Suitability of Geosynthetic Clay Liners based on Hydraulic Conductivity for Various Types of Leachate

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Abstract : A tremendous increase in the waste is observed specially in metropolitan cities with the increase in population and industrialization. Corresponding to this increase in the produced waste the number of landfill dumping sites are also on an increasing spree in most of the cities. A solution for the development of these dumping sites is provided by geosynthetic clay liners (GCLs) having low hydraulic conductivity and greater structural stability. GCLs are used as a part of liner system to contain the leachate percolation from solid waste management sites. GCLs are made by encapsulating bentonite between geotextiles (either woven or nonwoven), bonded together by needle-punching. Hydraulic conductivity of GCLs is dependent upon the chemical composition of bentonite as well as the chemical composition of leachate. In this study various commercially available GCLs are tested for their hydraulic conductivity for distilled water as well as for synthetically prepared leachates. A flexi wall permeameter apparatus is used for ascertaining the low hydraulic conductivities of different GCLs available. Economic feasibility of different available GCLs is also compared. Finally, suitability of GCLs based on type of waste for reducing the environmental impact due to landfill dumping sites is suggested.

***IndexTerms* - Geosynthetic clay liners (GCLs), flexi wall permeameter apparatus, low hydraulic conductivity, landfill dumping sites, synthetic leachate.**

I. Introduction

In last few decades, several variations geosynthetic clay liners (GCLs), have evolved as an alternative to compacted clay in liner systems. For waste containment units, GCLs may supplement or completely replace the required components of liner for low hydraulic conductivity (Daniel and Koerner, 1991). Several researchers in the past have (Daniel and Estornell, 1990; Eith et al., 1990; Grube, 1991; and Grube and Daniel, 1991) studied the various advantages and disadvantages of GCLs for waste containment applications with regard to different variations in the quality of wastes. In the year 2002, Zanzinger et al. mentioned that landfill site operators for waste management are highly interested in the use of GCLs, due to the ease of their installation. The GCLs typically comprise of powdered bentonite or granules of bentonite sandwiched between two geotextile carrier layers (Koerner, 1998). GCLs primary differ from each other with respect to the type of bentonite contained in the GCL and to the containment method (needle punching, stitch bonding, etc.). it has been reported by some research studies that under certain geochemical and mechanical conditions, damaged GCLs may heal themselves (Lin and Benson, 2000; Egloffstein, 2001, 2002; Witt and Siegmund 2001), provided adequate confining stress is present, for which the protective cover is sufficiently thick [at least 75 cm soil cover according to Egloffstein, 2001).

It can be seen from the literature that based on the chemical composition of bentonite and variation of its preparation, the engineering properties of the GCLs do change. It can also be noted from literature that the hydraulic conductivities of GCLs is affected by the chemical composition of the leachates. The research work described in this paper attempts to develop technical information on the engineering properties of commercially available GCLs in India, based on hydraulic conductivity for different chemical composition of leachates. The paper also gives an information with respect to the economic feasibility of the project and suggests suitability of different GCLs for different kinds of leachates. In this research work, 3 different GCLs are compared for hydraulic conductivity namely, bentonite particle GCL, polyester GCL, powdered bentonite GCL. The GCLs are tested for hydraulic conductivity with distilled water and two compositions of synthetically prepared leachates.

II. Methodology

Equipment named HS12.25 Flexi wall permeameter apparatus (Fig. 1) manufactured by HEICO Pvt. Ltd. is used for conducting permeability test on the three GCLs. The apparatus consisted of compressor for maintaining constant pressure, a motor for having de-aired water, a permeability cell where the sample is kept with porous stone and filter paper on both top and bottom of the sample (Fig. 2). The sample is subjected to confining pressure and back pressure simultaneously. Maximum time for measurement of hydraulic conductivity is taken as 100 days.

Three different types of GCLs were tested (Fig. 3), namely bentonite particle GCL (woven), polyester GCL (non-woven, adhesive based), powdered bentonite GCL (woven) in the permeability cell. Two synthetic leachates are prepared (SL1 and SL2), the chemical composition of which is shown in Table 1. Fluid used for swelling period and percolation period is same in all the cases. Synthetic leachate 1 (SL1) is a low ionic strength (10^{-3} mol/L) NaCl solution, whereas synthetic leachate 2 (SL2) is a high ionic strength (0.3 mol/L) $CaCl_2$ solution.

Figure 1 Photograph of flexible wall permeameter apparatus

Figure 2 Photograph of permeability cell

Bentonite Particle GCL | Polyester GCL | Powdered Bentonite GCL

Figure 3 Photographs of geosynthetic clay liners used for experimentation

Table 1 Chemical composition (mol/L) of synthetic leachates used for the study

Synthetic Leachate	Chemical Constituents							
	pH	Ca	Cl	Na	K	Mg	SO_4	HCO_3
SL1	7.5	2.0×10^{-6}	9.4×10^{-4}	1.1×10^{-3}	6.0×10^{-6}	3.9×10^{-6}	4.9×10^{-6}	9.4×10^{-5}
SL2	7.3	8.5×10^{-2}	1.7×10^{-1}	5.8×10^{-5}	1.1×10^{-5}	8.0×10^{-6}	3.8×10^{-6}	1.1×10^{-4}

III. Results and Discussion

The results obtained for hydraulic conductivity (100 days period) with distilled water for three different GCLs are shown in the form of X-Y plot in Fig. 4, with X-axis showing the maximum effective stress and Y-axis showing the hydraulic conductivity.

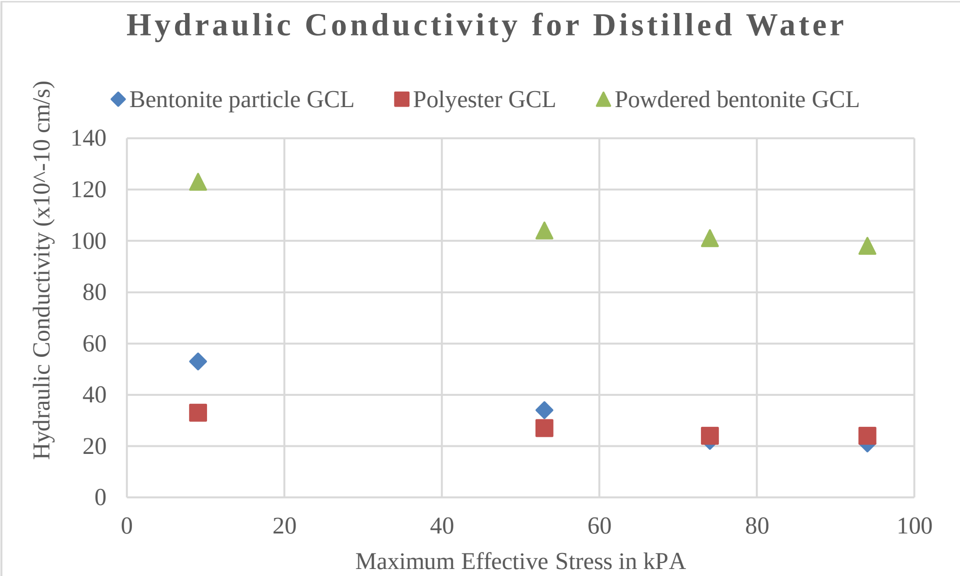

Figure 4 Experimentally found hydraulic conductivity for different GCLs with distilled water

It can be noted from Fig.4 that with the increase in effective stress the hydraulic conductivity decreases for all the three types of GCLs. Also, it can be noted that the lowest value of hydraulic conductivity is noted for bentonite particle GCL for highest effective stress. However, it can be noted that the most consistent in the hydraulic conductivity result is polyester GCL.

Figure 5 shows the experimental results for hydraulic conductivity obtained with SL1 for the three different GCLs with respect to the time in days at a constant effective stress. The readings are taken at an interval of 5 days for a period of 100 days. From Fig. 5, it can be noted that overall the permeability is increased as compared to that with distilled water. Here also it can be noted that the lowest value of hydraulic conductivity is noted for bentonite particle GCL, however, the most consistent performance with respect to the hydraulic conductivity is shown by polyester GCL with respect to time.

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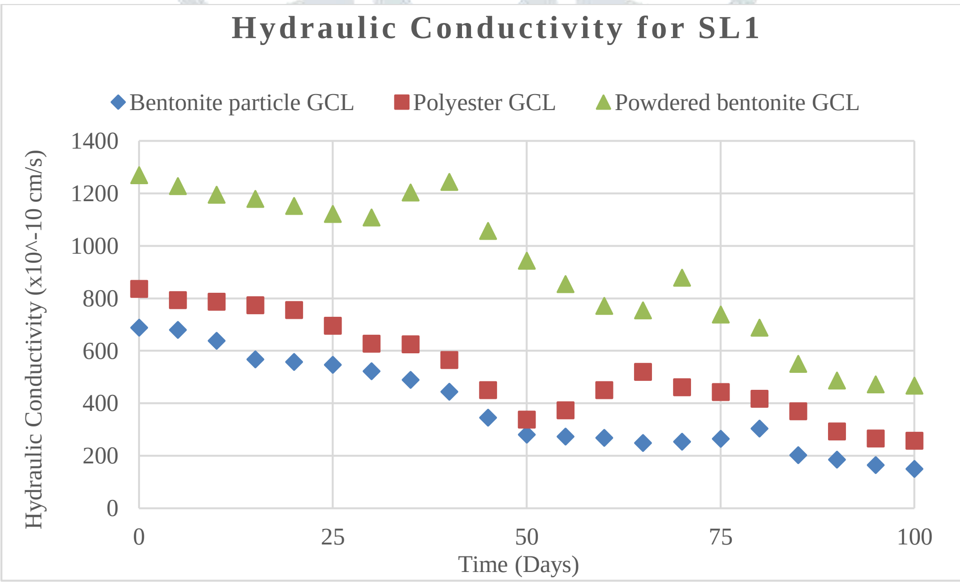

Figure 5 Experimentally found hydraulic conductivity for different GCLs with SL1

Figure 6 shows the experimental results for hydraulic conductivity obtained with SL2 for the three different GCLs with respect to the time in days at a constant effective stress. Here also, the readings are taken at an interval of 5 days for a period of 100 days. From Fig. 6, it can be noted that overall the permeability is increased as compared to that with distilled water and also with compared to SL1. Here again it can be noted that the lowest value of hydraulic conductivity is noted for bentonite particle GCL, but the most consistent performance with respect to the hydraulic conductivity is shown by polyester GCL with respect to time.

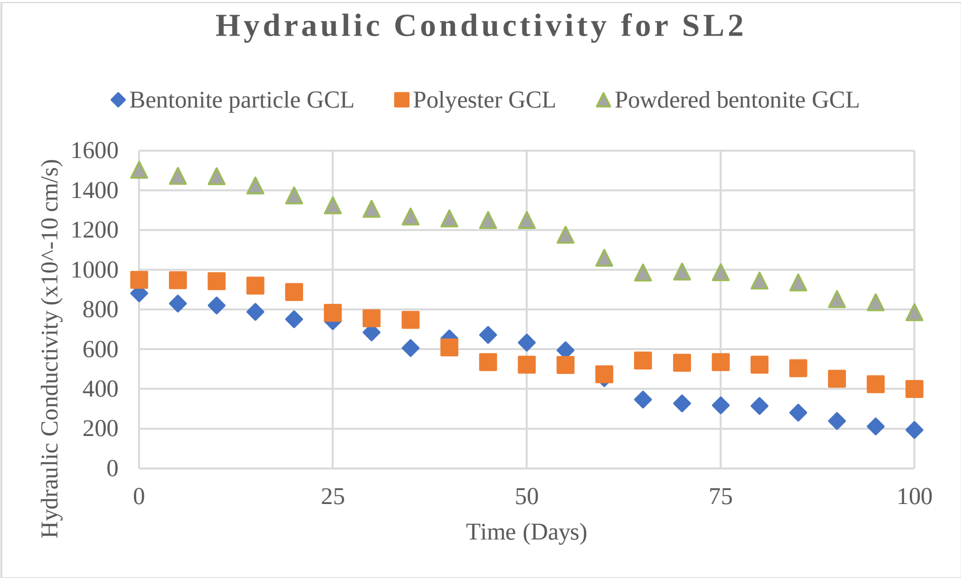

Figure 6 Experimentally found hydraulic conductivity for different GCLs with SL2

IV. Conclusions

Conclusions that can be drawn from this research work are as under:

- Polyester GCL provides the most consistent performance with distilled water as well as leachate, and it is also of non-woven type, hence much skilled labor is not required.
- Bentonite particle GCL gave the lowest hydraulic conductivity with increase in effective pressure with distilled water, however with lower effective pressure the hydraulic conductivity was higher.
- Bentonite particle GCL also gave the lowest hydraulic conductivity amongst the different GCLs tested with increase in time, for the synthetically prepared leachates.
- Hydraulic conductivity (or permeability) are noted to increase from distilled water to SL1, and from SL1 to SL2 for all the three GCLs, thus implying that with the increase in the ionic strength of leachate the permeability increases.
- With respect to economics, polyester GCL and bentonite particle GCL are equally viable, however they are a bit expensive as compared to powdered bentonite GCL. Hence, effective use of GCLs should be undertaken based on type of wastes, hydraulic conductivity and economics.

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