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Permeability Studies on Different Prefabricated Landfill Liners Developed Using Coir Geotextile and Polypropylene Felt

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ABSTRACT: Geosynthetic clay liners (GCLs) have now become a effective substitute for compacted clay liner (CCL) as the barrier layer in the cover and liner system in environment protection facilities. GCLs are prefabricated liners which comprise of a thin layer of bentonite bonded to a layer or layers of geosynthetics. The geosynthetics in GCLs are either geotextiles or geomembranes. Geotextiles- based GCLs are bonded together by needle punching, stitch bonding or using adhesives. The main function of geotextiles in GCLs is to keep bentonite in position till the GCL is placed as barrier. Geotextiles used in GCLs are usually made from polymeric materials. Geotextiles from natural fibres such as coir are abundantly available in the state of Kerala and they can be used as substitute for polymeric materials. These natural coir fibres are eco- friendly and less expensive than polymeric materials. But due to their large aperture size, bentonite comes out of cover fabric. A thin layer of polypropylene (PP) felt can be used as an additional material to prevent leakage. In this study different coir geotextile based prefabricated liners are developed by changing the type of coir geotextile and bentonite concentration. The permeability of each of these liners are studied and compared. The permeability of the developed liners was in the range of 10^{-5} cm/s to 10^{-6} cm/s.

KEYWORDS: landfill, leachate, benonite, geosynthetic clay liner, permeability.

I. INTRODUCTION

Waste is a byproduct of various human activities which lack any value and use. Safe and effective disposal of waste have always been a concern of the society. Various methods of disposing these wastes include land filling and incineration. Landfills are highly engineered permanent waste containment facilities, designed to minimize the ill effects of solid waste on the environment. In modern landfills, the waste is contained by a liner system and cover system on bottom and top respectively. The primary purpose of the liner system is to isolate the landfill contents from the environment and, therefore, to protect the soil and ground water from pollution originating from the landfill. Liner or cover systems consist of different layers such as vegetative layer, drainage layer, barrier layer, leachate detection and collection layers. Of this, barrier layer prevents the leakage of leachate. It was traditionally constructed by compacting locally available clay in layers called compacted clay liner (CCL). In recent years, CCL is replaced by Geosynthetic Clay Liner (GCL). GCLs are prefabricated liners which comprise of a thin layer of bentonite bonded to a layer or layers of geosynthetics. The geosynthetics in GCL can be either geotextiles or geomembranes. Geotextiles based GCLs are bonded together by needle punching, stitch bonding or using adhesives. The main function of geotextiles in GCLs is to keep bentonite in position till the GCL is placed as barrier. Geotextiles used in GCLs are made from polymeric materials. Geotextiles from natural fibres such as coir are abundantly available in the state of Kerala and they can be used as substitute for polymeric materials. These natural coir fibres are eco- friendly and less expensive than polymeric materials. But due to their large aperture size, bentonite leaks out of cover fabric. A thin layer of polypropylene felt (PPF) can be used as an additional material to prevent leakage. The PPF used for this study is very thin and flexbile. Since the main function of GCL is to keep bentonite in position, though natural geotextiles undergo biodegradation it can be used as an alternative to synthetic materials. In this study various prefabricated liners are developed and their performace is evaluated and reported based on their permeability.

II. LITERATURE REVIEW

The waste in engineered landfillis is contained by a liner system and cover system. The primary purpose of the liner system is to isolate the landfill contents from the environment and therefore, to protect the soil and ground water from pollution originating from the landfill. The most critical polluting agent of landfill is toxic leachate, which is produced when the water percolate through the solid waste extracts dissolved material [1]. Due to their very low permeability, compacted clay liner (CCL) is the main material that can form barrier layer for the flow of leachate outside landfill. Clay liners are used to limit or eliminate the movement of leachate and landfill gases from the landfill site [2]. In recent years, GCLs have often been used as substitutes for CCLs. The major advantages of GCLs include the more consistent physical properties, the lower leakage rates, the faster installation, and the reduced construction quality assurance requirements. The ability to withstand differential settlement and make them especially suitable for use in landfill covers. [3], [4]. GCLs also have greater self-healing capability under puncture as the availability of moisture resulting in swelling of bentonite. They also withstand relatively large differential settlements compared with CCLs which are constructed with typically lower plasticity natural clay soils [5], [6]. The greater self-healing capability of GCLs allows GCLs to overcome small defects, such as puncture holes, up to 75 mm in diameter upon hydration, and also generally leads to greater resistance of GCLs to increases in permeability resulting from climatological distress due to repeated freezing–thawing and/or wetting–drying cycles [7]. GCLs along with geomembrane in liner system can withstand a slope of one horizontal to three vertical [8]. A barrier with jute geotextile to prevent sulphate flow is already developed [9]. After which a GCL with a bentonite and kaolinite mixture on a biodegradable jute base was prepared [10]. Coir fibre obtained from the husk of coconut is among the strongest and most durable natural fibres, due to high lignin content. Coir mesh mattings are extensively used for erosion control along steep slopes. Geotextiles made from coir fibres have tremendous possibilities in various other geotechnical applications also. Good performance of coir geotextiles has been reported in drainage installations as vertical drains and blanket drains in embankments Coir geotextile serves as an effective reinforcing material for temporary clay structures in the wetland [11].

III. DEVELOPEMENT OF PEFABRICATED LINER

In this study, two types of prefabricated liners were developed by changing the method of bentonite concealing between the cover fabrics. Four samples were developed by varying the bentonite concentration. In the first type, a non-woven coir geotextile impregnated with bentonite was placed between two woven coir geotextiles. In the second combination, bentonite alone was filled between two woven coir geotextiles.

A. Materials

The materials used in the experimental study include three types of geotextiles, bentonite and river sand. Their properties are explained below. Woven coir geotextile, non- woven coir geotextile and thin polypropylene felt as cover fabric were used in the study. Their properties are summarized in table 1. Bentonite is naturally occurring clay with high swelling capacity, high ion exchange capacity and very low water permeability. The bentonite used in this study is calcium bentonite. The engineering properties of bentonite are presented in table 2.

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Table 3.1. Properties of geotextiles

Property		Woven coir geotextile	Non- woven coir geotextile	PP felt
Opening size (mm)		10 - 17	1.18	0. 150
Thickness (mm)		6.564	2.593	0.14
Mass per unit area (gsm)		532.83	761.04	25.64
Tensile strength (kN/m)	Machine direction	9.2	0.5	0.476
	Cross machine direction	6.9	0.24	0.476

Table 3.2. Properties of bentonite

Property	Value
Specific gravity	2.67
Free swell	17 per 2g
Liquid limit (%)	285
Plastic limit (%)	43
Permeability (cm/s)	1×10^{-8}
Maximum dry density (g/cc)	1.262
Optimum moisture content (%)	26.1
Percentage clay (%)	64
Percentage silt (%)	36

Natural water content of bentonite is more than 25%. They form small granules at this water content. The more the water content of bentonite, the larger the granules. Due to this, only 0.6% of bentonite passes through PPF at natural water content. In oven dry stage, it is 7%. River sand was used as a drainage layer below the liner.

B. Types of Prefabricated Liner

Prefabricated liner was made in four types by varying the type of cover/ carrier fabric and the quantity of bentonite. The details of the two are explained below:

The Sample 1 was prepared by impregnating non- woven coir with bentonite. This was covered by polypropylene felt and woven coir geotextile on both sides. The cross section of the liner is shown in fig. 3.1. The whole assembly was stitched together by nylon threads. The concentration of bentonite selected was 4000 and 5000 g/m^2. The samples were named Sample 1a and 1b. The diameters of the samples were 30 cm and thickness 1.85 and 1.9 cm respectively.

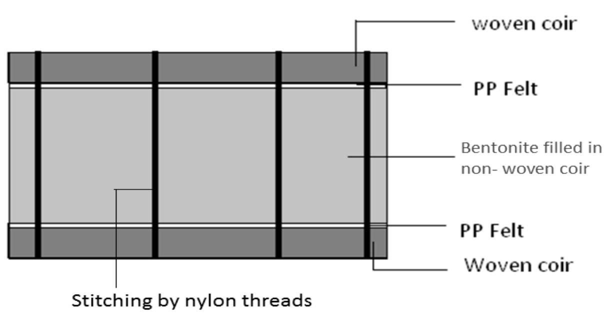

Fig.3.1. Schematic diagram Sample 1

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The Sample 2 was prepared by covering 4000 and 5000 g/m^2 of bentonite by polypropylene felt and woven coir geotextile. The whole assembly was stitched together by nylon threads. The samples were of diameter 30 cm and thickness 1.7 and 1.75 cm respectively. The cross section of the liner is shown in fig. 3.2.

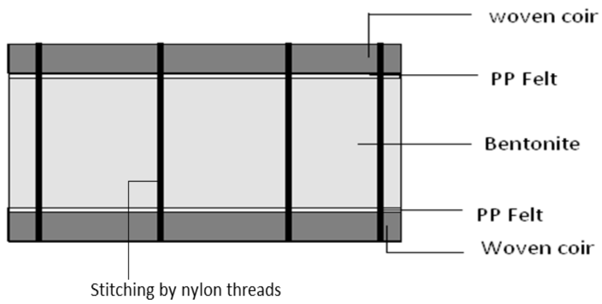

Fig.3.2. Schematic diagram Sample 2

IV. PERMEABILITY STUDIES ON DIFFERENT LINERS

The permeability of the coir based prefabricated liner was determined using constant head permeability method. The experimental set up consisted of a 30 cm diameter circular tank as shown in the fig. 4.1. The sand was filled in uniform density. Above which water was filled to a height of 24 cm. the side wall leakage was prevented by sealing with bentonite. The bentonite in the liner was allowed to saturate and swell for two days. The water level was made constant and the permeability was measured by collecting the water that passed through the liner for a specific time interval.

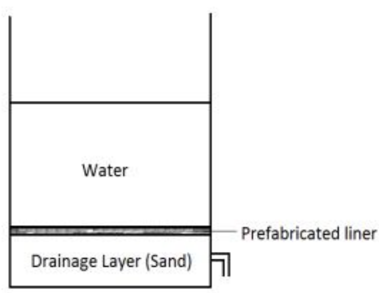

Fig.4.1. Experimental set up

V. RESULTS AND DISCUSSIONS

The permeability of the various samples of the developed liners found from the experiment are shown graphically as in fig. 5.1. The permeability of liner slightly decreased as the number of days increased. This may be due to increase in swelling of bentonite with time. The permeability of developed liner without non- woven coir geotextile was lower than the permeability of the developed liner with non- woven coir geotextile. This can be because of the presence of the flow paths between the irregular surfaces of non- woven coir geotextile and the bentonite. As number of days increased, these flow paths closed decreasing permeability.

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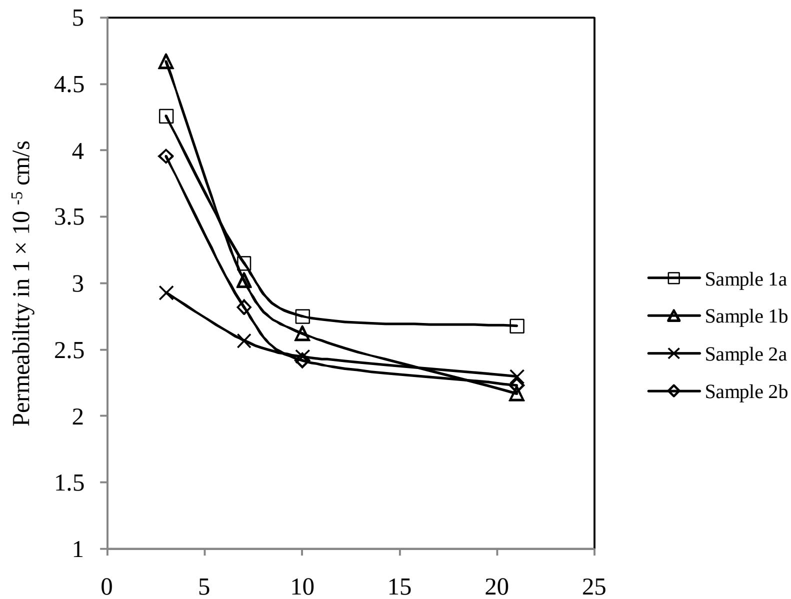

Fig. 5 Permeability- Number of daysrelationship

When the bentonite content increased from 4000 to 5000 g/m^2, the decrease in permeability was only 3.04 % in the case of developed liner without non- woven coir geotextile. The decrease in permeability with increase in bentonite content is not so much appreciable. The permeability of the samples was of the order of 10^{-5} and was nearing 10^{-6} cm/s. The prefabricated liner with higher amount of bentonite gave lower value of permeability. Problem observed was the leakage of bentonite during stitching of the liner. This was due to the use of oven dry bentonite. This can be reduced if bentonite in is granular form or with natural water content is used. Careful manufacturing methods can reduce leakage of bentonite and thus improve the performance of liner.

VI. CONCLUSION

Two different types of prefabricated liner have been developed. In the first type, 4000 and 5000 g/cm^2 of bentonite impregnated non- woven coir geotextiles respectively were covered with woven coir geoxtile and PP felt which formed the cover fabric to form two different samples. The whole assembly was stitched together with nylon threads. In the second type, two sample liners were developed by placing 4000 and 5000 g/cm^2 of bentonite respectively, between woven coir geotextile and PP felt that together formed the cover fabric. This was stitched together with nylon threads to form the required liner. The liner with bentonite simply kept inside the cover fabric has comparatively lower permeability. But with time the variation in permeability between with and without non- woven geotextile reduced. As the percentage of bentonite content increased from 4000 to 5000 g/m^2, the decrease in permeability was only by 3.04 % in the case of developed liner without non- woven coir geotextile. Hence it is better option to use 4000 g/m^2 bentonite without non- woven coir geotextile between cover fabric for better economy.

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