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Asphalt-Geotextile barriers for waste containment

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ABSTRACT: Asphalt impregnated geotextiles have been used as low hydraulic conductivity barriers in pavement sections, water impoundments and vapor barriers. Recently these materials have been combined with hydraulic asphalt concrete to form containment barriers for solid wastes. The hydraulic conductivity and vapor transmission properties of several asphalt-impregnated geotextiles has been evaluated. The hydraulic conductivities of the asphalt-impregnated geotextiles were generally in the range of 10^{-11} to 10^{-12} cm/s (at the lower limit of measurement capabilities). The vapor transmission rates ranged from 0.4 g/m^2/day to 6.5 g/m^2/day for water vapor and generally increased for solvent vapors. Inconsistent sealing of the test apparatus was considered to attribute to the magnitude and variability of the vapor transmission rates. Based on these results, asphalt impregnated geotextiles can provide effective barriers for containment of aqueous wastes; however, they may not be well suited for wastes containing pure solvents.

1 INTRODUCTION

Asphalt barriers have been used since the 1930's to control seepage through dams both as a core and as a surface barrier (Sherard et al. 1963). In the 1960's asphalt concrete was the state-of-the-art liner for solid waste disposal facilities (Asphalt Institute 1976). Although the practice subsided in the 1970's partially due to rising petrol costs, asphalt barriers for waste containment are presently enjoying a resurgence in applications (Bowders et al. 2000, 2001a). Current designs for asphalt barriers can include a geotextile impregnated with fluid applied asphalt (FAA-GT) either within or adjacent to an asphalt concrete barrier thus providing a multiple barrier system (Figure 1). Several options exist for the FAA-GT barrier. The geotextile can be placed on the surface of the site and then sprayed with asphalt cement in the field. Alternatively, several manufacturers are pre-coating or saturating the geotextile with asphalt cement. The product is then delivered to the project site where it can be readily installed. In all of the designs, the FAA-GT layer along with the accompanying layers act in composite to form a barrier to the migration of waste or waste constituents (leachate, gas). The focus in this paper is the characteristics of the FAA-GT component.

A full-scale, asphalt based containment barrier test pad was constructed in the field (Bowders et al. 2001). FAA-GT specimens were recovered from the test pad. The field specimens were then tested in the laboratory along with other FAA-GT specimens that were either prepared in the laboratory or received from manufacturers. Index properties along with hydraulic conductivity and vapor transmission rates were measured for the various specimens. The testing methodology, results and conclusions are presented in the following sections.

2 MATERIALS AND METHODS

The evaluation focused on FAA-GT specimens obtained from a full-scale test pad (Bowders et al. 2001) (Figure 2); however, for comparative purposes, three additional sources of FAA-GT specimens were secured. The additional sources included geotextile specimens that were coated with asphalt cement in the laboratory, and two different FAA-GT specimens that were supplied pre-impregnated with asphalt cement by the manufacturers (these are labeled Mftg A and Mftg B as shown in Table 1). All the geotextiles were nonwoven, needle-punched polypropylene.

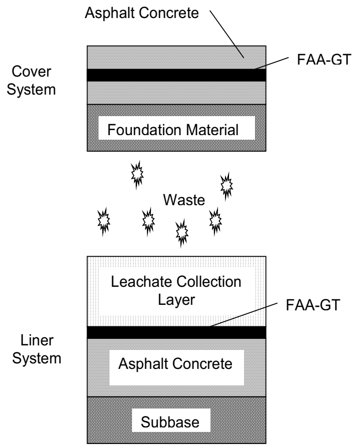

Figure 1. Examples of asphalt concrete and fluid applied asphalt-geotextile barrier applications.

Hydraulic conductivity tests and vapor transmission tests were performed on FAA-GT specimens obtained from each source. Circular (disk) specimens with a diameter of 105 mm were cut for the hydraulic conductivity tests. Each specimen was weighed and the mass per unit area determined prior to testing. Hydraulic conductivity tests were performed according to ASTM D5084 procedures. Both the falling head - rising tailwater and the constant volume procedures were used to measure the hydraulic conductivity. The permeant liquid for the majority of the hydraulic conductivity tests was tap water. However, leachate from construction and demolition debris was also used in a series of tests on the manufacturer supplied FAA-GT. The characteristics of the leachate are given in Table 1.

Figure 2. Sampling the field FAA-GT from the test pad.

Table 1. Characteristics of the construction and demolition debris leachate used to permeate the FAA-GT specimens

Characteristics	Leachate	Tap water
Color	Yellowish	Clear
pH	6.5	8.0
TDS (g/l)	2.7	0.3
TSS (g/l)	0.004	0
COD (mg/l)	672	3
Conductivity (ms/cm)	3.07	0.59

TDS = Total Dissolved Solids
TSS = Total Suspended Solids
COD = Chemical Oxygen Demand

The vapor transmission tests were performed using a modification of the ASTM D5886 and E96 tests. In these tests, approximately 115 ml of the desired fluid was added to a 230 ml glass jar. Circular specimens of FAA-GT with a diameter of 56 mm were cut and placed over the open end of the jar. The specimens were sealed to the end of the jar using bees wax and Teflon® tape, along with a securing ring (Figure 3).

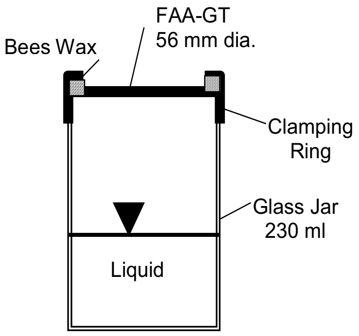

Figure 3. Set up for vapor transmission tests.

After each jar was sealed, the mass of the system was measured and the jar was placed in an exhaust hood and maintained at constant temperature (20^0 C). The mass of the jar and its contents was measured and recorded approximately every 3 to 5 days. For comparative purposes, vapor transmission tests were performed on a 0.8 mm, HDPE geomembrane using the same procedure.

The vapor transmission rate ($g/m^2/day$) was calculated by determining the rate of change in the mass (grams lost per day) for the jar-geomembrane system and dividing that rate by the total area of the geomembrane (Koerner 1998).

3 RESULTS AND DISCUSSION

Thirty hydraulic conductivity tests and one hundred vapor transmission tests were conducted on the various FAA-GT specimens. The results are presented in the following tables. Hydraulic conductivity is presented first followed by vapor transmission results.

3.1 *Hydraulic conductivity of FAA-GT*

The hydraulic conductivities measured for the various types of FAA-GT are presented in Table 2. The range of mass per unit areas for each type of FAA-GT is also given. All of the hydraulic conductivities for both tap water and construction and demolition debris leachate, are in the 10^{-11} to 10^{-12} cm/s. range. These values represent the lower limit of quantifiable conductivities when using the ASTM D5084 falling headwater - rising tailwater procedure. Evaporation, changes in temperature and minute changes in the applied hydraulic gradient act to drive small volumes of flow into or out of the specimen, which are then interpreted into hydraulic conductivities. Achieving steady state condition for all of these factors is difficult; however, a constant volume system was employed in an attempt to limit the effects of evaporation and changes in effective stresses. Under these conditions, hydraulic conductivities as low as $3x10^{-13}$ cm/s were measured for the FAA-GT specimens.

In general, there was no discernable difference in the hydraulic conductivity for specimens with 750 g/m^2 to 3000 g/m^2 bulk mass per unit area. All the geotextiles were on the order of 130 g/m^2 mass per unit area. The difference in the bulk mass per unit area was derived from the mass of asphalt cement impregnated in or on the surface of the geotextile. The variation in the measured hydraulic conductivities was assigned to testing technique rather than to true variation in the FAA-GT material properties.

Table 2. Hydraulic conductivity of various FAA-GT specimens.

Specimen	Field	Lab	Mftg A	Mftg B
Mass/unit area (g/m^2)	1674 to 3013	1061 to 1724	750	1600
Tap water (cm/s)	$1.4x10^{-11}$- $5.6x10^{-12}$	$5.6x10^{-11}$- $2.9x10^{-11}$	$2.5x10^{-11}$- $1.0x10^{-11}$	$1.2x10^{-11}$- $7.0x10^{-12}$
Construction dem. debris leachate (cm/s)	N/A	N/A	$2.6x10^{-11}$- $1.5x10^{-11}$	$1.2x10^{-11}$- $6.3x10^{-12}$

Mftg A – Manufactured pre-impregnated with asphalt cement
Mftg B – Manufactured pre-impregnated with asphalt cement

3.2 *Vapor transmission rates for FAA-GT*

The measured vapor transmission rates for the FAA-GT specimens are given in Table 3. Three, or more, tests were performed for each combination of FAA-GT type and fluid type. The minimum and maximum rates are reported for each combination tested.

The water vapor transmission (WVT) rate ranged from a low of 0.4 $g/m^2/day$ (field FAA-GT) to a high of 6.5 $g/m^2/day$ (laboratory prepared FAA-GT).

The solvent vapor transmission (SVT) rates were greater than the WVT rates. The methanol SVT rate ranged from 1 g/m^2/day to 12 g/m^2/day. Acetone SVT rate ranged from 80 g/m^2/day to 240 g/m^2/day. Xylene SVT rate ranged from 140 g/m^2/day to 180 g/m^2/day. A photograph of the SVE tests using xylene is shown in Figure 4. The chloroform SVT rate ranged from 2900 g/m^2/day to 3500 g/m^2/day.

Vapor transmission rates for the same fluids through a 0.8 mm HDPE geomembrane were reported by Koerner (1998) (Table 4). Neupane (2001) also used 0.8 mm HDPE geomembrane and the same test protocol used in the FAA-GT vapor transmission tests. The results are also shown in Table 4. All of Neupane's vapor transmission results for 0.8 mm HDPE are greater than those by Koerner. The cause of the difference is most likely attributable to the sealing procedure in the test set up (Koerner & Allen 1997). Neupane used bee's wax and Teflon® tape. In order to better compare the FAA-GT vapor transmission rates with those of the HDPE, a correction factor was developed by multiplying the FAA-GT vapor transmission rates by the ratio of the 0.8 mm HDPE rates of Neupane divided by the rates by Koerner. The correction factors for each of the fluid are given in Table 4. The FAA-GT vapor transmission rates corrected for the leaking seals are given in Table 5 along with the rates for 0.8 mm HDPE (Koerner 1998). The rates for water and methanol through FAA-GT and 0.8 mm HDPE are comparable. Acetone and xylene show a higher vapor transmission rate by about a factor of 6 to 7 through the FAA-GT compared to the HDPE. The chloroform vapor transmission rate is 40 times greater through the FAA-GT than through the HDPE.

Table 3. Vapor transmission rates for various FAA-GT specimens.

Fluid	Vapor Transmission Rate of FAA/GT (g/m^2/day)							
	Field Constructed		Laboratory Prepared		Manufactured A		Manufactured B	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Water	0.4	2.5	0.6	6.5	0.6	0.9	1.1	1.1
Methanol	1.1	1.6	7.6	9.1	2.0	5.0	6.1	12.3
Acetone	84.4	99.7	102.6	124.7	94.2	121.7	216.9	237.1
Xylene	163.4	178.5	151.8	181.0	142.3	161.4	146.3	161.3
Chloroform	2871.0	3153.8	3203.5	3560.5	3297.8	3377.6	3033.4	3115.7

Figure 4. Solvent vapor transmission tests showing FAA-GT and HDPE geomembranes exposed to xylene.

Table 4. Vapor transmission rates (g/m^2/day) for a 0.8 mm HDPE geomembrane and factors for correction of FAA-GT vapor transmission rates due to inadequate sealing system.

Fluid	Neupane 2001	Koerner 1998	Correction factor
Water	0.74	0.0017	0.02
Methanol	0.53	0.16	0.30
Acetone	16.1	0.56	0.03
Xylene	25.9	21.6	0.83
Chloroform	86	54.8	0.62

In general, the FAA-GT provided comparable vapor transmission rates to HDPE for water and methanol. FAA-GT has been used for methane gas barriers (Fournier 2000) and for water barriers (Bowders et al. 2001a). Acetone, xylene and chloroform, all solvents for petroleum distillates, degrade the asphalt cement component of the FAA-GT and lead to higher vapor transmission rates.

Table 5. FAA-GT vapor transmission rates (g/m^2/day) corrected for leaking sealing mechanism.

Fluid	0.8 mm HDPE Koerner 1998	FAA-GT field	
		Min	Max
Water	0.0017	0.01	0.06
Methanol	0.16	0.33	0.48
Acetone	0.56	2.9	3.4
Xylene	21.6	136	148
Chloroform	54.8	1794	1971

4 CONCLUSIONS

Hydraulic conductivity and vapor transmission tests were performed on fluid applied asphalt geotextiles (FAA-GT) and a 0.8 mm HDPE geomembrane. The hydraulic conductivity of the FAA-GT specimens was measured to be in the range of 10^{-11} to 10^{-12} cm/s (the lower limit of quantifiable measurements) for tap water. Leachate from construction and demolition debris did not change the hydraulic conductivity.

Vapor transmission rates for the FAA-GT were compared to those for 0.8 mm HDPE after correction for possible leakage around the sealing mechanism in the test set-up. The water and methanol vapor transmission rates for the FAA-GT were comparable to those for 0.8 mm HDPE. Acetone, xylene and chloroform all showed higher vapor transmission rates. The increased rates can be attributed to the capability of each of these liquids to dissolve the asphalt component in the FAA-GT membrane.

The findings indicate that FAA-GT can provide effective barriers to liquid and gas migration of water and aqueous solutions; however, they are not suitable for all situations, specifically for waste containing pure solvents. The FAA-GT typically ranges from 1.5 mm to 3.5 mm in thickness. When combined with a thicker barrier layer, such as compacted soil or hydraulic asphalt concrete, the composite action of the barrier can provide an effective alternative barrier technology for waste containment.

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