Performance/Durability of Polyurea Containment Liners versus Polyethylene Based Geomembranes.

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ABSTRACT
In this study the durability and large scale puncture performance of state of the art polyurea geomembranes is tested and compared to various polyethylene materials. The truncated cone test (Large Scale Hydrostatic Puncture, ASTM D5514) was used to determine a critical cone height for a 60 mil polyurea liner and 60 mil HDPE liner, a comparison was also made to CCH values previously published. The results of the study confirm previous findings that more flexible and elastic materials require greater cone heights to induce a puncture than less flexible materials. Polyurea is more flexible and behaves more elastically than any of the previously studied polyethylene materials and possessed a greater CCH. Considering the physical properties of seamless polyurea geomembranes it is often a superior choice for secondary containment as well as primary containment applications such as lined pits for fracturing operations.

1. INTRODUCTION

Puncture resistance of geomembrane lining systems is a key property as even small punctures compromise the performance of the containment and cause environmental contamination. Challenging subgrade conditions often require geomembrane selection based on durability and the ability to resist puncture due to the presence of protruding stones, organic matter or other sub optimal materials. Surveys have shown that approximately 25% of the damage to HDPE liners occurs during installation with 79% of the damage attributed to seams (Nosko et. al. 1996, Nosko et. al. 2000, Forget et. al. 2005). Nosko further determined that 81% of geomembrane punctures are due to stones (Nosko, Andrezal, Greggor, Gainer 2005). Polyurea liners with their seamless installation and excellent puncture resistance over foreign objects eliminate the largest contributors to liner damage.

One strategy for resisting puncture is the ability to resist to resist downward pressure of the effluent over a protruding object through high strength. A second and ultimately more realistic strategy is to stretch over the protruding object, conforming to the uneven subgrade and resisting puncture no matter how much downward pressure is applied. The design challenge of flexibility versus strength is common to many containment projects and data on newer materials such as polyureas needs to be generated.

Polyurea spray applied geomembranes have been used for roughly 15 years, during that time the technology has evolved greatly. Improved performance of polyureas as containment geomembranes has come from new formulations, improved application equipment and application procedures. QA/QC procedures for field projects have improved due to the above factors and polyureas provide superior environmental protection when compared to commonly used polyethylene liners. Polyureas behave in an elastic manner when impacted or stretched, returning to their original thickness when the stress is removed. This is an advantage over polyethylene systems, especially highly crystalline materials such as HDPE. The variety of polyethylene materials available tend to deform plastically and thin out irreversibly when impacted or stretched beyond their yield point. As a result they may fall below regulatory requirements without recovering.

Polyurea liners are often sprayed onto geotextiles when the subgrade is soil. The geotextile backing will have an influence on puncture behavior. In this study we did not consider geotextile cushioning due to the large number of suitable geotextiles and the required time to complete testing. It is our intention to expand our study and evaluate a number of geotextile/polyurea systems for future publication.

2. DESCRIPTION OF TRUNCATED CONE TEST

The Truncated Cone Test (ASTM D5514) is designed to better replicate actual field conditions faced by geomembrane containment liners, when compared to more commonly reported index puncture tests. In this study ASTM D5514 Procedure A was used and truncated cones were selected as the protruding objects which would induce puncture. This procedure examines a large sample of geomembrane (60 cm diameter circle in this case) The geomembrane is placed over three truncated cones arranged in a triangular configuration on the base of the apparatus. The cones are positioned in a circumference of 20 cm, each 120 degrees apart.

The cone tip does not come to a point but is truncated by cutting at 45 degrees a slice from a position part way up the cone, this blunts the tip somewhat and better replicates the sort of sharp objects a geomembrane would encounter during operation. The lowest point of the truncation is oriented so that it faces the middle of the apparatus.

The geomembrane is placed over the cones and secured around the circumference of the apparatus so that it does not move when the equipment is pressurized. Pressure is added to the top of the geomembrane (either with air or water) and is increased slowly at a rate of 7 kPa (1 psi) every 30 minutes. In the case of this study a time of 2 days was required to complete a passed test, i.e. a test where no puncture occurred. Sufficient pressure is added to the vessel that in order to avoid puncture the material must stretch completely over the cones, touching the base of the apparatus around the cone base.

In this study the Truncated Cone Test was chosen to determine durability and puncture resistance in a performance oriented test. More commonly reported index puncture tests such as ASTM D5833 are of limited value in replicating field conditions due to the small size of the sample (45 mm diameter circular sample). In ASTM D5833 a small rod is pushed on the sample until it breaks through, this procedure fails to model the actual behavior of geomembranes (Hullings and Koerner, 1991). The small size of the tested sample doesn't allow the large scale stretching behavior exhibited by elastic materials. ASTM D5833 is generally reported for polyethylene geomembranes and results tend to increase with increased tensile strength (Starck et. al, 2008)

3. PROPERTIES OF MNATERIALS TESTED AND MATERIAL RESULTS TAKEN FROM LITERATURE.

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One of the drawbacks in designing with polyurea as an alternative to polyethylene is the lack of comparable test methods between the two materials. For this study a small number of specified polyethylene test methods were completed on polyurea to act as a reference. In this case polyurea of comparable thickness matched polyethylene physical properties surprisingly well, considering the substantial difference between the materials on a molecular level.

HDPE 60 mil for this study was obtained from a known North American supplier, the polyurea utilized was Precidium™ ECS, LLDPE results are given for Enviro Liner™ 4040.

Table 1 shows the properties of the materials we compared.

4. CCH CCH RESULTS AND DISCUSSION

Table 2 shows the results of testing we conducted on HDPE 60 mil and Polyurea 60 mil.

The elastic material polyurea gave the greatest CCH and showed the best conformance to imperfections in the subgrade. This confirms the expected result that more flexible materials are more durable in this simulation of actual field conditions, and provide a higher level of environmental protection when compared to stronger and stiffer materials
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Less crystalline and more flexible polyethylenes such as Linear Low Density Polyethylene (LLDPE) gave much better performance than HDPE. It appears that critical cone height in polyethylenes improves as density decreases, the density of the HDPE tested in this study was measured at 0.951 g/ml, while the Geosynthetic Research Institutes GM specifications gives a maximum density of 0.939 g/ml for LLDPE.

Table 1: Properties of Tested Materials and Data from Literature

Material	Thickness	Property	Test Method	Result
HDPE[1]	60 Mil	Tensile Strength	ASTM D6693 Type IV	Yeild 18 kN/m Break 33 kN/m
		Elongation	ASTM D6693 Type IV	Yeild 12% Break 700%
		Puncture	ASTM D4833	480 N
Polyurea	60 Mil	Tensile Strength	ASTM D6693 Type IV	21.1 kN/m
		Elongation	ASTM D6693 Type IV	238%
		Puncture	ASTM D4833	433 N
LLDPE[2]	40 Mil	Tensile Strength	D638	21.7 kN/m
		Eliongation	D638	800%
		Puncture	D4833	271 N
CSPE-R[3]	36 Mil	Tensile Strength	D4595	30 Mpa
		Elongation	D4595	25%
		Puncture	D4833	639 N

[1]HDPE properties shown are minimum specifications as per GRI GM-13.

[2]Linear Low Density Polyethylene from Layfield Engineered Membranes and Films (a division of Layfeid) publication Puncture Resistance - Truncated Cone Study.

[3]Chlorosulfanated Polyethylene reinforced with a fabric Scrim. From Hullings and Koerner , 1991.

Table 2. CCH from Testing and Literature

Material	Thickness	CCH
HDPE	60 mil	1.27 cm
Polyurea	60 mil	6.35 cm
LLDPE	40 mil	Approx. 5 cm
CSPE-R	36 mil	1.8 cm

5. CONCLUSIONS

Seamless spray applied polyurea geomembranes possess outstanding durability and puncture resistance when compared to polyethylene geomembranes of varying density. Polyurea provides superior environmental protection for secondary containment applications such as tank farms, and particularly for primary containment applications such as synthetically lined ponds for fracturing operations. Very high strength fabric reinforced materials also do not compare to polyurea in terms of actual field performance. As the technology of formulations, application equipment, and application techniques has evolved, and installation advantages of a spray applied system over traditional sheet goods is better understood and accepted by industry and regulators, polyurea is quickly becoming a serious alternative to polyethylene in containment design. Major steps in field installation QA/QC of polyurea systems continue to evolve giving regulators and facility owners confidence in the level of containment provided by these products.

REFERENCES