Concerns using U.S. EPA 9090 Test Methods for Reinforced Geomembranes

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ABSTRACT: This paper presents test results and discusses the effects of immersion fluid on the physical and engineering properties (i.e. mass, density, strength, etc.) of reinforced and non-reinforced CSPE geomembrane. The U.S. EPA 9090 test as it applies to reinforced geomembranes will be discussed. Both reinforced and non-reinforced specimens were tested using U.S. EPA method 9090 with site-specific leachates from hazardous and industrial waste landfills. A parallel suite of tests was performed using potable water as the immersion fluid for control. An evaluation of test results of these materials was performed, in particular addressing the pronounced variability of U.S. EPA 9090 method test results for reinforced specimens and the absence of pronounced variability for the specimens without reinforcing.

A suggested methodology for testing (modify U.S. EPA 9090 test method) and evaluation (broaden FLEX model to account for intended use of the geomembrane) of reinforced geomembrane relevant performance criteria for use in waste containment systems is developed. The results of the analysis performed demonstrate the need to modify the U.S. EPA 9090 test method for reinforced geomembranes and upgrade the FLEX program.

1 INTRODUCTION

In 1986, the U.S. EPA proposed a compatibility test method referred to as the U.S. EPA Method 9090 Compatibility Test for Liquid Wastes and Membrane Liners (9090 test) (U.S. EPA, 1986). This 9090 test method has been adopted by the industry as a standard for evaluating the chemical compatibility of geosynthetics selected for use in waste containment systems. A modified version of this test method is soon to be adopted by the American Society of Testing and Materials (ASTM). In addition, in the late 1980s, the U.S. EPA developed an expert system called FLEX (Flexible Liner Evaluation eXpert) (U.S. EPA, 1990) to assist in the evaluation and interpretation of data obtained from the 9090 test.

As the standard, the 9090 test is broadly used. However, the method does not appropriately account for geomembranes reinforced with fabric such as chlorosulfonated polyethylene (CSPE - HYPALON, Registered Trademark, E. I. du Pont de Nemours), Ethylene Interpolymer Alloy (EIA - ELVALOY, Registered Trademark, E. I. du Pont de Nemours), polyvinyl chloride (PVC), etc. Results of the 9090 testing show high levels of variability due to sample preparation protocol that does not address the reinforcing fabric contained in the membrane. This variability may result in 9090 test results and FLEX interpretations that are not indicative of the geomembranes' performance relative to chemical resistance. Thus the upgraded test method proposed by the ASTM may be more appropriate for reinforced geomembranes.

2 U.S. EPA METHOD 9090

The 9090 test was developed to determine the effects of liquid phase chemicals (mixture/solutions) on geomembranes used to contain such chemicals. The 9090 test procedure prescribes that geomembrane specimens be incubated in an immersion fluid, which broadly represents the expected material to be contained, at 23°C and 50°C for 120 days, to simulate performance of the geomembranes in service. Test results of both unexposed and immersed geomembrane samples are evaluated at 30, 60, 90, and 120 days. Test values for both physical and mechanical geomembrane characteristics are recorded and compared to a control specimen (unexposed) to calculate the percent change of the properties with time.

Preparation of geomembrane samples is prescribed by the 9090 protocol for three types of geomembranes: thermoplastic, fabric reinforced, and semicrystalline. Each type is cut into unique patterns which are based on the geomembrane type. All samples are then immersed in the incubation fluid in the same manner, and tested for parameters applicable to the geomembrane type. The shortcoming of the reinforced geomembrane sample preparation is twofold: the exposure of the reinforcing fabric to the immersion fluid, and the number and orientation of continuous yarns (reinforcing fabric) in the prepared sample. Applications using reinforced geomembranes are designed such that the reinforcing fabric itself is not exposed. The only case where the 9090 test results, using this method of preparation, could potentially be applicable is in the event that a defect were present or created during the placement of the geomembrane, thus exposing fabric. Figure 1 presents an illustration of a fabric reinforced geomembrane, where the top ply of the CSPE has been pulled away to expose the reinforcing scrim.

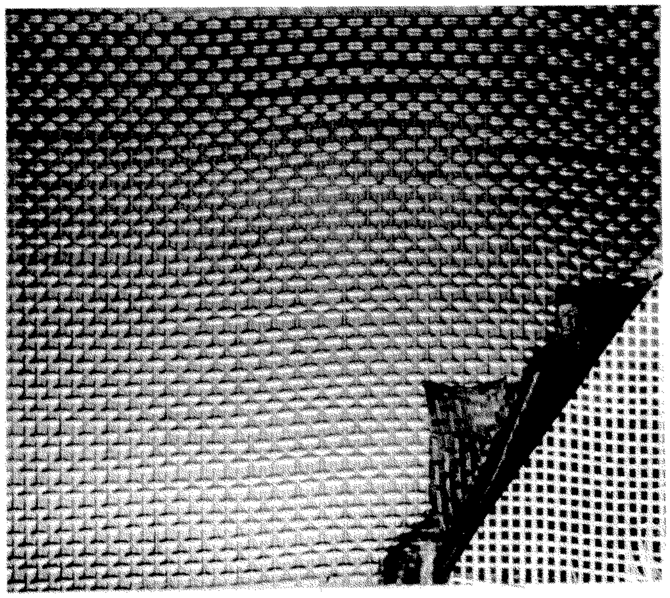


Figure 1. Fabric Reinforced CSPE Geomembrane

2.1 9090 Test Results

Both physical and mechanical property measurements for fabric reinforced geomembranes vary greatly under 9090 test conditions. For example, weight gain varies as a result of the reinforcing fabric transmitting fluid within the yarns, and strength varies due to the number of continuous longitudinal yarns in the test specimens. Table 1 illustrates the pronounced variability of the results obtained from the 9090 test relative to fabric reinforced geomembranes. This testing was done on CSPE samples both with and without reinforcing scrim. Samples were exposed to leachate collected from a hazardous waste landfill, where a CSPE liner has been in service for over a decade. Comparative tests were run by aging samples in potable water. These results illustrate the effect of the transmissivity phenomenon also referred to as "wicking". In addition, the results indicate the sensitivity of the 9090 test to the density of fabric yarns in a geomembrane specimen. The higher the number of yarns in a specimen, the higher the transmission rate of the fluid which results in a weight gain not seen in unreinforced geomembranes. For comparison, test results for supported and unsupported CSPE are presented in Table 1. As can be seen, results for the unreinforced CSPE are more consistent (i.e. low coefficient of variation) because of the absence of the fabric.

The pronounced variability shown in Table 1 could be interpreted as the immersion fluid having a measurable effect on the geomembrane, while in fact this variability is due to the direct exposure of the reinforcing fabric to the immersion fluid. Figure 2 presents graphical representations of test results, at 50°C immersed in leachate, for change in mass. Figure 3 compares the change in mass after exposing the CSPE geomembrane to leachate and potable water.

During the manufacturing process of fabric reinforced geomembranes, a fabric or scrim is coated or calendered on both sides with a polymer compound suitable for the intended use. The polymer compound or coating is the component which serves as the barrier and provides the chemical resistance, weatherability, etc., while the reinforcing fabric aids in the manufacturing of the sheet and imparts to the geomembrane dimensional stability, strength, and resistance to creep.

Because the reinforcing fabric is placed in contact with the immersion fluid during the 9090 test, and the number and orientation of continuous yarns in the test specimen are variable, the test results are biased due to the fabric characteristics, and are not representative of the geomembrane construction As stated earlier, the geomembrane is designed to avoid contact between the reinforcing fabric and the leachate. The polymer compound which essentially encases the fabric is that component of the geomembrane that will be exposed to the containment fluid in the field application.

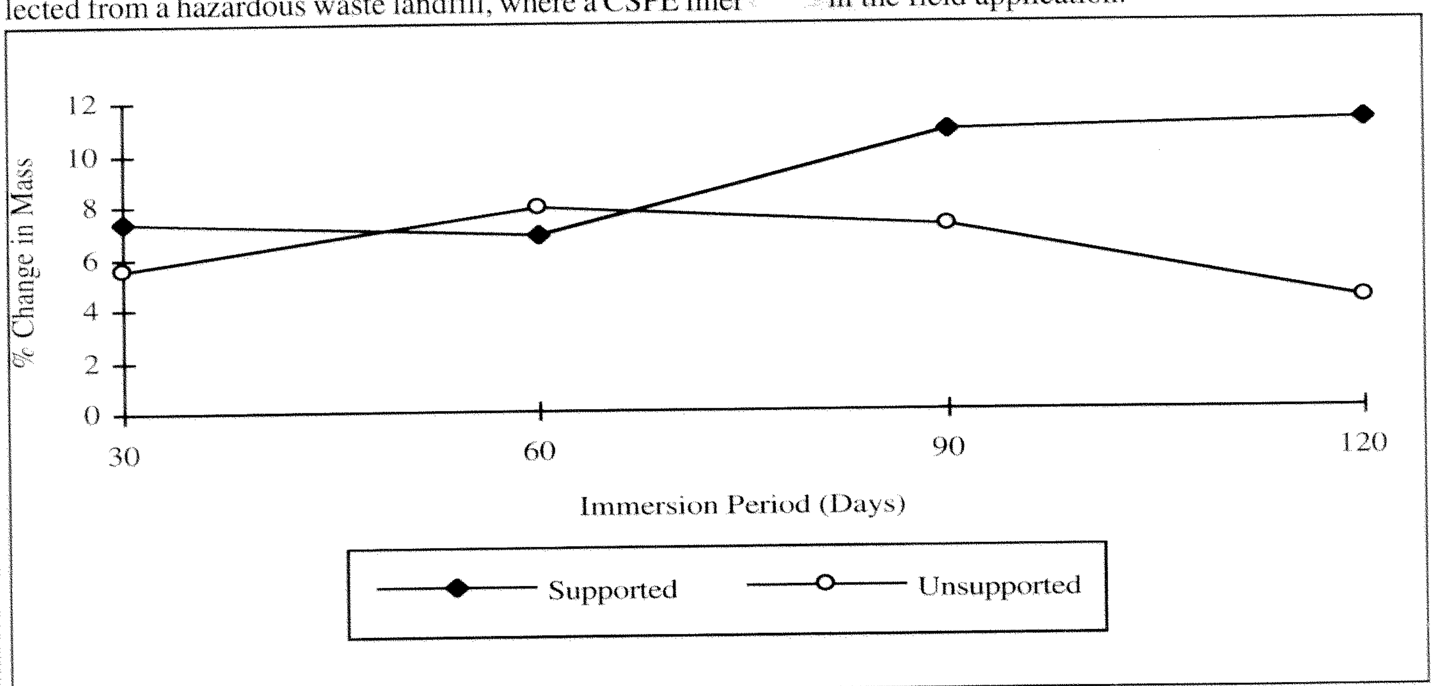


Figure 2. Mass Change for Supported and Unsupported CSPE Geomembrane, at 50°C

Table 1. Average Percent Property Change of CSPE Geomembrane.

Exposed at 23°C

Immersion Medium: Physical Property	Water Supported	Water Unsupported	Leachate Supported	Leachate Unsupported
Mass (EPA9090)	3.71	0.99	3.79	2.08
Thickness (ASTM D374C)	11.4	2.38	10.2	3.62
Specific Gravity (ASTM D792A)	-1.81	-0.40	-1.78	-0.43
Puncture Strength (FTMS101C, Method 2065)	-27.9	23.4	-25.4	16.3
Burst Strength (ASTM D751) (Mullen)	-10.3	—	-7.3	—
Tensile Strength (ASTM D751) (MD)	-64.3	—	-44.4	—

Exposed at 50°C

Immersion Medium: Physical Property	Water Supported	Water Unsupported	Leachate Supported	Leachate Unsupported
Mass (EPA9090)	8.55	4.43	9.08	6.26
Thickness (ASTM D374C)	20.1	7.87	18.8	9.50
Specific Gravity (ASTM D792A)	-3.38	-0.99	-2.74	-1.03
Puncture Strength (FTMS101C, Method 2065)	-22.0	24.1	-17.6	28.9
Burst Strength (ASTM D751) (Mullen)	-13.3	—	-8.8	—
Tensile Strength (ASTM D751) (MD)	-21.3	—	-17.3	—

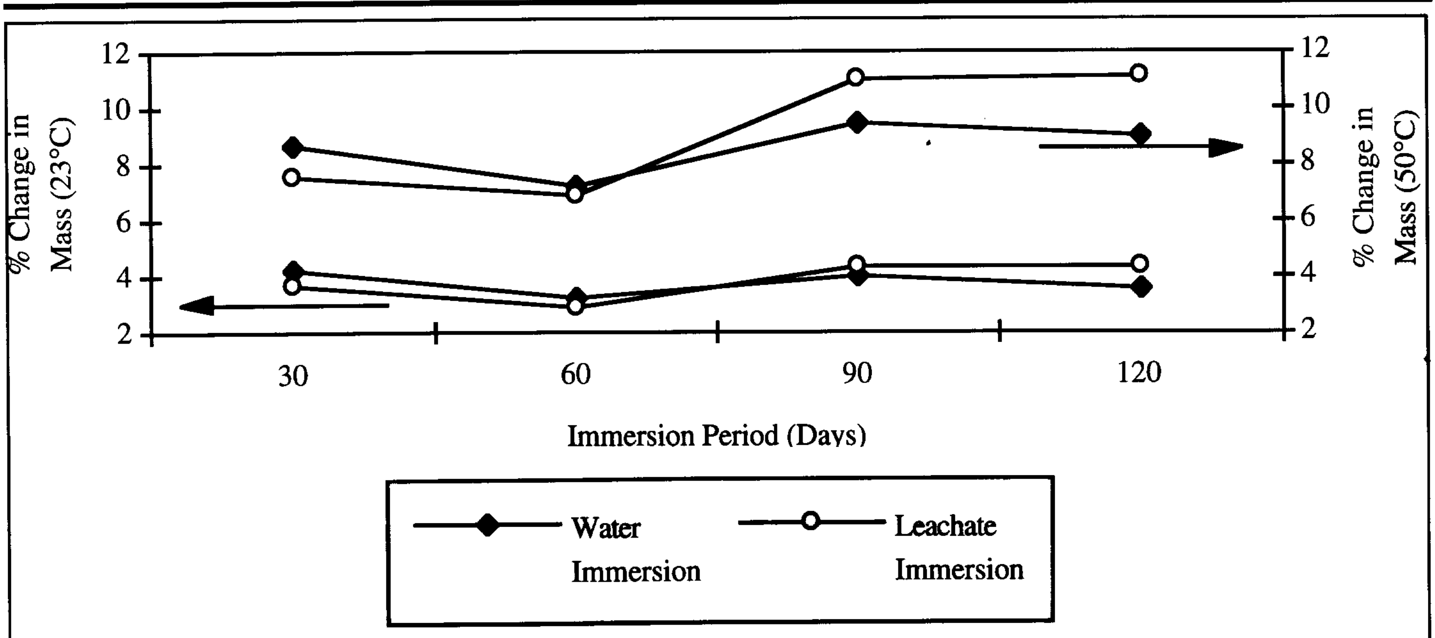
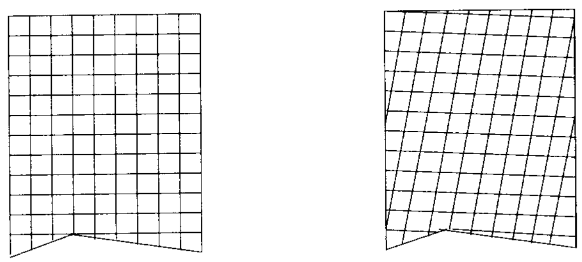


Figure 3. Mass Change for Supported CSPE Geomembrane.

Another way in which sample preparation can heavily influence test results is in the scrim pattern present in the test sample. For instance, the measured tensile strength is heavily influenced by the reinforcement as opposed to the polymeric coating. If the test samples are cut in such a way that the longitudinal yarns are not continuous throughout the length of the sample, then the strength of the sample will be decreased. Figure 4 illustrates this type of scrim pattern. This additional source of variability introduces additional need for expert judgment when evaluating these test results.



Ideal Pattern   Skewed Pattern

Figure 4. Scrim Patterns in Prepared Test Samples

3 FLEX MODEL

The 9090 test protocol does not provide a framework for interpreting the results obtained and reaching any conclusions. It suggests that the results be evaluated by "an expert in the field". As a result, FLEX was developed by the U.S. EPA as a tool for evaluating the 9090 test results. The FLEX model analyzes the 9090 test data using statistical methods and compares the results to National Sanitation Foundation (NSF) standards (NSF, 1991). A recommendation as to the appropriate need of the geomembrane is then prepared.

The program user must be aware that the FLEX model was intended as a tool for managing the data and preparing graphic representations of the results. In addition, the quality of the data reported by FLEX is dependent on the quality of data input from the 9090 test. An evaluation by an "expert in the field" is still required.

Therefore, an evaluator should examine the results obtained for fabric reinforced geomembranes. The FLEX program may not recommend the use of reinforced membranes designed to be in contact with the immersion fluid based on the data input from the 9090 test, even in cases where such membranes have proven performance. It should also be noted that the U.S. EPA no longer supports the FLEX model program.

4 PROPOSED TEST METHODS

ASTM recently proposed a standard practice for geomembrane immersion tests. This new standard is much like its predecessor, the EPA 9090 test. This proposed standard has revised certain sections of the 9090 test components to create an improved test method. Following is a list of some items that have been revised from the 9090 protocol:

- Twice as many tests on unexposed samples are required to increase the statistical base.
- An increase in the number of duplicate tests for mechanical testing increases the statistical base.
- Flood coating of the edges of reinforced fabric samples prior to aging is specified to deter immersion fluid contact, as appropriate.

The final item is most relevant to the discussion presented in this paper. ASTM has proposed a test that will accommodate fabric reinforced geomembranes where the fabric is not intended to come into contact with the immersion fluid. This type of testing will provide more consistent results for fabric reinforced geomembranes. Additional consideration should be given to using larger test specimens (100x200 mm) to mitigate the effects of variation in fabric weave between test samples, which will influence strength characteristics.

5 CONCLUSION

Fabric reinforced geomembranes such as CSPE, PVC, EIA etc., have a history of success in satisfactory performance applications dating back to the late 1950's. With over four decades of proven performance, an evaluator should use caution when the current 9090 test produces results that suggest a reinforced geomembrane is not suitable for applications such as landfill liners or surface impoundment. Furthermore, the variable data generated for fabric reinforced geomembranes may be used inappropriately as input variables in computer evaluation systems such as the FLEX model.

The fabric reinforcement component of geomembranes is an integral mechanism engineered with a specific function in mind. These reinforced geomembranes have a long documented history of successful performance. Project managers and designers should be cautious when reviewing current 9090 test data and specifically the interpretation of the data using expert systems such as FLEX.

6 REFERENCES

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