Utilisation Of Bentonite Halloysite Nanoclay Mix In Sandwiched Geosynthetic Clay Liners

Jinto Varughese Kuriakose
Department of civil engineering
Saintgits College of Engineering
Kottayam, Kerala,India

Dr. Hari G
Department of civil engineering
Saintgits College of Engineering
Kottayam, Kerala,India

***Abstract*—Sanitary landfilling is a low cost and well established waste disposal technique applied worldwide. However, it generates heavily polluted leachate. India being a tropical country receives heavy rainfall from south west monsoons and north east monsoons, promote water percolation into the landfill which aggravate the problems due to leachate percolation. So there arise an imminent necessity to devise a methodology which is highly efficient and economical to curb this menus. The study deal with the aspect of using Bentonite Halloysite mixture as a potential material for using as a landfill liner keeping in absorbing properties of halloysite nanoclay towards heavy metals and ammonia ions. The optimum needle density of the Geosynthetic clay liner and the mass density per square centimeter of the bentonite fill inside the GCL is determined. The impact of the Halloysite nanoclay in the bentonite composition used in the GCL on the atterberg limits and free swell index of the GCL filling is also evaluated to compare with the effect of montmorillionite nanoclay mixed with bentonite in GCL.**

Keywords—Geosynthetic clay liner, self healing capacity, needle punching, free swell index, halloysite nanoclay

I. Introduction

Sanitary landfilling is identified as the most effective and economical method of waste disposal applied around the globe. Still it produces effluents called leachate. In India the same methodology of waste disposal is accepted and widely used. But India receives an annual rainfall of 300mm to 650mm on an average. This accounts to a higher penetration of water into the landfill and greater contamination of groundwater. The study has revealed that the ground water quality near dumping sites does not conform to the drinking water quality standards as per IS : 10500. The impacts of indiscriminate dumping activity on ground water appeared most clearly as high concentrations of total dissolved solids, electrical conductivity, chlorides, chemical oxygen demand, and sulphates. High amount of metals like Na, K, Ca, Mg, Cd, Cu, Ni, Fe, Zn and Mn has also been detected in the groundwater samples near dumping area. Leachate characterization study also reveals high potential for groundwater contamination.

Extensive research conducted in and around the world had led to the development of many solutions that significantly reduces the risk of contamination by these hazardous substances. One of these solutions to reduce environmental risk is geosynthetic clay liners (GCL) filled with a layer of mineral, which are widely used in the current scenario. Comparing with the compacted clay liner (CCL), the GCLs posses better hydraulic conductivity and are economic in cost. The installation of the GCLs have an upper hand over CCLs, as they are less time consuming and less vulnerable to any installation defects. Owing to the low hydraulic conductivity and low cost of these clay minerals in between the layers of geomembranes, design engineers and environmental agencies have a growing interest in this. In most of the cases the bentonite is sandwiched between a pair of geotextile layers. The geotextile can be woven or non woven or a geocomposite. The bentonite can be either sodium bentonite or calcium. A lot of study is carried out in using sodium and calcium bentonite.The properties of the resulting layer depends upon the constituents of the bentonite and any mixture if employed in the layer.

The design considerations vary depending on the field of aaplications, which include : hydraulic conductivity, compatibility, interface shear strength, internal shear strength, freezing and thawing cycles, wetting and drying cycles and diffusion.

II. Literature Review

Didier et al. (1) showed that a very good seal can be obtained around objects inserted in GCL like plant roots. They pointed out that the healing kinetics of open holes up to 30mm diameter show that only a short time (15 days) is necessary to totally heal the effect. Egloffstein et al. (2) reported that the self-healing of a calcium bentonite takes place if a soil cover more than 0.75 meter thick is provided. Babu et al.(3) showed that all the GCLs tested had a good self-healing capacity for desiccation cracks or punctures. Sari and Chai investigated the self-healing capacities of two kinds of geosynthetic clay liners: geomembrane supported GCL and geotextile encased GCL. They showed that factors affecting the free swell index of bentonite change the self-healing capacity of GCL. They also reported that the applied stress has two possible effects on self-healing capacity: one is the squeezing of the hydrated bentonite into the damage hole and another is limiting the amount of hydration-induced expansion of bentonite. Although it is established that the self-healing capacity of sodium bentonite GCLs is high, experimental evidence published recently show that this capacity can be limited in various conditions, e.g. ion exchange in case of non-standard liquids and unexpected high effective stress according to Babu SGL et al. (4).

As per the studies of Makusa et al. (5) the GCL also leads in its installation, needs less skilled labor and lower cost. GCL has resistance to the effect of freeze/thaw cycles and easy to repair. It also offers flexibility to transport since it can be packed in a roll with about 4–6 m long and 0.75 m in diameter. The use of GCL cuts down the dependency on local soil availability and reduces the cost for landfill lining according to Budihardjo et al. (6). Recent studies have shown that using additives like fly ash and halloysite can improve the wet/dry durability of GCL, but they also increase its permeability and reduce the self-healing capacity as per the findings of Sakiewicz et al. (7). Mudimby et al. (8) have pointed out that additives which can improve the durability of GCL downgrade its hydraulic and sealing performance, because they generally reduce the plasticity index and liquid limit of bentonite. Plasticity index and liquid limits of bentonite are two key factors in determining the sealing performance of GCL. Bentonite with higher liquid limit has lower permeability because of the higher cation exchange capacity. So using additive which can improve both hydraulic performance (permeability and self-healing capacity) and wet/dry durability of GCL is of great importance. It can be said that no additive has been introduced till now that can improve both sealing performance and durability of GCL. Also, the effects of structural parameters like bentonite mass per unit area of GCL and needle-punching density on wet/ dry durability of GCL have not been investigated yet.

III. INITIAL TESTING ON GEOSYNTHETIC MATERIAL

The geosyntheic material was collected from Southern Felt & Geotex, Chennai, Tamil Nadu. In this study, non-woven polyester geotextile with an areal density of 300 g/m^2 is to be used for both upper and bottom layers of GCL specimens. The specimen was send for inhouse tests and the report was collected.

A. Thickness

The thickness tests were carried out on geotextile according to ASTM D 5199. The samples were cut into 20x20 (cm^2) and then, twenty different points of each sample were randomly chosen to be measured under the pressure of 2 kilo Pascal (kPa). The mean value of the results was reported as the sample thickness.

B. Tensile Strength

The tensile strength tests were carried out as per ISO:10319 on the geotextile using Universal Testing Machine. The maximum force per unit width observed during the test in which the specimen is stretched to rupture is 12 kN.

C. Elongation

The geotextile was tested for elongation at break at preloading as per ISO:10319 using Universal Testing Machine. It is measured in gauge length (mm) corresponding to an applied load of 1% of the maximum load. It is expressed in percentage of elongation to the original length before preloading.

IV. TESTING ON BENTONITE HALLOYSITE MIX

A. ATTERBERG LIMIT STUDIES OF BENTONITE-HALLOYSITE MIXTURE

The effect of Halloysite nanoclay on the atterberg limits of pure bentonite have to be studied. Different compositions have to be tried and tested for identifying the effect of the nanoclay on the bentonite mixture. Pure bentonite, 90% pure bentonite + 10% Halloysite, 85% pure bentonite + 15% Halloysite, 80% pure bentonite + 20% Halloysite are to tested according to IS 2720-5.

B. FREE SWELL INDEX OF BENTONITE HALLOYSITE MIXTURE

The free swell index of the mixture have to be deduced as it directly influence the hydraulic conductivity of the mixture. The procedure includes the following steps.

1. The free swell index of bentonite containing various amounts of nano-clay is determined according to IS 2720:1977
2. The bentonite Hal mix was sieved through 425 microns.
3. Pour 5g samples into two graduated cylinders.
4. Fill the cylinder with kerosene and distilled water to 100 mL mark.
5. Fill the cylinder with kerosene and distilled water to 100 mL mark

Free swell index is determined by using the equation

$$Free\ swell\ Index\ (\%) = \frac{Vd - Vk}{Vk} x100 \qquad (1)$$

V_d = Volume of the soil specimen read from the graduated cylinder containing water

V_k = Volume of the soil specimen read from the graduated cylinder containing kerosene.

C. BENTONITE MASS PER UNIT AREA OF GCL V/S HYDRAULIC CONDUCTIVITY

The optimum density in which the mixture have to filled in the GCL have to be identified. As in normal landfills vary the GCL density from 3.6 kg/m^2 to 6 kg/m^2, a range of 4 kg/m^2 to 6 kg/m^2 is so chosen that it is much convenient for the study.

D. PERMEABILITY STUDIES USING NEEDLE PUNCHED GCL

The effect of needle punching on the GCLs are to be studied as the hydraulic densities vary depending on the needle density attained. Stitching the geomembranes is a tiresome task and punching densities of 15, 30, 45 and 60 needles per square centimeter of GCL are used. The geomembranes are stitched together help of sewing machine used in the carpet production factories. The thickness of GCL with 4 kg/cm^2 density bentonite is identified 9mm. Layers of geotextile are linked through the fibers which are belonging to the geotextile layers and are almost perpendicular to the GCL sheet.

V. RESULTS AND DISCUSSIONS

A. INITIAL TESTING ON GEOSYNTHETIC MATERIAL

TABLE I. Material Properties

Property	Measurements
Thickness	2mm (ASTM D 5199)
Tensile strength (UTM)	12kN/m (ISO : 10319)
Elongation (UTM)	65% (ISO : 10319)

Thickness, tensile strength and the elongation characteristics conform to the standards of a geosynthetic materials which can be used as a liner in engineered land fill.

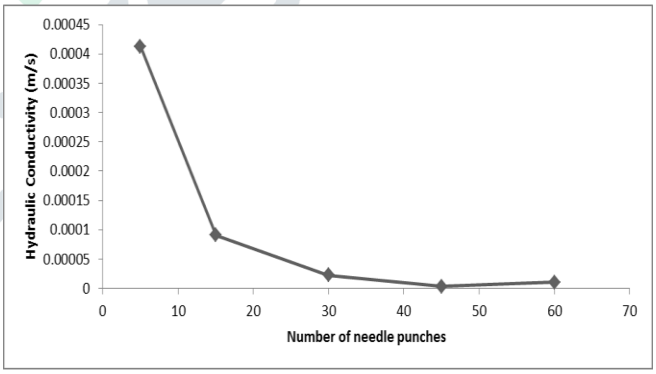

Fig 1. Effect of needle punching on permeability studies

GCL expands on contact with water and the fibres restrict the swelling of the bentonite halloysite mixture. If the restriction to swell is higher, more the hydraulic conductivity. It was observed that by increasing the density from 30 to 60 per cm^2, there is no considerable decrease in hydraulic conductivity.

B. ATTERBERG LIMIT STUDIES OF BENTONITE-HALLOYSITE MIXTURE

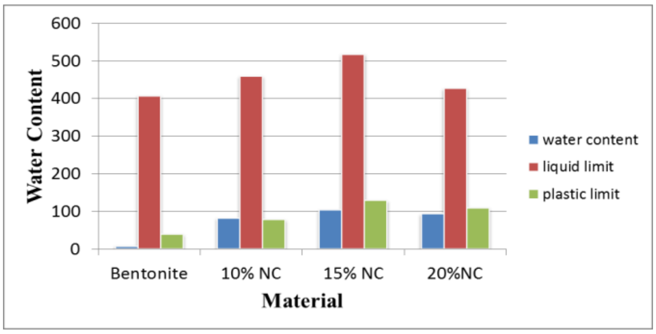

Fig 2. Effect of Nanoclay content on the atterberg limits

It can be seen that the plastic limit and liquid limit of bentonite are increased by nano-clay inclusion. It can be inferred increase in the plastic limit and liquid limit of bentonite modified by nanoclay may be due to the increase in specific surface area and a decrease in plastic and liquid limits of bentonite containing 20% of nano-clay compared to bentonite containing 15% of nano-clay is due to the partial agglomeration of nano-clay particles. 15% nanoclay content mix is chosen for further studies.

C. FREE SWELL STUDIES OF BENTONITE-HALLOYSITE MIXTURE

TABLE II. Free Swell Index

Material	Free swell Index
Normal bentonite	20
Bentonite + 5% Hal	23
Bentonite + 10% Hal	28
Bentonite +15% Hal	32
Bentonite + 20% Hal	26

Kerosene being non polar liquid does not cause swelling. Bentonite/nano-clay mixtures have higher swelling potential compared to bentonite samples without nano-clay.It can be attributed to the high reaction capacity of nano-clay. The increase in cation exchange capacity leads to increase in water absorption which makes the diffusive double layer around particles thicker.

D. MASS DENSITY STUDIES OF BENTONITE

TABLE III. Bentonite mass density

Bentonite mass per unit area of GCL	hydraulic conductivity
4	1.96E-06
5	1.78E-06
6	1.47E-06

By increasing the bentonite mass, the thickness of bentonite layer in GCL specimen increases leading to the decrease in equivalent coefficient of permeability. GCL specimens containing 4 kg/m^2 of GCL have 6 mm thickness, while the thickness of GCL specimen containing 6 kg/m^2 bentonite is about 7.5 mm. GCL specimens containing 4 kg/m^2 is taken for further studies due to the constraints in stitching.

VI. RESULTS AND DISCUSSIONS

The Bentonite Halloysite mixture of required compositions was prepared using an electric blender and was sent for the characterisation study to conform the uniformness and effectiveness of mixing. The resultant mixture was tested for Atterberg limits and Free Swell Index. The plasticity index and free swell index was found to be the highest for the 85% Bentonite and 15% halloysite mixture. The density with which the bentonite have to be filled is identified to be 4 kg/m^2.

In the study the effect of nanoclay additives on the bentonite on the atterberg limits, free swell and the mass density are experimentally studied. The following are the results of the experimental study:

1. The needle punching density of GCL have a considerable affect on the hydraulic performance of the GCL. The optimum punching density in order to enhance the hydraulic performance of the GCL is 30 to 45/cm^2.
2. Incorporating nanoclay particles improve the atterberg limits considerably and hence can contribute to the hydraulic performance of the GCL.
3. The free swell is observed to be increasing at a nominal range. The nominal increase can be attributed to the structure of the Halloysite nanoclay.
4. The nanoclay particles can highly improve the hydraulic performance of the GCL. The flow rate through the GCL can be highly decreased as much as 90% using 15% nanoclay content.

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