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Project Summary

Freeze-Thaw Cycling and Cold Temperature Effects on Geomembrane Sheets and Seams

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The effects of freeze-thaw cycling on the tensile strength of 19 geomembranes and 31 different seam types were investigated. The study was performed in three parts using different test conditions. Part I involved incubating unconfined specimens in freeze-thaw cycles and then performing tests at room temperature. Part II involved incubating unconfined specimens in freeze-thaw cycles and then performing tests at a temperature of -20°C. In Part III, the test specimens were confined at an elongation corresponding to 25% yield or break strength during the freeze-thaw cycles and then were tested at room temperature.

The paper describes the results of each part of the study separately and then investigates comparisons of Parts I versus II and Parts I versus III. As of 50 freeze-thaw cycles, the tentative conclusion is that neither geomembrane sheets nor their associated seams are adversely affected by the different conditions imposed. This tentative conclusion will be further challenged after completion of the 100 and 200 cycle testing.

This Project Summary was developed by EPA's National Risk Management Research Laboratory, Cincinnati, OH, to announce key findings of the research report that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The effects of freeze-thaw cycling on material durability should be a concern for any type of engineered barrier material installed in locations where ground freezing conditions exist. Research has shown that compacted clay liners (CCLs) become friable and experience an increase in permeability after only 10 to 15 freeze-thaw cycles as observed by Zimmie and La Plante (1990). Othman et al. (1993) have even found that the hydraulic conductivity increased 10 times after a single cycle. Because of such problems, CCLs are recommended to be placed beneath the depth of maximum frost penetration. In the continental United States, the frost depths range from zero to 3.0 m. Frost depths are significantly greater in Canada and Alaska. However, for alternate barrier materials such as geomembranes, little information is available regarding performance under freeze-thaw cycling. Geomembranes are almost always required by federal and state regulations for use in landfill covers. In freezing climates, geomembranes used in landfill covers will be subjected to the same freeze-thaw cycles as a CCL unless the depth of cover soil is greater than the maximum frost penetration depth. Other geomembrane applications in which freeze-thaw is a concern include: exposed geomembrane liners in surface impoundments, dams and canals, and floating covers in reservoirs and other liquid impoundments. Thus, the impact of freeze-thaw cycles on the performance of geomembrane sheets and seams should be investigated. It should also be noted that tensile stress may be induced when the geomembrane is experiencing freeze-thaw cycles.

This paper presents the early part of the test results from a geomembrane freeze-thaw study which is a joint effort between the Bureau of Reclamation and the Geosynthetic Research Institute. The focus of the study is to evaluate the effects of freeze-thaw on the tensile behavior of 19 different geomembrane sheets and 31 geomembrane seams. The study consists of three parts. Part I involves performing tensile tests at +20°C after freeze-thaw cycling. Part II involves performing tensile tests at -20°C after freeze-thaw cycling. Part III involves performing tensile tests at +20°C after freeze-thaw cycling, but the test specimens are being strained corresponding to 25% of their yield or break strength during the freeze-thaw cycling.

Literature Research

Although the effects of freezing of geomembrane sheets and their seams is an important issue, there is relatively limited published information available. Early case studies were written about the performance of synthetic liners for petroleum facility containment dikes in Canada. Thornton et al. (1976) visited seven sites and inspected six types of liners in northern Canada. They found that a polyethylene geomembrane which was installed in -30°C weather and seamed by a hot air welder was still in good condition. In addition, laboratory tests indicated that oil resistant PVC remained ductile around -18°C, but field experience showed that brittle fractures were inflicted at temperatures as high as 5°C. The report postulated that this discrepancy may be the result of a shift in the ductile-brittle transition temperature, caused by increased strain from in situ service loads. Laboratory testing was performed only in unstressed conditions such that the postulation has not been verified experimentally under sustained loading in combination with freezing.

Rollin et al. (1984) evaluated the tensile behavior of synthetic and bituminous membranes at temperatures of +23°C, -5°C, -15°C, -25°C and -35°C. Their results showed an increase in tensile strength and a decrease in strain as temperatures were decreased from 23°C to -35°C for both sheet and seamed samples. Also the seams appeared to behave satisfactorily at -35°C. LaFleur et al. (1985) studied the effects of freeze-thaw cycling on 5 geomembrane seams, but only 2 of those seams are currently still available. In their study, the seams were strained at 10% elongation, submerged in water and ice and subjected to 150 freeze-thaw cycles. No reduction occurred in any of the seam shear strengths. In addition, they evaluated the cold temperature seam strength of scrim reinforced geomembranes. At -35°C, they observed that the contribution of the fabric scrim is not significantly altered in comparison to 23°C, confirming the observation found by Allen et al. (1982). At -35°C the stress/elongation behavior of the composite is mainly governed by the geomembrane component. Although the above research efforts do not show a fundamental concern towards the freezing of geomembranes, the development of a wide data base of currently used geomembranes and their seams should be considered.

Test Materials and Incubation Condition

A total of 19 different sheet materials and 31 seam types were evaluated. The total number of freeze-thaw cycles will eventually be 200, however, this paper only includes data up to 50 cycles. The sheet and seam materials of all three parts of the study are the same. They include 19 different geomembrane sheets and 27 seam types. In Part II, the number of test materials was reduced to 6 different geomembrane sheets and 13 seam types. The types of geomembrane sheets and seams that were used in each part of the study are listed in Table 1.

Large sheet and seam samples (approximately 4 m long) were obtained from various manufacturers. Test specimens were died from the samples and were either 25 mm wide by 200 mm long or they were dumbbell shaped. They were then put in polyethylene bags by groups and were subjected to the freeze-thaw cycles. A description of each test material is also included in Table 1.

For Parts I and II the freeze-thaw cycles were created by placing the specimens in a household freezer set at -20°C for approximately 16 hr, and then removed to room temperature conditions for approximately 8 hr. The ambient room temperature was approximately +20°C. All specimens were initially dry. However, condensation was observed on the surface of the specimens during the thaw portion of the cycles. Thus, the specimens experienced some amount of wet-dry cycling, but to an unknown and essentially uncontrolled amount.

The Part III specimens required more elaborate incubation setup than those of Parts I and II. Specimens were confined by a metal frame containing spaces for 25 mm by 150 mm strips. Each specimen was strained to a length corresponding to 25% of its yield or breaking strength. The seamed specimens were placed in shear mode while subjected to the elongation. The entire metal frame, with specimens, was enclosed within a temperature controlled chamber. The chamber was set to provide freeze-thaw cycles of -20°C for 16 hr and +30°C for 8 hr.

Test Procedures

The experimental design for the numbers of freeze-thaw cycles was 1, 10, 20, 50, 100 and 200. However, certain cycles were not performed in Parts II and III of the study because of a lack of materials and time, as described in Table 2.

The full report was submitted in fulfillment of Interagency Agreement EPA Reference No. DW 14936139 between the U.S. Environmental Protection Agency and the U.S. Department of the Interior, Bureau of Reclamation, under joint sponsorship.

Table 1. *Type of Geomembrane Sheets and Seams*

Study Part	Geomembrane Type (i.e. Polymer)	Thickness* mm	Style	Sheet Test Specimen Shape	Seam Type
I, II, III, I, II, III	PVC-R cold temperature formula	1.1	Scrim reinforced	Strip	Chemical Hot Wedge
I, III I,III I, III	PVC	0.5	Smooth	Strip	Chemical Hot Wedge Dielectric
I, II, III I, II, III I, II, III	PVC	1.0	Smooth	Strip	Chemical Hot Wedge Dielectric
I, II, III II	VLDPE	1.0	Smooth	Dumbbell	Hot Wedge Fillet Extrusion
I, II, III II	VLDPE	1.0	Textured	Dumbbell	Hot Wedge Fillet Extrusion
I, III	VLDPE	1.5	Smooth	Dumbbell	Hot Wedge
I, III	VLDPE	1.5	Textured	Dumbbell	Hot Wedge
I,III	HDPE	1.0	Smooth	Dumbbell	Hot Wedge
I,III	HDPE	1.0	Textured	Dumbbell	Hot Wedge
I, II, III II	HDPE	1.5	Smooth	Dumbbell	Hot Wedge Fillet Extrusion
I, II, III II	HDPE	1.5	Textured	Dumbbell	Hot Wedge Fillet Extrusion
I, III	PP	1.0	Smooth	Dumbbell	Hot Wedge
I, III	PP-R	1.1	Scrim reinforced	Strip	Hot Wedge
I, III I, III	CSPE-R	0.9	Scrim reinforced	Strip	Chemical Hot Air
I, III I, III	EIA	0.8	Smooth	Strip	Chemical Hot Wedge
I, III I, III	EIA-R	0.9	Scrim reinforced	Strip	Chemical Hot Wedge
I, III	FCEA	0.8	Smooth	Strip	Hot Air
I, III	FCEA-R	0.8	Geotextile supported	Strip	Hot Air
I, III	EIA-R	0.8	Scrim coated	Strip	Hot Wedge

* *thicknesses are nominal values because this study consists of relative behavior within the same sheet or seamed material.*

Key to Abbreviations

PVC = polyvinyl chloride
VLDPE = very low density polyethylene
HDPE = high density polyethylene
PP = flexible polypropylene
CSPE = chlorosulphonated polyethylene
EIA = ethylene interpolymer alloy
FCEA = fully crosslinked elastomeric alloy
T = textured
R = scrim reinforced

Table 2. *Number of Freeze-Thaw Cycles Performed in Each Part of the Study*

Study	Freeze-Thaw Cycles							
Part	0	1	5	10	20	50	100	200
I	C	C	C	C	C	C	NC	NC
II	C	C		C		C	NC	NC
III	C	C		C		C	NC	NC

Note: C = complete and reported herein
NC = not complete at this time

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David A. Carson *is the EPA Project Officer (see below).*
The complete report, entitled "Freeze-Thaw Cycling and Cold Temperature Effects on Geomembrane Sheets and Seams," (Order No. PB96-177 175; Cost: $31.00, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
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The EPA Project Officer can be contacted at:
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