Session III

GEOTECHNICAL AND STRUCTURES

Development of a landfill clay liner using locally available expansive soil

W K A P Abeyrathne[1], K M T Pushpakumara[2], R K S P Ranaweera[3], Dr. N H Priyankara[4] and Dr. A M N Alagiyawanna[5]

Abstract

Solid waste is a growing problem in urban areas of Sri Lanka and management of waste, both liquid and solid has become a critical environmental concern due to the absence of engineered methods of disposing waste. Development of a simple engineered landfill facility utilizing a locally available material to suit landfill liner requirements is the most economical and the timely solution to this problem. In the present study, it was investigated the suitability of expansive soil which is commonly available in the south arid zone of Sri Lanka to use as clay liners in landfill facilities. The soil was improved by the addition of commercially available Bentonite to build a low hydraulic conductivity barrier. Further, the long term effect of soil -leachate interaction on hydraulic conductivity of the suggested liner was studied. Results showed that the engineering properties of expansive soil can be improved by the addition of bentonite to meet the landfill liner requirements. However, the original engineering properties of soil-bentonite mixtures were significantly affected by the leachate interaction over a period of time.

1. Introduction[1]

Currently, the attention given to the solid waste management in dry zone especially in arid zone of the country is very low due to the fact that all most all the major cities in Sri Lanka are situated in wet zone. However, solid waste management in dry zone is very important as the people depend very much on ground water for their drinking purposes and therefore, the contamination of ground water especially by the leachate generated in waste disposal sites should be kept at a minimum by following engineered waste disposal methodologies.

Engineered land filling is one of the best options to overcome the problems associated with contamination of ground water with leachate [1,2]. The liner system in an engineered landfill acts as a barrier for leachate and prevents the transportation of contaminants to the surrounding pollution prone environment. Hence liner system in a landfill becomes one of the critical design considerations [1,2]. A landfill liner is intended to be a low permeable barrier which is generally involves the application of clay or synthetic material layer [1,2,3]. Since, synthetic materials are very

[1,2,3,4,5] with the Faculty of Engineering, University of Ruhuna.
[1]arunodiabeyrathne@gmail.com;
[2]tharangapushpakumara@gmail.com;
[3]sunera.ranaweera@gmail.com;
[4]nadeej@cee.ruh.ac.lk;
[5]nayana@cee.ruh.ac.lk

expensive, compacted clay liners (CCL) are the most common liner system in developing countries.

Only a limited number of researches are reported with respect to investigation of suitability of expansive soil to use as a CCL material in landfill sites in Sri Lanka [3]. Therefore, a compacted clay liner was developed using expansive soil in this research study. Further, effect of soil-leachate interaction on engineering properties of suggested clay liner was investigated.

2. Methodology

In order to investigate the suitability of expansive soil to use as a clay liner, basic engineering properties of original soil collected from Hambantota were determined in the laboratory and presented in Table 1.

Table 1 – Engineering properties of soil-bentonite mixtures

Physical Property	Bentonite Percentage			
	0%	5%	10%	15%
Liquid Limit	41	41	43	49
Plastic Limit	24	28	30	22
Plasticity Index	17	13	13	27
Linear Shrinkage	16	17	19	31
Maximum Dry Unit Weight (kN/m^3)	17	16.9	16.6	16.3
Optimum Moisture Content (%)	19	19.5	22	28

Then different percentages of bentonite varying from 0-15% in steps of 5% on dry weight were mixed with expansive soil in order to improve the engineering properties of soil and depicted in Table 1. Further variations of hydraulic characteristics of soil-bentonite mixtures were studied.

Finally, the long term effect of leachate contact on hydraulic conductivity and volume change properties of liner material was evaluated by allowing the compacted soil-bentonite mixtures to interact with leachate for a period of four months.

3. Results and Discussion

3.1 Engineering Properties of Soil-Bentonite Mixtures

The variation of hydraulic conductivity of soil-bentonite mixtures is illustrated in Figure 1. It can be noted that the hydraulic conductivity of soil-bentonite mixtures decrease with the increase of bentonite.

With the increase of bentonite, which mainly consists of montmorillonite mineral, the diffused double layers surrounding the clay particles are getting thicker. (Figure 2) As a result, the flow paths between the double layers become pinched off and the hydraulic conductivity decreases. Further, according to the Gouy-Chapman theory, the hydraulic conductivity is inversely proportional to the double layer thickness. It can be noted that, a significant reduction in hydraulic conductivity with the addition of bentonite to the original soil. The clay liner requirement with respect to hydraulic conductivity, i.e. 1×10^{-9} m/s, can be achieved with the addition of 10% of bentonite to the original soil.

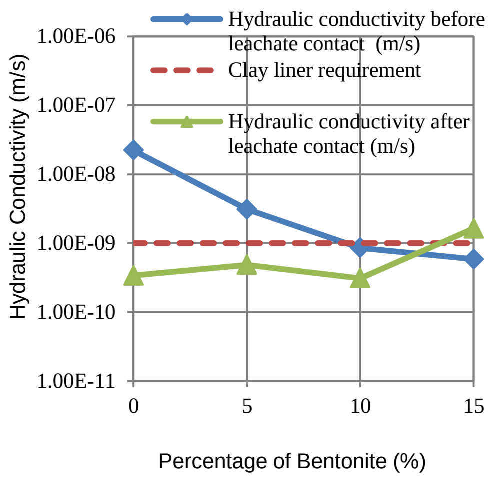

Figure 1 – Variation of hydraulic conductivity with bentonite percentage

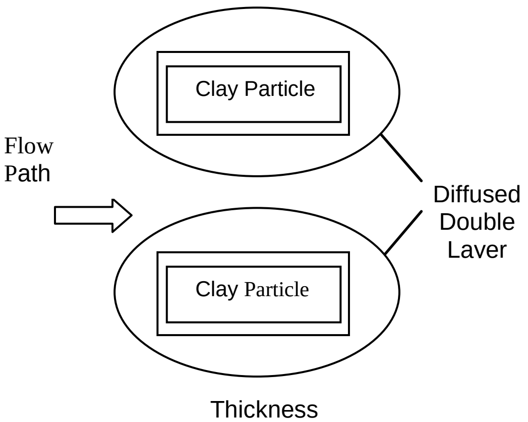

Figure 2 – Reduction of hydraulic conductivity due to increase of double layer thickness

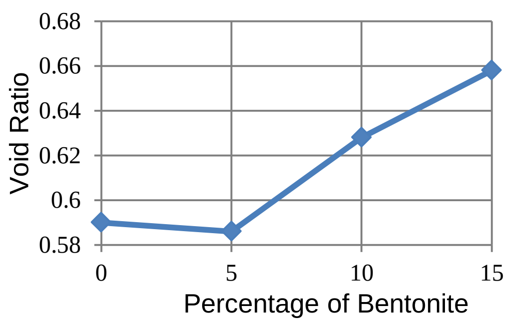

Figure 3 – Variation of void ratio with the addition of bentonite

On the other hand, due to the formation of diffused double layer creates repulsive forces along the sides of the clay particles making it difficult for individual clay particles stay closer to each other. Under these repulsive forces, these clay particles align themselves in a more parallel orientation forming a dispersed structure; hence increase the void ration over the increase of bentonite percentage. (Figure 3)

3.2 Engineering Properties of Soil-Bentonite Mixtures after Long Term Leachate Contact

The variation of hydraulic conductivity of compacted soil-bentonite mixtures after contact with leachate is also illustrated in Figure 1. It can be seen that hydraulic conductivity of original compacted expansive soil has been decreased significantly after the interaction with the leachate. However, with the increase of bentonite percentage the hydraulic conductivity has been slightly increased and when it comes to a bentonite percentage of about 14%, hydraulic conductivity has been increased comparing to the before leachate contact state. Consequently, clay liner requirement gets dissatisfied.

This reduction of hydraulic conductivity in original expansive soil after contact with the leachate is mainly associated with the clogging of soil particle tops due to precipitation of the suspended particles existing in the leachate and form a less permeable thin layer at the top. The slight increase of hydraulic conductivity over the soil-bentonite mixture after contact with the lachate is mainly due to reduction of diffuse double layer thickness, which causes increase of flow paths between the diffused double layers. In other words, soil-bentonite mixture has become less reactive (decrease swelling potential) after contact with leachate for a certain period. This is mainly due to the physic-chemical reactions between leachate and soil-bentonite mixture.

Similar results can be observed with respect to void ratio as shown in Figure 3 in soil-bentonite mixture after contact with leachate. The void ratio has been increased with the addition of bentonite, due to the effect of diffused double layer, where repulsive forces of clay particles increased the void spaces. The reduction of void ratio in the original expansive soil after interact with the leachate is mainly due to the precipitation of the suspended particles existing in the leachate, in the void spaces of soil, which leads to increase the volume of solid state in the soil; thus void ratio has been reduced.

4 Conclusions

Engineering properties of expansive soil can be well improved by mixing it with different percentages of bentonite. However, the rate of improvement of those properties gets reduced with the increasing bentonite percentage. Therefore, excessive addition of bentonite to expansive soil will not form a suitable mixture to suit clay liner requirements.

All the clay liner requirements other than the hydraulic conductivity get satisfied by the natural expansive soil itself and therefore hydraulic conductivity is the governing factor which determines the most efficient percentage of bentonite. According to the laboratory experiments it can be concluded that addition of 10% of bentonite by weight will yields the most economical soil-bentonite mixture to build clay liners in arid zone.

The original engineering properties of soil-bentonite mixtures can be significantly affected by leachate interaction over a period of time. After interact with leachate, the hydraulic conductivity has been significantly decreased in the original expansive soil whereas it has been slightly increased with the increase of bentonite percentage. Therefore, it can be concluded that, the satisfactory performance of the compacted clay liner is highly depends on the alteration of soil structure due to the soil-leachate interaction over a long period. These consequences will affect the satisfactory performance of the clay liner over time.

References

[1] A. Bagchi, *Design of landfills and integrated solid waste management*, 3rd edition, John Wiley and Sons Inc., pp 400, 2004.

[2] David E. Daniel, *Geotechnical practice for waste disposal*, 1st edition, Chapman and Hall, pp 97-186, 1993.

[3] S. Jayasekera, *Long term effects of landfill leachate on volume change and hydraulic conductivity properties of expansive clays*, Proceedings of the international conference on soil & rock engineering, 5-11 August 2007, Colombo, Sri Lanka, 2007.