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POLYUREA GEOMEMBRANES: HIGH PERFORMANCE SEAMLESS LINERS

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Abstract: Although polyurea geomembranes have been successfully used in the market for several years, technical information and performance evaluations are virtually nonexistent. Furthermore, when referring to construction specifications for polyurea geomembranes, physical properties of the coating and geotextile are listed rather than those of the geomembrane. Polyurea geomembranes have unique properties and they deserve the same comprehensive testing and reporting as the components used to form them. In this study, properties of polyurea geomembranes based on different geotextiles are reported and their unique characteristics are contrasted with traditional prefabricated liners. Woven, nonwoven, and spunlaid geotextiles of different weights were used to create the polyurea geomembranes, which were mechanically tested in two orientations. In addition, mechanical properties of these polyurea geomembranes were evaluated according to methods for elastomeric coatings and compared to methods for coated fabrics. The peel adhesion between the polyurea coating and geotextile was measured for each polyurea geomembrane, which revealed an unexpected high result for a woven polypropylene geotextile. High-resolution images of the polyurea/geotextile interface showed how the individual components interact to form a geomembrane. The polyurea geomembranes exhibited low permeability to water, as well as greater tensile strength, puncture resistance, and tear resistance than traditional thermoplastic liners.

Keywords: damage, geotextile, geomembrane, reservoir, woven geotextile, nonwoven geotextiles

INTRODUCTION

The development of geomembranes began over 50 years ago in the western United States in an effort to reduce the amount of water lost in canals and reservoirs (Forget et al. 2005). In 1976, President Gerald Ford signed the Resource Conservation and Recovery Act (RCRA) (Druschel et al. 1993), and directed the Environmental Protection Agency (EPA) to establish Federal regulations and standards (Fluet 1984) that addressed several environmental problems associated with hazardous waste. Geomembrane materials played a key role in meeting these standards, which lead to development of new geomembrane materials and tremendous growth in the geomembrane market. Geomembranes have been specifically developed to meet the economic and performance requirements for applications such as, chemical containment, pond liners, landfills, and secondary containment—just to name a few.

Over the past several years, the geomembrane market growth has mainly been driven by EPA standards and increasing public awareness of environmental safety. During this time, the market focus shifted from containment of hazardous waste leachate, to underground storage tanks, and more recently, to aboveground storage tanks for various chemicals. Secondary containment liners around aboveground storage tanks can be achieved by several means. Geomembrane materials are often times the most economical secondary containment liner option, when considering site conditions, regulatory requirements, and alternative materials. Geomembranes are typically composed of asphalt and synthetic polymers, which are either homogenous or formed over a reinforcing substrate. Currently, the most common prefabricated geomembranes of synthetic polymers are high-density polyethylene (HDPE), polyvinyl chloride (PVC), ethylene propylene diene monomer (EPDM), flexible polypropylene (fPP), and polyethylene (PE). Field-sprayed geomembranes are typically composed of polyurethane (Woolley & Peters 1976), polysulfide, and polyurea coatings (Loomis et al. 1997) applied over various types of geotextiles.

Over the past several years, the use of polyurea geomembranes has increased significantly as the industry has learned to successfully utilize this technology (Loomis 2002, Nosko & Touze-Foltz 2000). Polyurea geomembranes have been chosen as alternatives to traditional liners since they are seamless, fast curing over a wide range of temperatures and humidity, and offer high performance properties. These characteristics have made seamless polyurea geomembranes a preferred choice, and in some cases, the only choice for lining new and existing facilities with complex installation details.

EXPERIMENTAL

Materials

Several commercially available geotextiles were evaluated and combined with a spray polyurea elastomer to form geomembranes. The three types of geotextiles evaluated were woven, nonwoven, and spunlaid, and within each type different weights of each geotextile were evaluated. The woven geotextiles have a perpendicular pattern of monofilament and/or fibrillated (parallel threadlike filaments) network, and the nonwoven and spunlaid are randomly formed.

The nonwoven and spunlaid geotextiles have a heat treated, or calendared, side that preserves the dimensional stability and helps prevent damage during installation. During the application of the spray polyurea elastomer, the calendared surface is the preferable side for application due to its semi-smooth nature. A sample of EPDM was tested according to the same test methods for comparison purposes. Table 1 provides a detailed description of each geotextile and Figures 1 to 3 show examples of materials assessed.

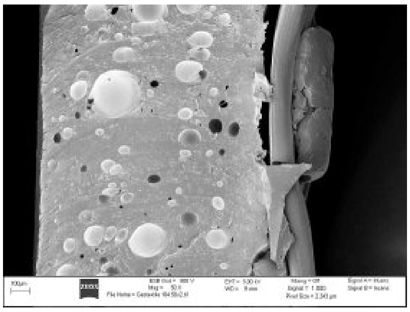

Figure 1. W-6 (woven, 50X).

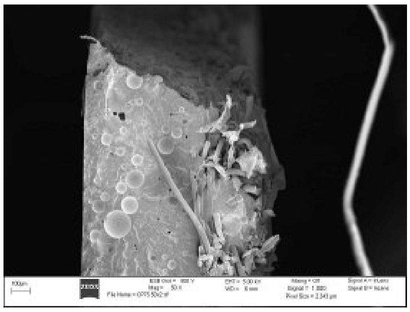

Figure 2. S-2 (50X).

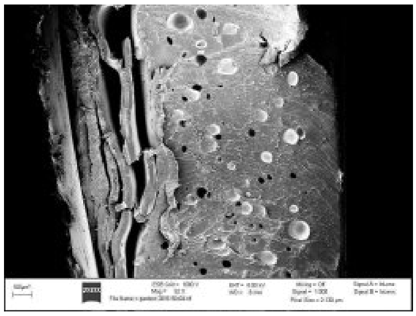

Figure 3. W-8 (50X).

Table 1. Geotextile and rubber membrane descriptions.

Type	Trade Name	Reference	Weight kg/m^2	Description*
Woven	GEOTEX® 104F	W-6	0.20	Perpendicular pattern, Black PP monofilament network
	GEOTEX® 200ST	W-5	0.15	Perpendicular pattern, slit film, Black PP
	GEOTEX® 4x4	W-13	0.44	Twill pattern Black PP monofilament/fibrillated
	GEOTEX® 2x2 HF (Propex 2016)	W-8	0.27	Perpendicular pattern, Black monofilament/White fibrillated PP
Nonwoven	GEOTEX® 601	NW-5	0.17	Random pattern, staple fiber, needle punched, Black PP
	GEOTEX® 1201	NW-11	0.37	
Spunlaid	Colbond CP75	S-2	0.08	Random pattern of a gray bicomponent PET core & PA skin (CP75 is the converted roll version of S75)
	Colbond S170	S-5	0.17	
Rubber	Firestone Pondgard	EPDM	1.53	Ethylene propylene diene monomer (EPDM), Black

*PET = poly(ethylene terphthalate), PA = polyamide (nylon)

Experiments

The spray polyurea elastomer formulation is considered a fast-set system that complies with the Polyurea Development Association (PDA) definition (PDA 2000) of a polyurea. The polyurea system was processed using a Gusmer H-20/35 proportioner at 19.3 MPa with a primary and hose temperature setting at 65°C. The spray gun was a Graco Fusion Air Purge with an AW3333 module. A sheet of this polyurea product was created without a substrate and tested four weeks later according to ASTM D 412-98 Test Methods for Vulcanized Rubber and Thermoplastic, ASTM D624-00 Test Method for Tear Strength of Conventional Vulcanized Rubber and Thermoplastic Elastomers, ASTM D 1938-02 Test Method for Tear-Propagation Resistance (Trouser Tear) of Plastic Film and Thin Sheeting by Single-Tear Method, and ASTM D 2240-04 Test Method for Rubber Property—Durometer Hardness. Gel time was recorded as the amount of time the spray polyurea elastomer flowed vertically.

The geomembranes were created by laying the geotextile horizontally and spraying the polyurea elastomer in a crosshatch pattern until complete coverage was achieved. The maximum and average peel adhesions of the geomembrane samples were measured according to ASTM D1876-01 Peel Resistance of Adhesives (T-Peel Test). It is important to note that the thickness of geotextiles vary depending on the pressure applied. ASTM D 5199-01 Measuring the Nominal Thickness Geosynthetics was employed to obtain the thickness of each geotextile and geomembrane. The polyurea geomembrane samples were cured a minimum of four weeks at 20°C, and the thickness measurements were used to calculate mechanical properties.

The geotextiles and geomembranes were tested according to ASTM D 751-00 Coated Fabrics-Procedure A Grab Test Method and ASTM D 4533-04 Trapezoid Tearing Strength of Geotextiles, in two opposite directions, to observe how the geotextile orientation affects the physical properties. Tensile and elongation properties were conducted according to ASTM D 751-00, and the trapezoid tear strength was measured to compare the tear propagation of each material. In addition, the geomembranes were tested according to more traditional coating test methods (e.g., ASTM D 412, D 624, D 1938). According to ASTM D4833-00 Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products, the puncture resistance was recorded when the rod completely ruptured the test sample at a rate of 300 mm/min.

The average permeability was measured according to ASTM E96-05 Water Vapor Transmission of Materials-Procedure B Water Method at 23°C for spunlaid, woven, and nonwoven geomembranes. High-resolution images of W-6 (woven), W-8 (woven), NW-5, and S-2 (spunlaid) were acquired with a Zeiss Ultra (Mark II) thermal field emission microscope. The samples were prepared by applying a gold/palladium layer with an all-round SEM sputter coater prior to image acquisition.

RESULTS AND DISCUSSION

Spray Polyurea Elastomer

The properties of the 100% solids fast-set spray polyurea elastomer are found in Table 2. These results provide a baseline for understanding how the spray polyurea coating properties are influenced by the geotextile substrate. Polyurea coatings are known to influence the geotextile dimensional stability when they cure. The polyurea coating in this study experienced a linear shrinkage of about 1%, so when it is applied to a geotextile, the total area was reduced by this same percentage. This shrinkage must be taken in account during the design and installation of the geomembrane lining system. Also, all of the mechanical properties of polyurea coatings are influenced by the spray gun design and processing parameters (Loomis 2002). For this study, the process parameters were held constant, and an air purge spray gun was chosen to minimize air entrainment and produce a dense polyurea coating.

Table 2. Property of the spray polyurea elastomer coating (Reference 1020442-4/1020441).

Property	ASTM	Results	Property	ASTM	Results
Gel time, sec	NA	4	Shore D	D 2240	47
Thickness, mm	D 5199	1.4	Shrinkage, %	NA	0.93
Tensile Str., MPa	D 412	21	Puncture Resist., N	D 4833	582
Elongation, %	D 412	445	Density, g/cm^3	NA	0.94
Tear (Die C), kN/m	D 624	88	Perms, 2.2 mm	E 96-Water Method	1.6
Tear, N	D 1938	71	Avg. Permeability, cm/s		2.0×10^{-10}

Woven Geotextiles

The design and strength of woven geotextiles makes these materials ideal for roadway/soil stabilization, erosion control, and drainage. The W-6 is specifically designed for filtration or drainage applications, and the fast-setting spray polyurea elastomer was capable of penetrating the "mesh" or finely woven monofilaments. Filling the pores of the woven geotextile was not significant enough to physically bond the spray polyurea elastomer, resulting in 100% adhesive failure at only 13.8kPa. The polyurea geomembrane exhibited a high elongation (349%) when tested according to ASTM D 412, which is surprising considering the grab tensile elongation was only 31%. This difference is attributed to the lack of adhesion between layers, allowing the polyurea coating properties to dominate the result.

Table 3. Property comparison of W-6 & W-5.

Coating Test Methods	ASTM	Polyurea Coated W-6				Polyurea Coated W-5			
Thickness, mm	D5199	1.8				1.9			
Tensile Str., MPa	D412	15.8				18.5			
Elongation, %	D412	349				315			
Tear (Die C), kN/m	D624	77				79			
Tear, N	D1938	92.9				114			
Peel adhesion, kN/m	D1876	0.4, 100% adhesive				1.2, 100% adhesive			
Geotextile & Coated Fabric Test Methods		**W-6 Geotextile**		**Polyurea Coated W-6**		**W-5 Geotextile**		**Polyurea Coated W-5**	
Thickness, mm	D5199	0.4		2.1		0.7		2.8	
Puncture Resist., N	D4833	761		903		467		903	
Orientation		A	B	A	B	A	B	A	B
Grab tensile strength, kN	D751	1.6	1.4	2.2	2.4	0.97	1.04	1.89	2.10
Grab elongation, %	D751	21	30	31	21	12	21	24	13
Trapezoid tear, N	D4533	498	396	551	547	436	574	355	662

The orientation of the geotextile does not contribute significantly to the results, which speaks to the uniformity of the weave, and consistent strength of the individual monofilaments. Under high magnification, the entrained air and the lack of adhesion between the polyurea coating and polypropylene are quite evident. The W-5 is designed for soil separation and stabilization, and the physical properties of the polyurea geomembrane were very similar to the W-6 results. The W-13 has a unique twill pattern that is relatively tight with a smooth surface. The polyurea elastomer membrane thickness was higher than other woven geotextiles due to its higher profile surface.

The tensile and elongation properties were impressive (Table 4), but adhesion to the black polypropylene monofilament (warp) and black fibrillated polypropylene (fill) was very low. Grab tensile strength, trapezoid tear strength, and puncture resistance of this polyurea geomembrane, were the highest of all the materials tested.

W-8 is similar to the other three woven geotextiles in composition, and it is specifically designed for high performance reinforcement applications. The most surprising result discovered in this study was the polyurea coating adhesion to this woven geotextile. The woven monofilament/fibrillated fabric is not identical on the front and backside, and this difference allows the polyurea elastomer to mechanically bond to one side and not the other (Figures 4 and 5). Even though the adhesion to the polypropylene surface is poor, the monofilaments are woven such that they create a wide gap over two fibrillated strands on the "black" side. This gap offers a space for the polyurea coating to flow under and encapsulate the monofilament strand, resulting in a strong anchor point.

Figure 4. Sample of W-8 with improved peel adhesion on the monofilament polypropylene side, or "black" side.

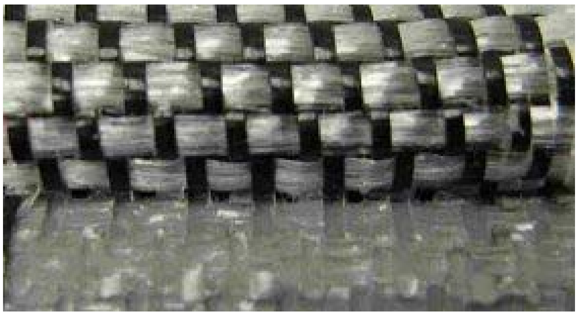

Figure 5. Sample of W-8 with lower peel adhesion on the fibrillated polypropylene side, or "white" side.

Table 4. Property comparison of W-13 woven polypropylene.

Coating Test Methods	ASTM	Polyurea Coated W-13			
Thickness, mm	D5199	2.5			
Tensile Str., MPa	D412	28.7			
Elongation, %	D412	313			
Tear (Die C), kN/m	D624	54.6			
Tear, N	D1938	120			
Peel adhesion, kN/m	D1876	0.9, 100% adhesive			
Geotextile & Coated Fabric Test Methods		**W-13 Geotextile**		**Polyurea Coated W-13**	
Thickness, mm	D5199	1.04		3.35	
Puncture Resist., kN	D4833	1.26		1.73	
Orientation		A	B	A	B
Grab tensile strength, kN	D751	2.72	2.80	3.96	3.98
Grab elongation, %	D751	19	19	21	24
Trapezoid tear, kN	D4533	1.67	1.18	1.92	1.69

The adhesion to the opposite side was dramatically lower due to the tightness of the weave. Further testing revealed that testing the peel adhesion at different geotextile orientations did not significantly change the results. Overall, the polyurea coated W-8 physical properties were excellent according to both the Coating & Geotextile Test Methods.

Table 5. Property comparison of W-8.

Coating Test Methods	ASTM	Polyurea Coated W-8* (*Right angle)			
Thickness, mm	D5199	1.6			
Tensile Str., MPa	D412	29.4			
Elongation, %	D412	368			
Tear (Die C), kN/m	D624	58.6			
Tear, N	D1938	80.1			
Peel adhesion, kN/m	D1876	"White" side	0.7, 100% adhesive; 0.9, 100% adhesive*		
		"Black" side	2.4, 100% adhesive; 2.8, 100% adhesive*		
Geotextile & Coated Fabric Test Methods		**W-8 Geotextile**		**Polyurea Coated W-8***	
Thickness, mm	D5199	0.8		1.9	
Puncture Resist., kN	D4833	0.84		1.17	
Orientation		A	B	A	B
Grab tensile strength, kN	D751	1.66	1.65	2.32	2.44
Grab elongation, %	D751	20	17	22	18
Trapezoid tear, kN	D4533	0.70	0.69	0.64	0.66

Nonwoven Geotextile

Nonwoven geotextiles have been used for many years to form a geomembrane in the field (Fluet 1984) with spray-on types of polymers. Nonwoven fabrics are commonly used to extend the life of asphalt pavements and overlays, along with other applications such as soil stabilization. Nonwoven geotextiles have a relatively smooth surface that is calendared and easily absorbs polymeric materials. The heavier weight nonwoven geotextile have increased grab tensile strength over lighter weight geotextiles, but the difference is reversed with tensile strength when tested according to the coating test methods (Table 6). This reversal in tensile strength is due to the ASTM D 412 test sample geometry and geotextile characteristics, which emphasizes the importance of using ASTM D 751 for coated fabrics, instead of traditional coating test methods.

The random nature of the polypropylene fibers (~30 mm) is quite evident, as they become encapsulated in the polyurea coating. Under stress testing, such as ASTM D 412, these fibers remain within the polyurea coating and reduce ultimate tensile strength and elongation. These encapsulated fibers are responsible for the very high peel adhesion and the 100% cohesive failure during testing.

Table 6. Property comparison of NW-5 & NW-11.

Coating Test Methods	**ASTM**	**Polyurea Coated NW-5**				**Polyurea Coated NW-11**			
Thickness, mm	D5199	2.1				4.8			
Tensile Str., MPa	D412	5.88				4.57			
Elongation, %	D412	72				86			
Tear (Die C), kN/m	D624	65.6				85.2			
Tear, N	D1938	173				274			
Peel adhesion, kN/m	D1876	6.5, 100% cohesive				9.5, 100% cohesive			
Geotextile & Coated Fabric Test Methods		**NW-5 Geotextile**		**Polyurea Coated NW-5**		**NW-11 Geotextile**		**Polyurea Coated NW-11**	
Thickness, mm	D5199	2.2		3.9		2.9		4.3	
Puncture Resist., kN	D4833	0.47		0.79		0.88		1.03	
Orientation		A	B	A	B	A	B	A	B
Grab tensile strength, kN	D751	1.11	0.81	2.16	1.8)	1.53	1.70	2.91	2.90
Grab elongation, %	D751	70	66	58	87	57	55	63	64
Trapezoid tear, kN	D4533	0.55	0.36	0.63	0.68	0.77	0.76	0.86	0.92

Spunlaid Polyester

Spunlaid polyesters are typically lightweight geotextiles composed of polyester or polypropylene, and are commonly used in the automotive, roofing, and flooring markets. The two products tested have a thermally bonded polyester core and a polyamide skin to produce a nonwoven geotextile with excellent thermal and mechanical properties. In fact, the highest tear strengths (Table 7, Die C) and lowest trapezoid tear strengths were achieved with both of the spunlaid geotextiles. The high tear resistance (Die C) indicates that it is very difficult to initiate a tear, but once the tear is started, the low trapezoid tear resistance shows that it propagates more easily than the nonwoven and woven polyurea geomembranes.

Table 7. Property comparison of S-2 & S-5.

Coating Test Methods	**ASTM**	**Polyurea Coated S-2**				**Polyurea Coated S-5**			
Thickness, mm	D5199	1.1				2.1			
Tensile Str., MPa	D412	11.8				14.1			
Elongation, %	D412	74				60			
Tear (Die C), kN/m	D624	95.9				96.6			
Tear, N	D1938	52.3				97.7			
Peel adhesion, kN/m	D1876	4.9, 100% cohesive				8.2, 100% cohesive			
Geotextile & Coated FabricTest Methods		**S-2 Geotextile**		**Polyurea Coated S-2**		**S-5 Geotextile**		**Polyurea Coated S-5**	
Thickness, mm	D5199	0.43		1.5		0.76		1.8	
Puncture Resist., kN	D4833	0.15		0.39		0.33		0.54	
Orientation		A	B	A	B	A	B	A	B
Grab tensile strength, kN	D751	0.35	0.42	1.34	1.45	0.98	0.92	1.76	1.93
Grab elongation, %	D751	59	59	83	75	64	68	68	62
Trapezoid tear, kN	D4533	0.16	0.17	0.29	0.26	0.35	0.33	0.28	0.27

The surface of the geotextile is smooth on both sides and the polyurea coating easily saturated the network of fibers. A surprising result was the high tensile strength (ASTM D 412) of the geomembrane, even though with the polyurea coating being impregnated with fibers. A drop in elongation indicates defects in the polyurea coating from these fibers, but due to the excellent mechanical properties of the spunlaid geotextile, greater tensile strength are observed as compared to other nonwoven geotextiles.

Permeability

Understanding that geotextile characteristics influence the absorption of polyurea, leads to the question of how these geotextiles influence the permeability of polyurea geomembranes. The permeance is evaluated using ASTM E96 and the test procedure employed, either Procedure A or Procedure B, is chosen to reflect the service conditions. For dry conditions, 0-50% relative humidity, Procedure A—Descant Method, or "dry-cup", is used, and these results are often reported in building and energy conservation codes (Table 9). Permeance results for 100% solids polyurea coating are often reported to be below 1.0, according to the "dry-cup" method.

Table 8. Scale of permeance levels commonly used by building codes and industry literature (U.S. HUD 2006).

Description (Test "dry cup")	**Perms (g/hr ft^2)**
Vapor impermeable (barrier)	< 0.1
Vapor semi-impermeable	0.1 -1
Vapor retarder	< 1
Vapor semi-permeable	1 -10
Vapor permeable	> 10

Under wet conditions, the permeance value for all materials is greater than under dry conditions. For example, a 15-pound asphalt felt has a 1.0 perm for the dry-cup procedure, and 5.4 perms for the wet-cup procedure. Therefore, coatings and membranes that will be saturated on one side, Procedure B—Water Method, or "Wet-cup", is the best method for determining the permeance. In Table 10, the permeance and average permeability results are listed for EPDM, spunlaid, woven, and nonwoven geomembranes. The average permeability for each polyurea geomembrane was on the same order (10^{-10}) as EPDM, and the type of geotextile did not significantly influence the rate.

Even though the permeability was similar for each geomembrane, the permeance (Perms) was significantly lower for the nonwoven geomembranes. "Perms" is a performance property, and not a property of the material, so it is important to consider both the test conditions and thickness of the material. For example, when polyethylene is tested under dry conditions ("dry-cup"), the perms decrease as the film thickness increases (e.g., 0.16 for 0.05mm, 0.08 for 0.1mm, and 0.06 for 1.5mm). The test samples of the nonwoven polyurea geomembranes were almost twice as thick as the spunlaid polyurea geomembranes, so a lower perm result is expected. A lower permeance result for the thicker polyurea geomembrane reveals an important point about reporting a material's "Perms". A reported value for water vapor transmission in terms of "Perms" is meaningless unless the test method (Dry-cup vs. Wet-cup), and thickness of the test sample is reported alongside the results.

Table 9. Moisture vapor transmission results for EPDM and three polyurea geomembranes.

ASTM E 96-05 Procedure B Water Method	**EPDM**	**Polyurea Coated S-2**	**Polyurea Coated W-8**	**Polyurea Coated NW-5**
Type of Geotextile	Rubber	Spunlaid	Woven	Nonwoven
Thickness, mm.	1.14	1.32	1.52	2.39
Permeance (g/Pa*s*m^2)	1.1×10^{-7}	1.0×10^{-7}	1.0×10^{-7}	9.0×10^{-8}
Permeance (Perms)	2.0	1.8	1.8	1.6
Average Permeability (Permeance* thickness, g/Pa*s*m or cm/s)	1.3×10^{-10}	1.4×10^{-10}	1.5×10^{-10}	2.1×10^{-10}

Seamless Geomembrane

Polyurea geomembranes are frequently used for industrial applications to form a seamless liquid barrier, and the seamless characteristic is uniquely different from traditional geomembranes such as, EPDM, PE, fPP, and PVC. The seamless nature of polyurea geomembranes arises from the excellent intercoat adhesion that forms between two layers of the polyurea, when applied within the recoat time of the polyurea system, to form one continuous seamless liquid barrier. When two layers of polyurea are overlapped outside of the recoat time, the surface is treated with a primer to promote the adhesion between the two layers. Surveys (Nosko et al. 1996, Nosko et al. 2000, Forget et al. 2005) have reported that approximately 25% of the damage to seamed liners occurs during installation, and 79% of the damage is attributed to the seams. Seamless polyurea geomembranes provide a solution to this problem by eliminating the possibility of defective seams or damage to the liner while seaming.

Seam failures are certainly a concern with traditional liners (Peggs 2001), but even more of a concern is puncture resistance. The majority of punctures occur while covering the liner, and 68% of the damage is due to stone punctures (Nosko et al. 2000). When comparing geomembranes properties in the form that they are used in service, polyurea geomembranes have a puncture resistance that is 2.5 to 10 times greater than EPDM and HDPE (Table 11). So, the elastomeric nature of polyurea geomembranes combined with its high mechanical properties, offer this seamless liner greater protection from damage during installation and service than traditional liners.

Table 10. Property comparison of geomembranes in the form that they are installed for service.)

	ASTM	EPDM	HDPE*	Polyurea Coated W-8
Thickness, mm	D5199	1.1	1.5	1.9
Puncture Resistance, N	D4833	147	480	1,170
Tensile Strength, MPa	D412	9.83	26.2	29.4
Tear Resistance, N	D1004	49.3	186.5	92.4

(*Poly-Flex Corporation 6/04

The value of a more puncture resistant seamless liner can be illustrated in the following example. Consider a liner with just one defect that is 1mm in diameter. Assume the containment area of liquid waste is 929 m^2 by 3 m deep, or 2.8 million litres. The leak rate through this defect is 284 litres per day. In one year, the loss of liquid into the surrounding soil would be 103,477 litres. This simple example illustrates how a single defect can leak a large volume of liquid into the surrounding soil. The value of installing a durable seamless liner is quickly realized when comparing the cost of installing seams, inspecting and testing seams, repairing a punctured liner, and cleaning contaminated soil surrounding a failed liner.

Choosing the right geotextile for creating a polyurea geomembrane is very important, and the choice will depend on the application and polyurea coating used to form the geomembrane. When selecting a geotextile to form a polyurea geomembrane, it is important to take into account the geotextile mechanical properties, adhesion of the polyurea coating, weight, color, and thickness.

For example, a black 300g nonwoven geotextile and a gray polyurea coating are commonly used over earthen substrates to create a seamless liner for containment of industrial wastewater. Also, polyurea geomembranes created with woven geotextiles are typically used when extra strength is required in applications such as, large aquatic ponds that contain heavy rocks.

CONCLUSIONS

Each polyurea geomembrane created in this study possesses unique properties imparted by the polyurea coating and the type and weight of geotextile. Test methods for coated fabrics, ASTM D 751, produced useful results for observing how the polyurea coating was modified by the woven, nonwoven, and spunlaid geotextile properties. Woven geotextiles produced polyurea geomembranes with high tensile strength and puncture resistance, but with poor adhesion to the polyurea coating, with the exception of W-8. Nonwoven geotextiles offer good puncture and tear resistance, and excellent adhesion for the polyurea coating, but at the expense of a lower coverage rate due to absorption. In addition, doubling the weight of the nonwoven geotextile increased the polyurea geomembrane mechanical properties by approximately 30%. Spunlaid geotextiles are easily saturated by the polyurea coating and have a high resistance to tearing, but once a tear is initiated, it propagates more easily than in nonwoven and woven polyurea geomembranes. High-resolution imaging revealed the intricate entanglements of geotextile fibers, and especially the lack of chemical adhesion to the polymer surfaces. In summary, there are two prominent characteristics of polyurea geomembranes that distinguishes them from traditional liners such as EPDM and HDPE. First, polyurea geomembranes have superior puncture resistance and tensile strength properties that when combined with its elastomeric nature, creates a ductile liner with greater resistance to damage during installation and service. Second, polyurea geomembranes are seamless liquid barriers, capable of forming liquid tight seals around complex shapes and penetrations.

The market for geomembranes is expected to grow in size, since geomembranes are very effective at protecting the environment from pollution and hazardous chemicals. Traditional liners continue to dominate the market since they are cost-effective and efficient to install over large areas, but they are not suitable for all applications (Fluet 1984). The market and applications for polyurea geomembranes will continue to grow, as Government Agencies, Applicators, and Design Engineers realize the limitations of traditional liners, and the value of a high performance seamless liners.

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