Prediction of Leakage through Composite liner due to Geomembrane defects

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Abstract:
The most popular method currently in use is landfill disposal. Landfill lining structures play a key role in creating a buffer between the waste and the environment. We are one of the key components of landfill design and construction. The composite liner's geomembrane portion is almost impervious to liquid flow, defects in the geomembrane can occur even when construction and assembly are closely tested. Quantifying the risk of leakage through the composite liner is very important because of a geomembrane fault as it may contaminate the surrounding area. In this analysis the effect of liquid head, low permeability bentonite thickness and increase in defect hole diameter on discharge through the geomembrane defect was studied. An analytical equation is proposed based on the study.

Keywords: Geomembrane, defect, water head, thickness of bentonite, discharge, composite liner.

1. INTRODUCTION
Landfill waste disposal is the most popular method currently being used in operation. Also basic landfill activities and closure mechanisms will lead to a significant reduction in adverse environmental impacts. Lining networks play a significant role in building a buffer between waste and climate. We are one of the most important elements of landfill design and construction[2-6]. Liner framework envelops the waste and isolates it from direct contact with the environment surrounding it. For many years compacted clay liners have been used as engineered hydraulic barriers over waste storage installations. Some liner and cover schemes have a single compact soil liner, while others may have two or more compact soil liners. Despite the inevitable use of compacted clay liners, a conventional landfill system uses geosynthetics to benefit, reducing the likely long-term adverse environmental impact. Barrier layers constructed of two or more components are known as composite liner. These become the most widely used filler for the insulation or sealing facilities used for storing water, chemicals, material and waste. As a result, they are intensively studied, particularly in terms of their hydraulic and diffusion properties, chemical stability, mechanical behavior, resilience, and gas migration[1]. Liner with a geomembrane placed above low permeable soil is one of the most commonly used composite liners. Although the geomembrane part of a composite liner is almost impervious to liquid flow, there may be flaws in the geomembrane, even with construction and assembly being carefully controlled[8,10]. Thus, quantifying the risk of leakage through the composite liner due to geomembrane defect is very important.

2. MATERIALS AND METHODS

Composite liner related to the thesis is a liner positioned above a low permeability soil with a geomembrane. Bentonite is commercially available in the low-permeability soil chosen for the permeability test[9]. Bentonite properties are given in Table 1. Because the soil’s permeability is very small, the time required to perform the permeability test is very large. Due to time constraints the soil was mixed with sand in the ratio 3:1 to achieve the permeability of 10^-7 cm/s. The particle size distribution curve for sand is shown in Figure 1.

![Particle Size Distribution Curve](image)

Figure 1 The particle size distribution curve for sand

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Liquid Limit (%)</td>
<td>450</td>
</tr>
<tr>
<td>2</td>
<td>Plastic Limit (%)</td>
<td>93</td>
</tr>
<tr>
<td>3</td>
<td>Plastic Index</td>
<td>357</td>
</tr>
<tr>
<td>4</td>
<td>Specific Gravity</td>
<td>2.3</td>
</tr>
<tr>
<td>5</td>
<td>U.C.C(kg/cm²)</td>
<td>1.794</td>
</tr>
<tr>
<td>6</td>
<td>Coefficient of permeability (cm/s)</td>
<td>10^-10</td>
</tr>
</tbody>
</table>

Table 1 Engineering properties of bentonite
Thickness of the geomembrane (polyvinyl chloride) used for the experiment is of 1 mm thick with smooth surface. Holes of 2mm, 4mm, 6mm, 8mm and 10mm were made on the geomembrane to conduct the experiments by varying the water head, thickness of soil and permeability of the soil.

Figure 2 shows a schematic sketch of the test setup. The composite sample is prepared in the permeameter by placing 20 mm thick amended soil at a water content of 200% and defected geomembrane above it. The porous discs were placed above the geomembrane. Steps were taken to prevent leakage. To simulate the field condition and to ensure contact between geomembrane and the soil, sand was placed above the geomembrane to a height of 100mm.

The sample is fully saturated by allowing water to flow upward from the base to the top. This was done by attaching the constant head reservoir to the outlet pipe. The upward flow is maintained for 15 days, to saturate the soil.

After the soil sample has been saturated, the upper portion of the mould is filled with water and water is allowed to flow through the sample. The outlet of the mould is connected to a graduated standpipe. To prevent evaporation, 5 mm height a oil was maintained above the water is standpipe throughout the experiment. Quantity of flow through the soil was noted by varying area of defect in geomembrane, thickness of soil, and head of water. Tests were conducted at a temperature of 25°C.

The defects on the geomembrane were made by punching holes of diameter 2mm, 4 mm, 6mm, 8mm and 10mm at the center of the specimen. Tests were conducted at soil thickness of 10mm, 20mm, 30mm, and 50mm.

**IV RESULT AND DISCUSSION**

**A) Effect of variation in head on discharge**

Permeability tests were carried out by varying the head of water and area of defect of the composite liner[11]. Rate of discharge through the composite liner with the geomembrane defect were measured by varying heads of 50mm, 100mm, 150mm, 200mm, 250mm, and 300mm and varying the diameter of the geomembrane defect ie, mm, 4mm, 6mm, 8 mm and 10mm. (corresponding percentage area of defect are 0.04, 0.16, 0.36, 0.64, and 1.00 respectively). The variation in discharge with head is shown in Fig. 3. From the graph it can be seen that as the head increases discharge also increases. All the curve shows similar trend. From the figure it can be seen that the percentage increase in discharge for all the curves is greater than 85% for increase of head from 50mm to 300mm. It suggests that there is more impact of raise of head on the risk of leakage by composite liner due to geomembrane defect [12-16].

**Fig. 3 The variation in discharge with head**

**B) Effect of variation in defect area on discharge**

Permeability tests were carried out with geomembrane defect of varying defect diameters of 2mm, 4mm, 6mm, 8mm and 10mm at heads of 50 mm, 100mm, 150mm 200mm, 250mm and 300mm. Variation of discharge through composite liner due to geomembrane with increase in defect area of geomembrane is shown in Fig. 3. From the graph it can be seen that as the area of defect increases the rate of discharge also increases. From the table it can be seen that the percentage increase in discharge for all the cases is greater than 45%.

**C) Effect of variation in thickness of soil on discharge**

Permeability tests were performed with faulty geomembrane of different thicknesses of the composite liner's low permeability soil for various geomembrane defect areas.
thickness of soil was 10mm, 20mm, 30mm and 50mm. Variation in discharge with increase in thickness of soil are shown in Fig. 5. From the graph it can be seen that as the thickness of soil increases, discharge through the defect in composite liner decreases. From the graph the percentage increase in discharge when the head increase from 50mm to 300 mm for 10 mm and 20mm thick soil is 80 %, whereas for 30mm and 50 mm thick soil is around 40 %. It is clear that the effect of ahead is more when the thickness of soil sample is less.

D) Comparison of experiment result with available equations.

Experiment results were compared with the Darcy's equation, Faure's equation and equation given by Giroud.et.al[8]. The relation of experimental results with theses equations is shown in Fig. 6 Fig. 7, Fig. 8 and Fig. 9. It can be seen from the diagrams that experimental values lie between the product of Darcy's equation and the equation Giroud.et.al[8,17,18].

Fig 5 Variation in discharge with increase in thickness of soil

Fig 6 Comparison Values with existing Equations 2 mm Diameter Defect

Fig 7 Comparison Values with existing Equations 4 mm Diameter Defect

Fig 8 Comparison Values with existing Equations 6 mm Diameter Defect
V PROPOSED EQUATION

Experiments were performed to determine the risk of leakage due to a geomembrane defect through a composite lining. Based on experiment result an equation has been derived for leakage through composite liner. The parameters considered for the derivation are area of defect, permeability of soil, head of water and thickness of soil. The software used is SPSS.

Equation

\[
\begin{align*}
Q &= k_s \cdot d \cdot h_w \cdot H_s \\
Q &= \text{lower bound of the leakage rate (m3/s)} \\
k_s &= \text{hydraulic conductivity of the low-permeability soil (m/s)} \\
d &= \text{diameter of the circular hole (m)} \\
h_w &= \text{liquid depth on top of the geomembrane (m)} \\
H_s &= \text{thickness of the low permeability soil (m)}
\end{align*}
\]

Where,

\[Q = \text{lower bound of the leakage rate (m3/s)}\]
\[k_s = \text{hydraulic conductivity of the low-permeability soil (m/s)}\]
\[d = \text{diameter of the circular hole (m)}\]
\[h_w = \text{liquid depth on top of the geomembrane (m)}\]
\[H_s = \text{thickness of the low permeability soil (m)}\]

Assumptions

- The geomembrane and the soil are completely in contact.
- The geomembrane fault is circular.

REFERENCES


