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Air Permeability of Geosynthetic Clay Liners

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Abstract: - **A Geosynthetic Clay Liners (GCL) is a woven fabric-like material, primarily used for the lining of landfills. It is a kind of geomembrane and geosynthetic, which incorporates a bentonite or other clay that has a very low air permeability as well as low hydraulic conductivity. In this paper, a review of the main findings is presented with the focus on the critical aspects affecting the gas permeability of GCLs. Air permeability is the volume of air passing through a medium. A porous medium such as sand or like allows the air or some other gases to pass through it. The air permeability should be reduced inorder to avoid the groundwater pollution. Air permeability of a GCL gets affected by the type of bentonite used in it, the moisture content and the pressure applied on it. As the moisture content increases, the air permeability seems to get decreased. GCL type is also a main factor which affects the air permeability.**

Index Terms— Geosynthetic Clay Liner, Hydration, Air permeability, Moisture effect

I. INTRODUCTION

Over the past decade, Geosynthetic Clay Liners (GCLs) have gained widespread popularity as a substitute for compacted clay liners in cover systems and composite bottom liners. GCLs are mainly adopted as a water as well as gas barrier in nuclear waste repositories. They are also used as environmental protection barriers in transportation facilities or storage tanks, and as single liners for canals, ponds or surface impoundments. As a result, they are being investigated intensively, especially in regard to their hydraulic and diffusion characteristics, chemical compatibility, mechanical behavior, and durability and gas migration. There are different types of classifications for GCL depending upon their manufacturing process and the materials used. i.e.,woven geotextiles or non-woven geotextiles. This study concentrates on the air permeability of GCL by varying the moisture content as well as differential pressures. The test is done in the gas permeability apparatus. The major components of the system are a pressurized nitrogen gas cylinder, pressure regulators, pressure gauges, anemometer and permeability cell. Nitrogen is selected as the source of gas since it is a relatively inert gas and has very low water solubility. The gas pressure supply is controlled by a series of regulators. The regulators are used to step down the pressure and allow it to be kept constant. Pressure gauges are used to monitor the pressure at the entrance of the gas cell as well as to know the pressure at the exit of the gas cell. Mainly used materials for the study were two types of GCLs as well as sand. The GCLs were hydrated before testing for minimum 24-48 hours. However, the effect of differences between the GCLs on the gas permeability at higher volumetric water content will be dependent on the pressure. The moisture contents play an important role in the reduction of air permeability. Low air permeability results in the reduction of ground water pollution. The main objective of the present project is to study the effect of moisture content on the air permeability of different GCLs at different pressures.

II. LITERATURE REVIEW

Abdelmalek Bouazza et al. (2003) found a device to measure air permeability of partially saturated GCL and studied the effect of volumetric water content on the intrinsic permeability. The air permeability apparatus gave the value of air permeability of the GCL at various moisture contents and differential pressures. GCL subjected to confinement reduces the permeability.

Thaveesak Vangpaisal et al. (2004) conducted studies to find out the GCL having low gas permeability. Along with the moisture content effect, the confinement effect over the gas permeability was also studied. Normally GCL swells when they come in contact with water. Swelling increases as the hydration increases. Needle-punched GCL showed low gas permeability than that of stitch bonded GCL. Moisture content is inversely proportional to gas permeability. Hsin Hsin-Yu Shan et al. (2000) developed an equipment to find air permeability and studied the air flow through hydrated GCL. Needle punched fibre has thicker geotextiles which gave a loess gas permeability. Desiccation cracks increases air permeability.

G.Didier et al. (2000) conducted gas permeability test to study the air permeability of mainly two GCLs named Bentofix and Bentomat. They came to a conclusion that a decrease in gas permeability occurred due to the increase in the moisture content. The size and shape of the gravel in the drainage layer immediately above the GCL was found to affect its gas permeability, when subjected to high overburden pressure.

R.J. Trauger et al. (2000) determined the flow rate of certain landfill gas constituents through a GCL. The study assessed the GCL's effectiveness as a gas barrier in comparison to that of a compacted soil liner. The gases used were methane and benzene, since these were some among the poisonous gas generated from the waste repositories. Methane gas flow rate through the GCL appears to be 4 to 5 orders of magnitude less than through the CCL. Whereas, the benzene flow rate decreases due to sorption.

III. METHODOLOGY

The air permeability apparatus was connected to a nitrogen cylinder which is filled with nitrogen gas which has 1.78 x 10-5 Pa s dynamic viscosity. The apparatus is having an upper and lower cylinder. First the lower cylinder is being filled with sand up to 20mm height and then place the GCL to be tested and the attach the upper cylinder. The GCL to be tested should be hydrated for a minimum of 24-48 hours and maximum up to 7 days. After placing the GCL inside the upper cylinder fill it with 20mm sand and then get the cell closed with the piston. The nitrogen gas is applied to the cylinder at a pressure (P1) of 100, 200 and 300kPa respectively. After note down the outlet pressure P2. Also measure the velocity of the N2 gas at the outlet using anemometer. This will give the air permeability of the corresponding GCLs at different moisture contents. The air permeability is found at different moisture contents.

The air permeability (Ka) can be calculated by the equation given below:

$$Ka = \frac{2Q_2P_2\mu L}{A(P12 - P22)} \quad \text{-----(1)}$$

Where,

K_a - Air permeability (cm^2)
Q_2 - Discharge of air (cm^3/s)
P_1 - Pressure at the inlet (kPa)
P_2 - Pressure at the outlet (kPa)
μ - Dynamic Viscosity of N2 gas (1.78 x 10^{-5} Pa s)
L - Length of the specimen (cm)
A - Area of the specimen (cm^2)

IV. EXPERIMENTAL PROGRAM

This chapter deals with the various materials used in the present study. It also presents the description of the testing programme and the procedure adopted in the tests.

The air permeability apparatus is used for the study of the air permeability of different geosynthetic clay liners. The test setup is shown in figure 1.

Fig. 1. Air permeability apparatus

A. Materials Used

Material used for the experiments are sand having size 2.36mm and two types of Geosynthetic Clay Liners.

1) Geosynthetic Clay Liners

Geosynthetic Clay Liners used in this study were of two types: GCL1 and GCL2. GCL1 was composed of bentonite powder sandwitched in between a nonwoven geotextile and a woven geotextile. Whereas GCL2 was impregnated with bentonite granules in between nonwoven and woven geotextiles. Both the GCL was having woven geotextile as their carrier geotextile. GCL1 was artificially made in the laboratory and GCL2 was needle punched type which was provided from Gorantla Geosynthetic Pvt. Ltd. Both the GCLs are as shown in figure 2 and figure 3 below:

Fig. 2. GCL 1

2)Sand

Sand was collected from Pattambi region, Palakkad. Preliminary tests were conducted to study the basic properties of the sand used. Figure 4 shows the sand taken for the study:

Fig. 4. Sand

B. Tests conducted

The main objective of this study is to find out the air permeability of GCL with different moisture contents at different pressures. The test was carried out in Air Permeameter for both the GCLs.

Properties of the sand and bentonite used is summarised in table 1 and 2.

TABLE I. BASIC PROPERTIES OF SAND

Properties	Values
Effective size (D10 mm)	0.24
D30 (mm)	0.44
D60 (mm)	0.68
Uniformity coefficient (Cu)	1.28
Coefficient of curvature (Cc)	2.63
Type of soil	SP
Specific Gravity G	2.62
Maximum dry density (g/cc)	1.78
Minimum dry density (g/cc)	1.56

TABLE I. BASIC PROPERTIES OF BENTONITE

Properties	Values
Specific gravity	2.29
Liquid Limit (%)	3.47
Plastic Limit (%)	73
Plasticity Index (%)	274
Maximum Dry Density (g/cc)	1.05
Optimum Moisture Content (%)	58.0

V. RESULTS AND DISCUSSIONS

The GCL1 and GCL2 at different moisture contents were tested in the air permeameter at different pressures. The moisture contents at which both the GCLs were hydrated was 30%, 70% and 100%. As the moisture content increases the air permeability of both GCLs decreases but keeps on increasing with the increased pressure. But comparatively GCL2 shows lower air permeability than that of GCL1.

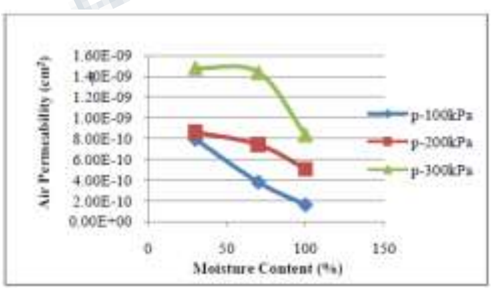

Fig. 5. Effect of applied pressure on air permeability of GCL1 at different moisture contents

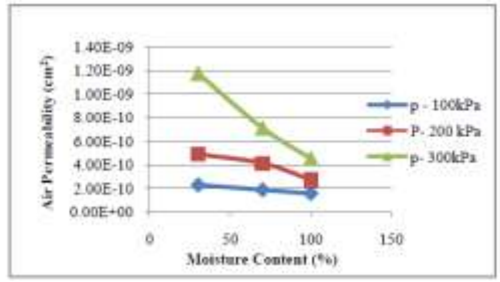

Fig. 6. Effect of applied pressure on air permeability of GCL2 at different moisture contents

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