The Use of a Spray Elastomer for Landfill Cover Liner Applications

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ABSTRACT: Current practice is to use a low permeability soil and/or geosynthetics to perform as the hydraulic barrier in a final cover for a landfill. Materials that are being used in final closures have several potential problems. This paper describes an investigation into the use of a particular spray elastomer in landfill cover liner applications. Material testing was done prior to field application to assist in the design of the appropriate formulation for the elastomer. Materials testing was also completed on samples retrieved from the field site periodically. The testing assisted in determining the durability, properties and characteristics of the elastomer. Preliminary results from the spray elastomer investigation suggest the material to be appropriate for landfill final cover applications. Future efforts need to address the mechanics of a spraying system that would be compatible with the immense nature of many landfill lining projects.

1.0 INTRODUCTION

The disposal of municipal solid waste has become a very sensitive issue ever since the discovery that waste could pollute and damage the environment if not disposed of properly. These concerns prompted the government to impose rules and regulations on the disposal of waste. In order to prevent groundwater and other forms of contamination, regulations were developed that require landfills to be lined with hydraulic barriers, geomembranes and/or natural materials. (Koerner)

Once a landfill has been filled with waste, a final closure will be constructed on the closed facility. The final closure, or cap, functions like a roof. The final closure attempts to prevent water from infiltrating into the closed landfill, where it will produce leachate. Final closures are the last step in the encapsulation of a landfill.

Landfilled waste degrades and consolidates over time. Due to this fact, a final closure system can not exert high loads on the top of the landfill, and also must maintain some flexibility. The cap must be able to withstand differential settlements that may occur due to the waste consolidation and degradation. Natural soil materials, which can exhibit flexural cracking, can not be placed in tension.(Cheng, et al) A geosynthetic hydraulic barrier must be able to strain effectively and still be able to retain it's hydraulic barrier properties.

Final closures have several components, each of which have different purposes. A typical final closure consists of, from the top of the waste to the surface of the closed landfill; a pre-cap fill, a hydraulic barrier, a drainage layer, and a vegetative soil layer (Figure 1). (US EPA)

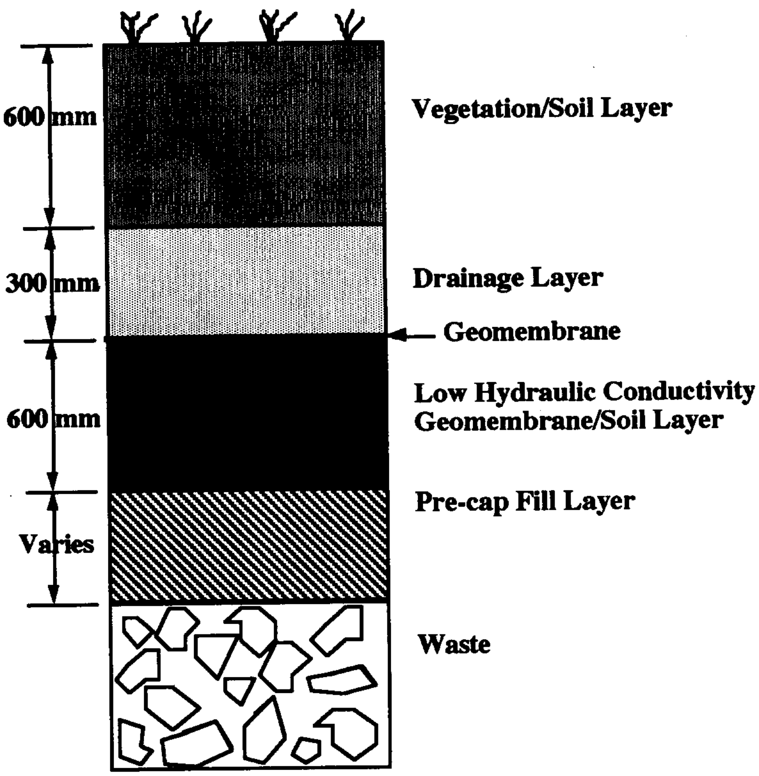

Figure 1 - Typical Landfill Cover Cross-section

The need for a dependable, flexible material for a hydraulic barrier in a landfill final closure is evident. A spray elastomer can perform well under the necessary conditions involved in landfill final closures. The flexible characteristics of this material can perform well under differential settlement conditions.

The current methods of final closure of landfills differential settlement conditions.

The current methods of final closure of landfills involves using a geomembrane or a natural soil for the hydraulic barrier. Both of these materials have potential problems, the natural soil barrier will exhibit flexural cracking, as mentioned previously. Geomembranes can also be affected by differential settlement, which can over stress the geomembrane to the point of rupture. Some other potential problems with geomembrane barriers are low interface friction angles and extensive installation practices.

Spray elastomers are easily applied as a hydraulic barrier, and offer many advantages over current geosynthetic barrier systems. The elastomer can be sprayed onto a prepared surface without the need of heavy equipment or extensive labor. The spray elastomer requires fewer seams, due to it's continuous spray application, and therefore can be applied faster than some other geomembranes. The elastomeric characteristics of this type of material are ideal for use in an application where differential settlement is common.

2.0 PROJECT DESCRIPTION

The purpose of this study was to determine the effectiveness of a spray elastomer for use in a final closure of a landfill. Many different tests were performed to aid in the determination of the characteristics of this material. The tests were all chosen for their relevance to the application of this material as a hydraulic barrier in a final closure.

The polyurea was also field and factory applied to a non-woven geotextile. The geotextile was used as a carrier and uniform application surface for the spray elastomer.

2.1 Tests Performed on Factory Sprayed Material

Index property tests were performed to determine the basic properties and characteristics of the polyurea material. This data was obtained in order to make comparisons with other geomembranes. The majority of the tests were mechanical tests, which were used to determine strength properties of this material. Several other tests were also performed to determine other properties which would be important for use in designing a landfill final closure.

ASTM standard index property tests that were performed on this material were as follows: ASTM D 638 - standard test method for tensile properties of plastics; ASTM D 1004 standard test method for initial tear resistance of plastic film and sheeting; ASTM D 1682 standard test method for breaking load and elongation of textile fabrics; and ASTM D 4885 determining performance strength of geomembranes by the wide strip tensile method. These tests were chosen because of there general acceptance and wide spread use in the field of geosynthetics. The data collected was used for comparison with other types of geomembrane materials.

Other tests were performed to determine specific properties of this material which would be important for landfill closures. These tests included the following: ASTM D 5321 standard test method for determining the coefficient of soil and geosynthetic or geosynthetic and geosynthetic friction by the direct shear method; ASTM E 96 water vapor transmission; and GRI GM-4 three dimensional geomembrane tension test.

All of the tests mentioned above were chosen because of there relative importance to landfill final closures. The direct shear tests were performed between the spray elastomer in contact with other types of geosynthetics, and with natural soils that might be found in a final closure. The water vapor transmission tests were performed to determine the amount of water that could pass through the material. The axi-symmetric tests were performed to simulate a void that could form under the final closure due to differential settlement of the waste. The detailed procedures for each of the tests performed can be found in the proper references.

2.2 Tests Performed on Field Sprayed Material

This project also included the application of the polyurea material to an existing landfill cap in Michigan. The field applied material was also tested for certain mechanical and hydraulic properties. The following tests were performed on the field samples: ASTM D 638 - standard test method for tensile properties of plastics; and ASTM E 96 water vapor transmission. These tests were performed at various field exposures.

The field spray was sprayed on a very light weight (2.3 oz./SY) non-woven heat-bonded geotextile. This textile acted as a uniform spray surface for the spray elastomer. A previous field application of this material on a clay surface indicated that the use of a thin geotextile was warranted. If the soil surface is not prepared well, then the polyurea could flow into some of the cracks, thereby increasing the amount of material that is required to obtain a quality hydraulic barrier. It was proposed and accepted, to use a thin geotextile to act as a smooth uniform surface for application of this material. The laboratory portion of this project also tested factory sprayed polyurea onto the same geotextile that was to be used for the field spray. All of these tests were performed on the field exposed material so that a comparison could be made with the factory sprayed materials. Since the field testing program is ongoing, therefore no conclusions can be drawn at this time. The results of the field performance of this material to date, indicates that it is suitable for a landfill cap application.

3.0 MATERIAL CHARACTERISTICS

The spray elastomer that was studied for this paper was a polyurea material. The polyurea polymer is an elastomeric material that is formed by combining two solid components, without the use of a catalyst. The polyurea membrane or coating is applied through a spray process, during which the two components are mixed, heated and pressurized. The two components are an amine terminated resin and chain extenders with isocyanates (Primeaux II). The chemical formula is shown below in Figure 1.

$$\underset{\text{Isocyanates}}{\mathrm{R\text{-}NCO}} + \underset{\text{Amines}}{\mathrm{R'\text{-}NH_2}} \longrightarrow \underset{\text{Polyurea Polymers}}{\mathrm{R\text{-}NH\text{-}\overset{\overset{\displaystyle O}{\|}}{C}\text{-}NH\text{-}R'}}$$

Figure 1 - Polyurea Chemistry

The mixing and spraying process allows for the rapid application of the elastomeric material. This material has a very fast set, or gel, time. The gel time for this material has been reported to be less than 5 seconds (Primeaux II). This polymer system can be spray applied in several coats to gain the necessary thickness, with no delamination of layers.

One of the primary benefits of using this type of material for a final closure is the ease of application. The ability to spray the elastomer onto any surface gives this material an added benefit over other geomembranes. The spray elastomer can conform to any subgrade condition, thereby allowing it to "grip" the surface and increase the friction angle. The elastomeric properties of this material also make it an excellent choice for final closure applications. The need for far fewer seams is also a clear benefit to this type of material.

The goal of this project was to determine if a polyurea spray elastomer could be effectively used as a hydraulic barrier in a final closure of a landfill. With the many advantages of this material, it can be seen that this material can be effectively used for a hydraulic barrier.

4.0 RESULTS AND DISCUSSION

4.1 Factory Material Test Results

The results of the index property tests performed on the factory sprayed material are presented in Table 1. The test values presented are averages of tests that were performed on several specimens.

Table 1 - Spray Elastomer Test Results

Test Method	Value
Strength @ Failure ASTM D 638	20.8 MPa
Elongation @ Failure ASTM D 638	450 %
Tear Resistance ASTM D 1004	4.0 N/mm
Strip Tensile ASTM D 1682	17.8 MPa
Strip Tensile ASTM D 1682	670 %
Wide Width Tensile Strength @ Failure ASTM D 4885	10.3 MPa
Wide Width Tensile Elongation @ Failure ASTM D 4885	560 %
Puncture FTMS 101C	16.6 N/mm
Water Vapor Transmission ASTM E 96	7.1×10^{-10} cm/sec

Two of the other tests that were conducted on this material were the direct shear and the three-dimensional tension test. The results from these two tests are presented in Tables 2 and 3.

Table 2 - Direct Shear Results

Sample	Friction Angle (°)	Cohesion (psi)
Spray Elastomer Sprayed onto Soil	38.7°	2
Spray Elastomer onto Geotextile	14.5°	0
Spray Elastomer/Geotextile onto Soil	37.4°	0

The direct shear results also show that this material, when sprayed directly onto a prepared soil surface, develops a relatively high friction angle. The same material sprayed onto a nonwoven geotextile will develop a similar friction angle, as seen in the results of the direct shear tests of the spray elastomer/geotextile against the same soil. The sprayed on polyurea intrudes into the cracks and micropores of the soil surface, which leads to a resulting cohesion value. The nonwoven geotextile can also develop a similar "gripping" of the soil.

The use of a nonwoven geotextile above the spray applied elastomer, will result in a rather low friction angle (14.5°). The need for a geotextile above the elastomer would be for a protective layer between a course drainage stone and the elastomer, or as the lower textile on a drainage composite.

Table 3 - Three Dimensional Tensile Test Results

Sample	Spray Elastomer
Maximum Stress (MPa)	2.6
Elongation @ Yield (%)	5.1
Stress @ Break (MPa)	1.2
Elongation @ Break (%)	126

The GRI GM-4 tests showed promising results for landfill cap applications. The material exhibited a large strain value at break, and developed a good strength value as well. Both of these values are good for landfill cap applications where strength and elongation are needed to handle the potential differential settlements.

4.2 Material Comparisons

There are several different geomembrane materials available on the market today, but only a few of them are favored for use in final closures of landfills. The geomembranes that are most favored for this application are polyethylenes and polyvinyl chloride. Each of these materials is compared with the spray elastomer product below.

A typical thickness of 1.0 mm for a very low density polyethylene (VLDPE) geomembrane is used for a hydraulic barrier in a cap. Table 4 compares the spray elastomer to values for 1.0 mm VLDPE.

Table 4 - Spray Elastomer versus 1.0 mm Very Low Density Polyethylene

Property	Test Method	Spray Elastomer	VLDPE
Dogbone Tensile	ASTM D 638	20.83 MPa 450 %	21.7 -24.2 MPa 780 - 950 %
Tear Resistance	ASTM D 1004	81 N	72 - 99 N
Puncture Resistance	FTMS 101C	0.34 kN	0.23 - 0.29 kN
Water Vapor Transmission	ASTM E 96	7×10^{-10}	———

Average values of the spray elastomer were used for comparison to the VLDPE. The values for the spray elastomer were calculated from multiplying the normalized values by the thickness (1.0 mm). As can be seen in Table 4, the strength of the spray elastomer is relatively close to the VLDPE, as well as the tear and puncture values. The strain is about half of the value of the VLDPE though.

Polyvinyl chloride (PVC) is another geomembrane that is typically used in final closure applications. The PVC also exhibits high strain and moderate strength values, much like the VLDPE. A typical thickness of 1.0 mm for a PVC geomembrane is used for a hydraulic barrier in a cap. Table 5 compares the spray elastomer to values for 1.0 mm PVC.

Table 5 - Spray Elastomer versus 1.0 mm Polyvinyl Chloride

Property	Test Method	Spray Elastomer	PVC
Strip Tensile	ASTM D 1682	17.84 MPa 670 %	15.87 MPa 350 %
Tear Resistance	ASTM D 1004	63 N	45 - 54 N
Puncture Resistance	FTMS 101C	0.26 kN	0.29 kN
Water Vapor Transmission	ASTM E 96	7×10^{-10}	———

Average values for the spray elastomer were calculated again using the same method as was mentioned for the comparison of the spray elastomer to VLDPE. Table 5 shows that the strength, tear resistance and puncture resistance are approximately the same for the spray elastomer.

5.0 CONCLUSIONS AND RECOMMENDATIONS

In general, the material properties of the spray elastomer are comparable to both PVC and VLDPE. Mechanical properties, as well as hydraulic properties, are also very beneficial for use in landfill final closures. The primary difference between the spray elastomer and currently used geomembranes, is in the installation procedures. The spray elastomer may have some unique advantages in this regard. Further research in the installation procedures of the spray elastomer is suggested.

The spray application system allows for this material to be applied on any surface without using heavy equipment which could damage the subgrade. The application process is simple, involving no extra seaming or deploying equipment. Seams are made at the start of a new day by over spraying onto the previous days' membrane. This process is more economically feasible as compared with conventional geomembrane systems that require extra equipment and personnel. The polyurea may cost more than low density polyethylene or polyvinyl chloride, on a mil thickness basis, but the savings in construction costs is more evident for the spray elastomer.

To sum up the results of this testing on the polyurea spray elastomer, the following conclusions are drawn. First, this material, based on the index properties and the installation procedures, is very suitable for landfill final closures. Second, the unique installation process is one of the primary benefits of this material. Third, due to this spray application process, a lower number of seams is produced in the hydraulic barrier. Lastly, the polyurea is a much more durable material than other spray applied elastomers, for instance the polyurea is unaffected by moisture.

It is recommended that further testing be done on this material in regard to the ultraviolet ligth degradation, the seaming, the tension creep, and the installation of this spray elastomer.

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