# GEOSYNTHETIC DAM LINING SYSTEMS

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**Abstract:** The overall goal of this project is to contribute towards the use of geosynthetics in the design of dams and other hydraulic systems. More specifically, this project aims at quantifying the leakage through geomembrane and composite liners under conditions representative of dams. There has been previous work done regarding leakage quantification but only under relatively small heads (e.g. 0.3 m). However, the use of geosynthetic liners for dams involves heads much larger than those in environmental applications. Accordingly, experimental data is needed to evaluate leakage flow for use in the design of these geosynthetic lining systems. A testing program involving quantification of leakage under high heads through geomembranes, soils, concrete and combinations of various other geosynthetics is under way at the University of Texas at Austin. The research objectives, experimental setup, and expected impact in the field of geotechnical engineering are presented in this paper.

## INTRODUCTION

Geosynthetics are human-made materials (typically polymers) that are used in conjunction with soil for reinforcement, drainage, filtration and infiltration barrier applications. Geosynthetics have been used in a large number of geotechnical, transportation, environmental and hydraulic engineering applications as they provide cost-effective, long-lasting solutions to problems associated with these systems. Geomembranes are generally thin sheets of polymer material and are primarily used in applications involving liquid containment, making these materials the most common geosynthetic used in hydraulic structures. By using geomembranes in hydraulic applications, the infrastructure of water conveyance and storage can be protected and its effective service life extended.

Dams are among the most critical of civil engineering structures. They provide an important source of water for agricultural, municipal and industrial use. As dams age, deterioration and structural damage are of major concern as they can lead to water loss and even failure. Seepage of water through a dam is the most common cause of deterioration and structural damage. External erosion by the reservoir water generates cracking in the facing of the dam, which leads to an increase in the flow of water into the dam body and, ultimately, to internal erosion and structural instability.

Geomembranes provide inexpensive but effective solutions to address problems associated with dam leakage and deterioration. In fact, geomembranes have been used in many applications as a solution to dam seepage problems since 1959. However, geomembranes are not absolutely impervious to water and are inherently vulnerable to

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damage during installation and throughout the service life of the dam. This damage is the main mechanism of water infiltration through geomembranes.

Defects are unavoidable even if construction quality control and assurance methods are used during installation. Giroud and Bonaparte (1989) conducted a study, based on data obtained from quality assurance and forensic analyses, to determine the frequency of defects that can be expected in landfill liners. The authors found that an average of one defect per 10 m of field seam (occurring when two geomembrane sheets are attached together in the field) without quality assurance or quality control and one defect per 300 m of field seam when quality assurance and control measures are used. Based on these data, it is safe to assume that defects will be present in a geomembrane lining system for dams.

Evaluation of the effect of high water pressure on a flawed geomembrane has been, at best, limited. Up to now, the majority of research conducted regarding leakage through defects has dealt with quantifying leakage rates in landfill liners through laboratory testing (Brown et al. 1987; Benson et al. 1995). However, dams are subjected to significantly larger water heads (height of water in the reservoir) than landfill liners experience while in service (the maximum allowable head permitted by federal regulations in landfills is 0.3 m). The effect that these high hydraulic heads has on leakage rates through defects in a geomembrane liner has not been thoroughly investigated.

For the reasons discussed above, quantification of the amount of leakage that passes through the defects in a dam lining system is necessary. Investigation into how various materials beneath a geomembrane in a liner system affect the leakage rate and characteristics of flow is also needed. In some cases, drainage systems have been installed to collect water permeating the geomembrane liner and its defects in order to minimize infiltration into the dam structure. Specifically, geonets and geotextiles have been used in drainage applications. Also, dams often have vertical or near-vertical facing, so gravity has a different role in the system when compared with landfills, especially when drainage layers are being considered. Consequently, orientation of the liner is another important factor to be considered in this testing program.

## RESEARCH OBJECTIVES

The rate of leakage through a defect in a geomembrane liner under high hydraulic heads is being investigated as part of the ongoing study at the University of Texas at Austin. This research is being conducted as a research activity of the Center of Polymers in Hydraulic Systems (CPHyS) of the Geosynthetics Institute (GSI). Other aspects of the research include investigation of the effect of the construction material and the presence of geosynthetic layers beneath the geomembrane. Orientation of the liner is another important factor to be considered in this testing program.

The primary objective of this research is to evaluate and quantify the leakage through a defect in a geomembrane liner under high hydraulic heads. Specific objectives for the experimental program include but are not limited to the following:

1. Quantify the leakage rate through a geomembrane liner using material combinations typical of dam systems (e.g. concrete, soil).
2. Quantify the effect of hydraulic head for values that are realistic for dams and evaluate the suitability (or not) of formulations developed for low heads (for verification purposes).

3. Quantify the effect of orientation of the liner system on flow (from horizontal to vertical).
4. Gather experimental data needed to validate models to be developed for prediction of flow rates.
5. Evaluate the significance of "intimate contact" between the liner and the material behind the liner on the flow rate through liners subjected to high hydraulic heads.

## EXPERIMENTAL PROGRAM

Evaluation of the leakage characteristics and the factors that affect leakage is expected to lead to the identification of measures that will minimize the flow through and deterioration of dams.

The following variables are being considered during this experimental program:

1. *Hydraulic head:* Tests are being conducted for heads ranging from 0.3 m to 60 m.
2. *Underlying material:* Tests are being conducted using various combinations of geosynthetics (e.g. geomembrane/geotextile) and materials commonly used in dam construction (e.g. concrete and soil).
3. *Defect characteristics:* Common defects include defective seams due to the welding process and puncture holes that occur during construction. Seam defects are thin, rectangular slits and holes can be modeled using circular shapes. The influence of the defect characteristics on the leakage rate through the system will be evaluated.
4. *Liner orientation:* Tests will be conducted using various liner inclinations that are applicable to dam liners (landfill liners are positioned horizontally whereas dams have facings, and thus liners, that are vertical or near vertical).
5. *Initial water content (for cases involving soil):* Water infiltration through a soil layer is influenced by the degree of saturation. The effect of the initial soil moisture condition on the flow characteristics through a soil will be investigated.

The current testing setup uses a permeameter cell with a diameter of 0.15 m. The permeameter cell has been constructed of clear acrylic (Figure 1). The cell is split into two parts, the bottom part of which would contain the soil or concrete specimens. The cell is suitable for conducting tests for various liner orientations, ranging from vertical to horizontal. The geomembrane is placed between the two sections and sealed using O-rings at the cell interface. The ends contain O-rings to provide a water-tight seal. A porous stone is placed at the bottom of the mold and water inlets are situated at the top and bottom of the cell. A pressure panel is used to control hydraulic heads in the system, as well as for measurement of the outflow. During infiltration, the changes in water content in the soil, when soil is used, will be monitored using time domain reflectometry (TDR) probes. These measurements will be used to characterize the flow of water as it moves through the soil profile.

## CONCLUSIONS

Previous research conducted to quantify leakage through geomembrane defects concerned only landfill liners with low hydraulic heads. The research discussed herein pertains to the quantification of the leakage rates through geomembrane liners under high hydraulic heads, simulating dam conditions.

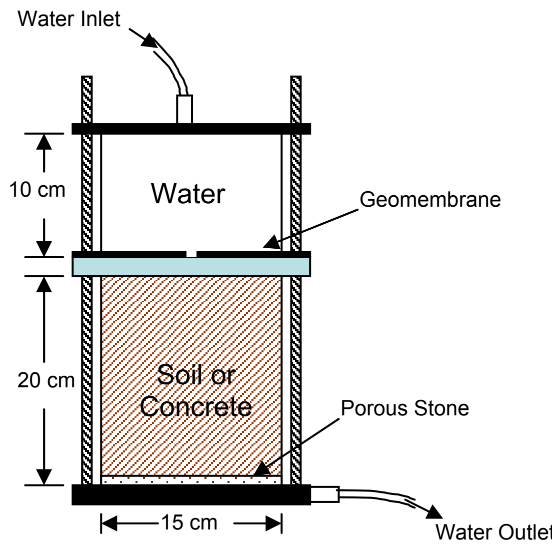

Figure 1: Permeameter cell.

The results of this research could have the following impact on geotechnical practice:

- *Development of methods for predicting leakage rates through geomembrane liners on upstream dam facing:* The leakage rates that are observed in the laboratory will lead to a model that will predict leakage rates in field applications.
- *Improved design for drainage components of a dam liner (based on leakage rates predicted using methods developed during my research):* Once the model is extended to field conditions (e.g., many defects) and a leakage rate is predicted, the drainage layer and outlet should be capable of handling the design flow rate without endangering the structure while maintaining the cost-effectiveness of the design.
- *Development of design recommendations for the installation of a geomembrane hydraulic barrier during the construction of a dam, as well as during rehabilitation of existing dams:* An alarm system could be installed that would monitor the leakage rate at the outlet to alert if a given rate is exceeded, indicating that the hydraulic barrier is damaged and no longer effective.
- *Promote the use of geosynthetics in dams.*

**REFERENCES**

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