Permeation properties of HDPE geomembranes

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ABSTRACT: This paper evaluates the permeation properties of HDPE geomembranes intacts and after exposure to UV rays (weathering) after 12 years. Water vapor transmission tests (WVT) were performed in HDPE geomembranes (1.00 mm). Fresh and exposed samples were evaluated without imperfections and with holes of 1.6 and 3.0 mm. The goal of the imperfections and the UV degradation is the evaluation of the increase in the flux of the geomembrane. Results show, for instance, that the hole of 3.0 mm presented an increase about 650% in the values (fresh samples).

1 INTRODUCTION

The two main mechanisms concerning the leakage in the geomembranes are permeation and flow. While permeation is characterized by a differential pressure in an intact geomembrane, the flow occurs in defects such as holes or cracks (Sharma & Lewis 1994).

Since the flow through holes can occurs at the seams or due to defects caused by punctures or tears, it is very important to know how it can affect the flow rates in the geomembranes. Besides that, geomembranes can be exposed to UV rays in canals, for instance, and the degradation can change the flux properties of the material.

Generally, the main tests used to estimate the flow through geomembranes are water vapor transmission (WVT) at low pressures and liquid permeater tests at higher pressures.

In this sense, this paper presents some results of WVT tests in HDPE geomembranes intacts and exposed to weathering after 12 years. The WVT tests evaluated the permeation on the geomembranes intacts and with imperfections (holes).

2 MATERIAL AND METHODS

The research was performed in the follow sequence:

• Characterization of the physical and mechanical properties of the samples by standard tests in laboratory;

• Evaluation of permeation properties of the samples according the ASTM E96. It was analyzed fresh samples and geomembranes that were exposed for 12 years (weathering exposure). For both conditions the tests were performed on samples without imperfections and geomembranes with holes of 1.6 and 3.0 mm.

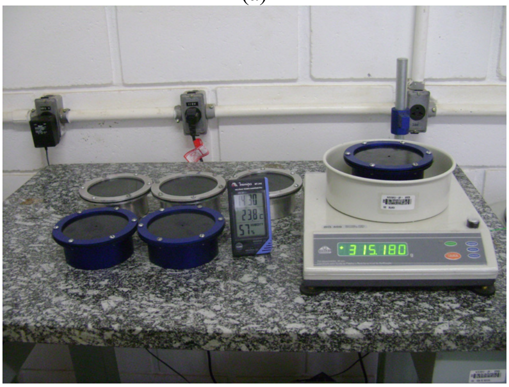
• Comparison of the permeation properties (fresh and exposed samples).

The materials utilized are HDPE geomembranes (1.0 mm). The geomembranes that were exposed for 12 years are exposed on a panel at State São Paulo University at Ilha Solteira (Unesp).

The properties analyzed were thickness, density and tensile properties (yielding). The following standards were used like a guide: ASTM D638 (Standard Test Methods for Tensile Properties of Plastics), ASTM D792 (Standard Test Methods for Specific Gravity and Density of Plastics by Displacement) e ASTM D5199 (Measuring Nominal Thickness of Geotextiles and Geomembranes).

Permeation tests were performed according the ASTM E96. In this sense, cups were constructed in a way that the geomembranes could be subjected to a differential pressure gradient. As a result, the water vapor transmission (WVT) and the permeability of the geomembranes could be determined by the weight of the set (Figure 1). The temperature and the relative humidity need to be know. The tests were performed in a control environment.

(a)



(b)

Figure 1. (a) Cups used in the WVT tests (b) view of the set in a control environment

Two kinds of samples were analyzed: with no hole and with holes of 1.6 and 3.0 mm. The goal of the holes in the samples is to verify the variation of permeation on the samples. Besides that, a degraded sample was analyzed to check the variations of UV rays on the permeation property.

3 RESULTS AND ANALYSIS

Tables 1 and 2 show, respectively, the results obtained to the physical and tensile properties of the fresh samples.

Tables 3, 4, and 5 present the permeability tests results on the samples (fresh samples intact and fresh samples with holes before and after UV exposure).

The Figure 2 shows the variation of the permeability values concerning the geomembranes.

Physical, mechanical, and permeation properties results are in agreement to the literature values and manufacture specifications.

Concerning the WVT tests, it should be noted that the permeability values increases when a hole occurs to both fresh and exposed samples.

Table 1. Physical properties - fresh samples

GM	t (mm)	Weight (g/m^2)	Density
1.0	0.98	1040	0.953
CV (%)	2.30	1.90	0.90

GM = geomembrane; CV = coefficient of variation; t = thickness

Table 2. Tensile properties (yielding) – fresh samples

GM	σ (MPa)	ε (%)	E (MPa)
1.0 L	14.0	14.0	416.0
CV (%)	9.8	9.8	12.8
1.0 T	15.0	14.0	460.0
CV (%)	10.4	10.4	9.5

L = longitudinal; T = transversal; σ = tensile strength; ε = deformation; E = elasticity modulus

Table 3. Results (average) of water vapor transmission (WVT)

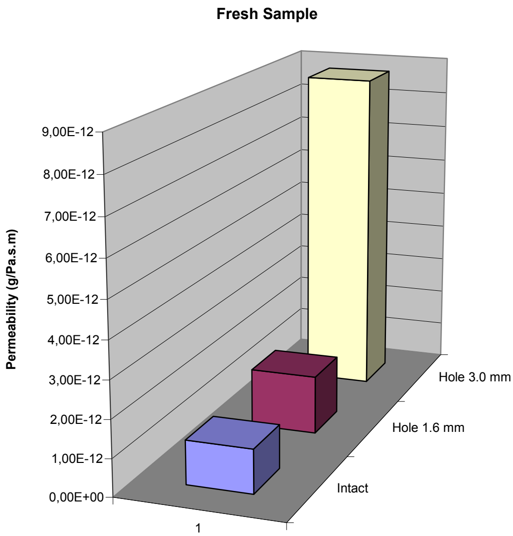
Permeability (g/Pa.s.m)		
Hole diameter (mm)	Fresh	Exposed
-	$1.17 x 10^{-12}$	$3.45 x 10^{-12}$
1.6	$1.57 x 10^{-12}$	$4.66 x 10^{-12}$
3.0	$8.75 x 10^{-12}$	$7.03 x 10^{-12}$

Table 4. Variation of WVT values – fresh samples

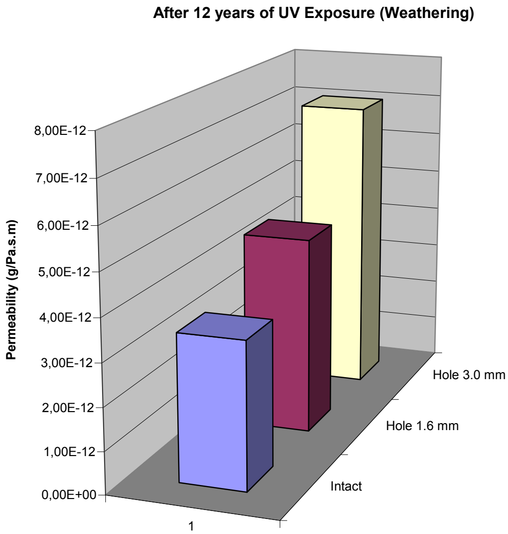
Permeability (g/Pa.s.m)		
Hole diameter (mm)	Fresh	Variation (%)
-	$1.17 x 10^{-12}$	-
1.6	$1.57 x 10^{-12}$	33.73 (+)
3.0	$8.75 x 10^{-12}$	647.37 (+)

Table 5. Variation of WVT values – exposed samples

Permeability (g/Pa.s.m)		
Hole diameter (mm)	Exposed	Variation (%)
-	$3.45 x 10^{-12}$	-
1.6	$4.66 x 10^{-12}$	35.06 (+)
3.0	$7.03 x 10^{-12}$	103.76 (+)



(a)



(b)

Figure 2. Variation of the permeability results after WVT tests (a) fresh samples (b) after 12 years of UV exposure

The Figure 2a shows the variations in the permeability values considering the holes of 1.6 and 3.0 mm (fresh sample). An increase of 33.73% occurred when a defect of 1.6 mm was induced. However, a hole of 3.0 mm results in an increase of ≅ 650% in the permeability value. Concerning the exposed sample, this variation is ≅ 102%. Besides that, the variation of permeability value considering the exposed sample and the fresh sample (without imperfection) is about 195% (increase).

Is spite of the highest variations presented, it must take in account that the permeability coefficient values are still in the same order of magnitude for both fresh and exposed samples (10^{-12}).

However, the samples tested are very small and they can't reflect the exact variation presented by the holes that can occur in geomembranes in the field. Generally, the flow through holes occurs at the seams or due to defects caused by punctures or tears. The flow rates through pinholes in a good-quality geomembrane are minimal compared with the rates through holes. In this sense, is important to observe the assumptions of Giroud and Bonaparte (1989): a frequency of one hole per acre with good quality assurance (QA) and good quality control (QC) and a frequency of 10 holes per acre or greater with a poor QA/QC; a large hole (1 cm^2) for sizing lining system and LCRS components; and a small hole (3.1 cm^2) for performance calculations such as estimating the flow in the leakage collection layer under typical operating conditions.

4 CONCLUSIONS

Permeation tests (WVT) were performed in HDPE geomembrane of 1.0 mm. The tests showed high variations (increase) in the permeability values when a defect (hole) was induced.

In spite of the variations presented, the permeability coefficient values were the same order of magnitude for both fresh and exposed samples.

The results showed that the permeation properties suffered alterations with the exposure to the UV rays. However, a hole it was more expressive in the variations occurred.

The variations presented here are illustrative only and should not be taken as basis for any type of decision or projects. More realistic and appropriate analyses must be carried out. In this sense, a research is still under progress to evaluate the synergism of the UV rays, flux and creep of geomembranes.

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