7}cm/s [5]. 90% fly ash with 10% cement at 5% wet of optimum moisture content is also found to be satisfied for liner purpose [6]. For liner usage improvement of soil can carried out through fly ash addition. Addition of fly ash in soil improves the geotechnical properties, such as CBR value, bearing capacity etc. Since it is pozzolanic in nature, curing time has also great influence on properties of fly ash-soil mixtures [7] [8] [9].

3. Methodology

Initially an extensive literature study conducted on landfill liners, which includes its function, types and material suitability etc. Based on the literature study, objectives were selected considering the scope of work. As per objectives liner materials under study were collected and determined their properties. Then amended soil prepared using locally available lateritic soil and bentonite clay. Bentonite replaced with laterite from 0 to 60% form different liner mixes such as M, M1, M2, M3, M4, M5 and M6. Among the mixes the optimum combination of amendment determined based on permeability. From this mix bentonite replaced with fly ash upto 50%. For each mix determined the properties such as, consistency limits, dry density, optimum moisture content, permeability, and UCC strength. Finally a liner mix selected based on permeability.

4. Materials and properties

Materials used in this study include bentonite, laterite and fly ash. Various tests were conducted to determine the properties of materials. The bentonite clay used in this study is calcium bentonite, collected from Ernakulam, Kerala, India. Lateritic soil used in the study is locally available, collected from Kottayam, Kerala, India and fly ash from Velloor HNL, Kottayam, Kerala, India; it is of class F fly ash. Properties of the materials are shown in Table 1. The particle size distribution curve of bentonite, fly ash, and laterite are shown in Figure 1, 2 and 3 respectively.

Table 1: Properties of bentonite, fly ash and laterite

Property	*Bentonite*	*Fly ash*	*Laterite*
Specific gravity	2.1	2.51	2.24
Liquid limit (%)	479.9	Non plastic	48.57
Plastic limit (%)	41	Non plastic	23.57
Plasticity index	438.9	-	25
Shrinkage limit (%)	Very high shrinkage	30.51	20.83
Optimum moisture content (%)	42	50	18
Maximum dry density(g/cm^3)	1.1	1.02	1.74
UCC (kN/m^2)	71.87	35.99	16.8
Permeability(cm/s)	21.53×10^{-9}	1.25×10^{-4}	6.36×10^{-4}

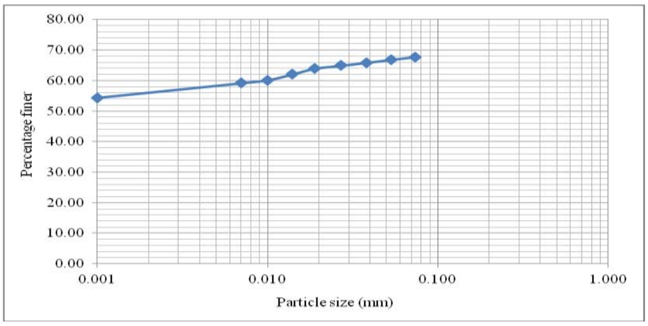

Figure 1: Particle size Distribution Curve-Bentonite

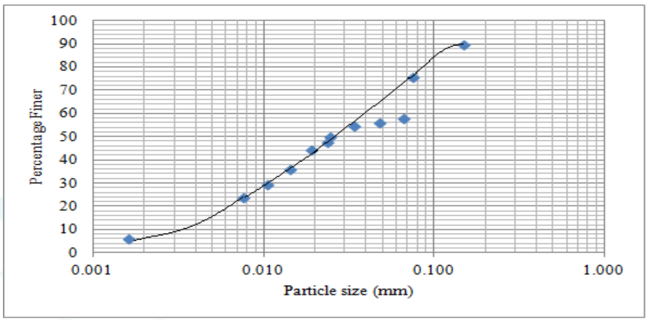

Figure 2: Particle size Distribution Curve-fly ash

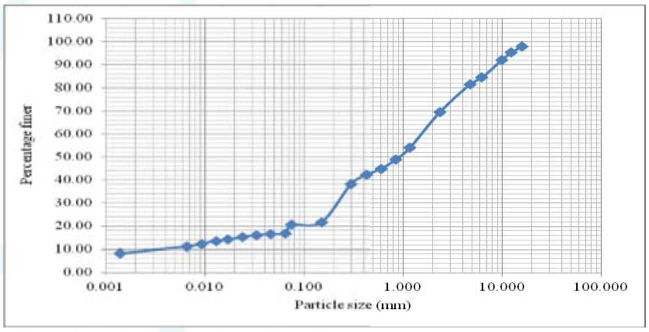

Figure 3: Particle size Distribution Curve-laterite

5. Results and discussions

5.1 Test on bentonite-laterite mixes

As per IS: 2720 Part 7 standard proctor test conducted in order to obtain compaction characteristics of amended soil (bentonite-laterite) mixtures. Compaction test results are shown in Table 2 and Figure 4. Permeability of each mixes filled in MDD and OMC were determined by conducting falling head test as per IS: 2720 (Part I7)-1986, the test results are shown in Table 3.

Table 2: Compaction test results of bentonite-laterite mixes

Mix	*MDD (g/cm^3)*	*OMC (%)*
M - 100% bentonite and 0% laterite	1.11	42
M1- 90% bentonite and 10% laterite	1.19	39
M2- 80% bentonite and 20% laterite	1.20	38
M3- 70% bentonite and 30% laterite	1.22	36
M4- 60% bentonite and 40% laterite	1.29	29
M5- 50% bentonite and 50% laterite	1.34	27
M6- 40% bentonite and 60% laterite	1.39	26

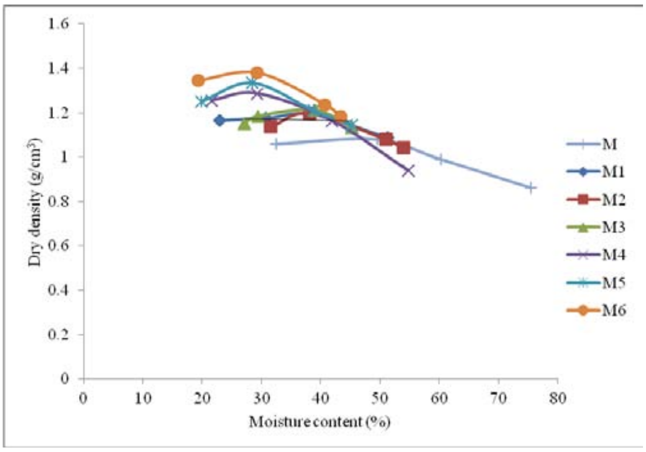

Figure 4: Compaction characteristics of Bentonite-laterite mixes

Table 3: Permeability test results of bentonite-laterite mixes

Mix	*Permeability (cm/s)*
M - 100% bentonite and 0% laterite	21.53×10^{-9}
M1- 90% bentonite and 10% laterite	19.3×10^{-9}
M2- 80% bentonite and 20% laterite	14.8×10^{-9}
M3- 70% bentonite and 30% laterite	8.9×10^{-9}
M4- 60% bentonite and 40% laterite	4.47×10^{-9}
M5- 50% bentonite and 50% laterite	10.32×10^{-9}
M6- 40% bentonite and 60% laterite	18.5×10^{-9}

- Results show that the addition of laterite to bentonite increases dry density from 1.11 g/cm^3 to 1.39 g/cm^3 and decreases OMC from 39% to 26%. Hydraulic conductivity decreases upto 40% then increases. The reason for this can be attributed to the fact that, the voids created through partial replacement of bentonite with laterite are filled by finer particle of bentonite. Hence the resultant mix shows higher dry density and water required to reach the maximum dry density is lesser. Upto certain limit the voids can be filled efficiently, beyond that limit voids increases with laterite addition. So that permeability increases beyond 40% laterite content.
- Mix with 60% bentonite and 40% laterite having lowest permeability of 4.47×10^{-9} cm/s obtained as optimum mix (M4) of bentonite and laterite.

5.2 Test on bentonite-laterite-fly ash mixes

From the optimum combination (M4 mix) of bentonite-laterite mix, fly ash replaces, bentonite upto 50% and conducted test on each trial mixes. Consistency limits, compaction characteristics, permeability and UCC strength of each mix were determined. Variation of consistency limits found as per IS: 2720 (Part 5)-1985, IS: 2720 (Part 6)-1972 with addition of fly ash in amended soil shown in Table 4 and Figure 5. As per IS: 2720 Part 7 Standard proctor test conducted in order to obtain compaction characteristics of bentonite-laterite-fly ash mixes. Compaction test results are shown in Table 5 and Figure 6. Permeability of each mixes filled in MDD and OMC were determined by conducting falling head test as per IS: 2720 (Part I7)-1986, the test results are shown in Table 6. UCC strength of each mixes were conducted according to IS: 2720 (Part 10)-1973, shown in Table 7 and Figure 7.

Table 4: Consistency limits of bentonite-laterite-fly ash mixes

Mix	*LL (%)*	*PL (%)*	*PI (%)*
M4- 60% bentonite and 40% laterite 0% fly ash	203.6	37.5	166.1
M41-10% of bentonite replaced by fly ash from M4	180	33.33	146.67
M42-20% of bentonite replaced by fly ash from M4	171.89	31.25	140.64
M43-30% of bentonite replaced by fly ash from M4	158.4	30	128.4
M44-40% of bentonite replaced by fly ash from M4	141.45	20	121.45
M45-50% of bentonite replaced by fly ash from M4	102	16.67	85.33

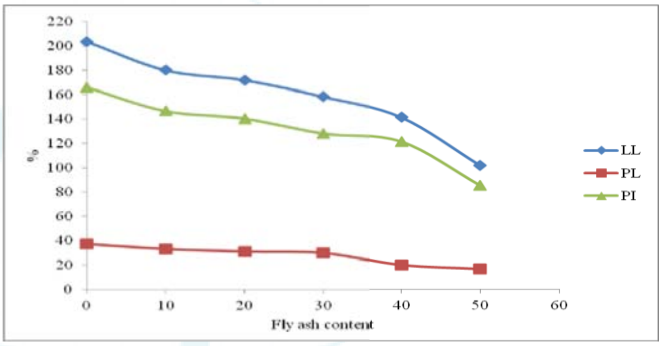

Figure 5: Variation in consistency limits of bentonite - laterite-fly ash mixes

Table 5: Compaction test results of bentonite -laterite-fly ash mixes

Mix	*MDD (g/cm^3)*
M4- 60% bentonite and 40% laterite 0% fly ash	1.290
M41-10% of bentonite replaced by fly ash from M4	1.390
M42-20% of bentonite replaced by fly ash from M4	1.344
M43-30% of bentonite replaced by fly ash from M4	1.342
M44-40% of bentonite replaced by fly ash from M4	1.340
M45-50% of bentonite replaced by fly ash from M4	1.338

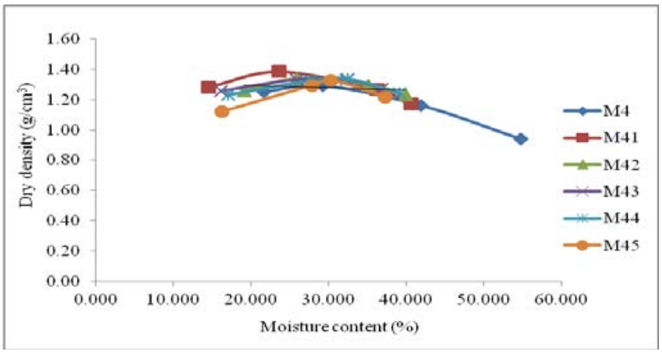

Figure 6: Compaction characteristics of bentonite-laterite-fly ash mixes

Table 6: Permeability test results of bentonite-laterite-fly ash mixes

Mix	*Permeability (cm/s)*
M4- 60% bentonite and 40% laterite 0% fly ash	4.47×10^{-9}
M41-10% of bentonite replaced by fly ash from M4	8.32×10^{-9}
M42-20% of bentonite replaced by fly ash from M4	9.12×10^{-9}
M43-30% of bentonite replaced by fly ash from M4	1×10^{-8}
M44-40% of bentonite replaced by fly ash from M4	9.13×10^{-8}
M45-50% of bentonite replaced by fly ash from M4	1.63×10^{-5}

Table 7: UCC strength results bentonite-laterite-fly ash mixes

Mix	*UCC (kN/m²)*
M4- 60% bentonite and 40% laterite 0% fly ash	27.03
M41-10% of bentonite replaced by fly ash from M4	31.594
M42-20% of bentonite replaced by fly ash from M4	43.194
M43-30% of bentonite replaced by fly ash from M4	61.102
M44-40% of bentonite replaced by fly ash from M4	79.234
M45-50% of bentonite replaced by fly ash from M4	57.226

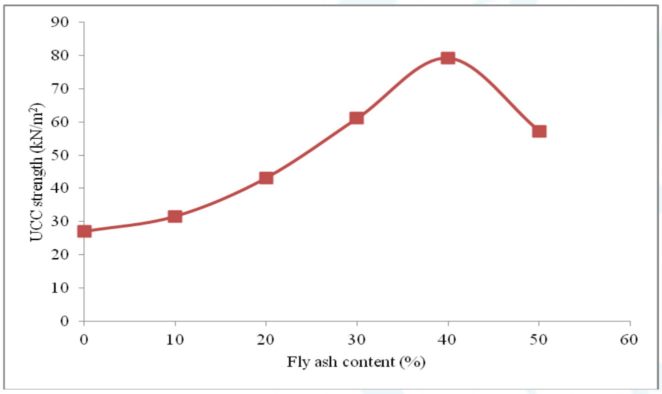

Figure 7: UCC strength vs. fly ash content of bentonite-laterite-fly ash mixes

- From the optimum mix bentonite replaced by fly ash from 0 to 50 % results, decrease in consistency limits such as liquid limit, plastic limit, and plasticity index. It is due to the non plastic nature of fly ash. Since bentonite is highly plastic and fly ash is non plastic in nature, replacement of bentonite with fly ash reduces plasticity.
- Compaction characteristics, shows that replacement of 10% bentonite by fly ash from M4 mix results an increase in dry density from 1.290 g/cm^3 to 1.390 g/cm^3 and decrease in OMC from 29% to 25%. This is due to the effect of fly ash weight. In this study bentonite used is found to be lighter than fly ash. Hence with the addition of fly ash, initially increases the dry density. But further addition, gradually decreases dry density from 1.390 g/cm^3 to 1.338 g/cm^3, this is because of the formation of voids. For those mixes optimum moisture content increases from 25 % to 32%, this was due to the increased need of water for hydration reaction of cementious fly ash.
- Permeability of M4 mix increases from 4.47×10^{-9} cm/s to 1.63×10^{-5} cm/s with the replacement using fly ash. Bentonite forms a diffused double layer in amended soil mix to prevent fluid percolation. But the addition of fly ash, to the mix disturb double layer. This is due to cation exchange occurring between bentonite and fly ash.
- Upto 40% replacement of bentonite with fly ash leads to increase in UCC strength from 27.03 kN/m^2 to 79.234 kN/m^2 then decreases to 57.226 kN/m^2.

Above results shows that, for to maximize the usage of fly ash, it can replace bentonite upto 40% from amended soil liner. Which satisfies the requirement of the permeability of liner ($<1\times10^{-7}$cm/s). Properties of the resultant mix and particle size distribution curve are shown in Table 8.

Table 4.7 Properties of liner Mix

Properties	*Results*
Specific gravity (G)	2.15
Gravel, >4.75 (%)	5
Sand, 4.75-0.075 (%)	23
Silt, 0.075-0.002 (%)	42
Clay, ≤0.002 (%)	30
Liquid limit (%)	141.45
Plastic limit (%)	20
Plasticity index (%)	121.45
Optimum moisture content (%)	31
Maximum dry density (g/cm³)	1.341
Unconfined compressive strength (kN/m²)	79.234
Permeability (cm/s)	9.13×10^{-8}

6. Conclusion

Following conclusions are obtained from the present experimental studies.

- 60% bentonite with 40% laterite is considered as optimum mix of amended soil based on permeability. For which a lowest permeability of 4.47×10^{-9} cm/s is obtained.
- In economic view, for to maximize the usage of fly ash, 40% bentonite can be replace from the amended soil liner mix. It is found to be suitable for liner application, since the permeability of resulting mix shows less than 1×10^{-7} cm/s.
- The selected liner shows a permeability of 9.13×10^{-8} cm/s.

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