UV degradation of hdpe and pvc geomembranes in laboratory exposure

Lodi, P.C.
São Paulo State University (UNESP) - Ilha Solteira (Brazil)

Bueno, B.S.
University of State of São Paulo (USP) at São Carlos (Brazil)

Zornberg, J.G.
University of Texas (UT) at Austin (USA)

Lodi, P.C., Bueno, B.S., and Zornberg, J.G. (2010). "UV Degradation of HDPE and PVC Geomembranes in Laboratory Exposure." Proceedings of the *9th International Conference on Geosynthetics*, 9ICG, Guarujá, Brazil, May, Vol. 2, pp. 821-824.

Keywords: UV degradation, weathering, geomembranes, mechanical properties

ABSTRACT: This article evaluates the effects of UV degradation in HDPE geomembranes that were exposed both in laboratory and outdoor conditions. The laboratory tests were performed using a weatherometer assembled at EESC-USP in accordance to ASTM G154 and GM11. Weathering exposure was also evaluated and the results were compared to the laboratory results. Mechanical and physical properties were evaluated and compared to intact samples. Small variations were noticed for physical properties The results show variations differentiated for the mechanical properties after each period. Mathematical adjustments were evaluated concerning the resistance and deformation of the geomembranes in both exposures. The results showed that polynomial adjustments were more adequate than the exponential adjustments.

1 INTRODUCTION

Geomembranes can be affected by the solar radiation during the installation of the liner since these materials are uncovered. Many geosynthetics, especially polyolefins geomembranes, are very sensitive to the ultraviolet (UV) rays. The penetration of the sun short wavelengths can degrade (break of polymer chemical bonds) the material. In this sense, the prevention of the degradation process is done by the addiction of many UV stabilizers and antioxidants.

Many manufactures and researchers recognized that is very important to know and understand the behavior of geomembranes concerning the UV degradation as well the weathering effects. Outdoors applications are very common and the photodegradation of polymers is a process can lead to polymer chain scission and eventual degradation of polymer properties.

So, this paper presents some results of UV radiation on geomembranes that were exposed in laboratory and field for some periods.

2 MATERIAL AND METHODS

The main steps of this research are listed below:

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

•Weathering exposure of the samples on a panel according the ASTM D1435 and D5970;

•UV exposure in laboratory according the ASTM G154 and GM11;

• Characterization of the physical and mechanical properties of the samples after each specific period of exposure;

•Comparison of the properties (fresh and exposed samples) considering each analysis period.

The materials utilized are HDPE geomembranes: weathering exposure (0.8 and 2.5 mm); laboratory exposure (0.8, 1.0, 1.5 and 2.5 mm). The total time of weathering exposure was 30 months. Samples were taken after 6, 12, 18 and 30 months.

In the laboratory we need to know how much time it was necessary to get the same level of degradation. In this case it was considered only a time of 18 months (1.5 years).

The radiant exposure in the UV range can be calculated by integrated the light energy for the wavelengths from 295-400 nm (UV-A lamps). The UV irradiance from 295-400 nm is 39 Watts/m^2 (energy total). In this sense, is possible evaluate the time necessary to achieve the UV radiance in a UV weatherometer (see Lodi et al. 2008). The total time considered of UV exposure was 2 months with taken of the samples after 15, 30, 45 and 60 days. 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).

The panel used for the weathering exposture has an inclination of 45 degrees at the São Paulo State University at Ilha Solteira-Unesp (according the ASTM D1435 and D5970). In this place there is a meteorological station for the acquisition of the weathering data.

In the laboratory the geomembranes were exposed to the UV rays in equipment at the geosynthetic laboratory at the University of the State of São Paulo at São Carlos. The lamps used were UVA-340 with wavelength of 315-400 nm. Cycles of 20 hours UV at 75 ± 3°C followed by 4 hours condensation at 50 ± 3°C were used according the ASTM G154 and GM11.

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 and 4 show the UV radiation values (cumulative) for both weathering and laboratory exposures.

Regarding to the physical properties, small oscillations occurred after the final period both to laboratory and outdoor exposure.

The Figures 1 and 2 show the behavior of the tensile properties versus cumulative UV radiation. The UV radiation values are used when is desirable the number of hours of exposure in laboratory that represents the behavior of the material in outdoors applications. In a simple way: to represent the behavior of the material in outdoor it just necessary the accelerated testing in laboratory. So, the first of all is the characterization of the material in outdoor exposure. After that, the laboratory exposure can be done. If the adjustment between the two results is appropriate it can possible an extrapolation to the outdoor condition considering larger times.

Table 1. Physical properties - fresh samples.

GM	t (mm)	Weight (g/m^2)	Density
0.8	0.78	776	0.95
CV (%)	0.83	0.66	0.83
1.0	0.98	1040	0.95
CV (%)	2.50	2.00	0.90
1.5	1.49	1700	0.95
CV (%)	0.85	0.91	0.50
2.5	2.48	2562	0.95
CV (%)	0.51	0.70	0.44

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

Table 2. Tensile properties (yielding) – fresh samples.

GM	σ (MPa)	ε (%)	E (MPa)
0.8 L	19.0	15.0	332.0
CV (%)	2.1	2.1	18.9
0.8 T	19.0	15.0	330.0
CV (%)	2.9	2.9	17.7
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
1.5 L	16.0	16.0	305.0
CV (%)	2.8	2.8	8.9
1.5 T	16.0	15.0	372.0
CV (%)	2.1	2.1	10.1
2.5 L	18.0	15.0	406.0
CV (%)	5.7	5.7	10.2
2.5 T	20.0	14.5	381.0
CV (%)	3.8	3.8	10.7

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

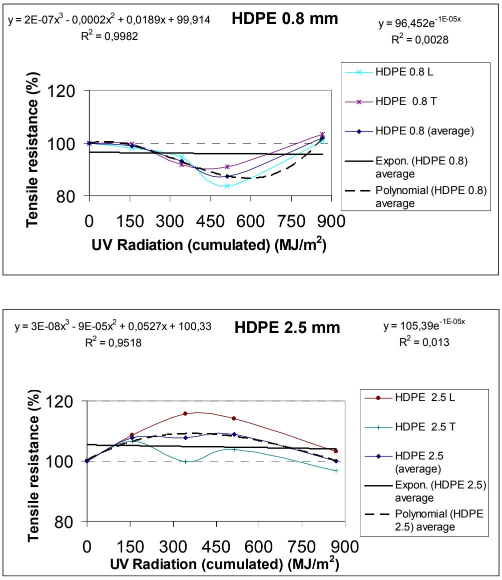
Table 3. Cumulated UV radiation (weathering).

Time (months)	UV radiation (MJ/m^2)
0	0.0
6	158.5
12	343.3
18	512.1
30	867.8

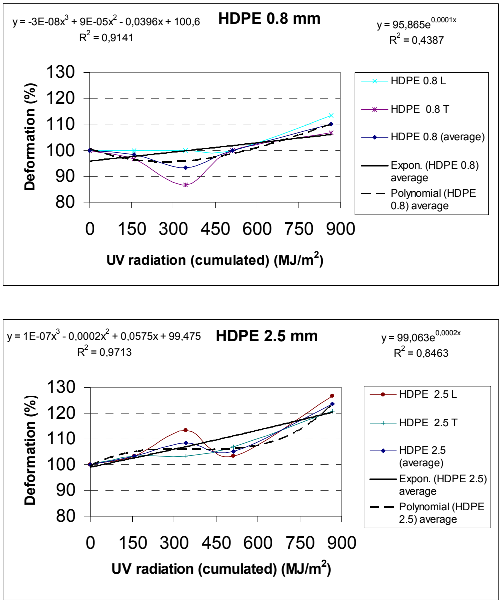
Table 4. Cumulated UV radiation (laboratory).

Time (days)	UV radiation (MJ/m^2)
0	0.0
15	50.5
30	151.6
45	303.3
60	505.4

The equations showed in the figures are exponential and polynomial adjustments. Note that the values are the average of transversal and longitudinal directions. It is possible also an analysis of the two thicknesses, however, the materials suffering degradation process concerning the thickness. So, the idea here presented is also evaluate the influence of the thickness on the prediction of the behavior of the material.

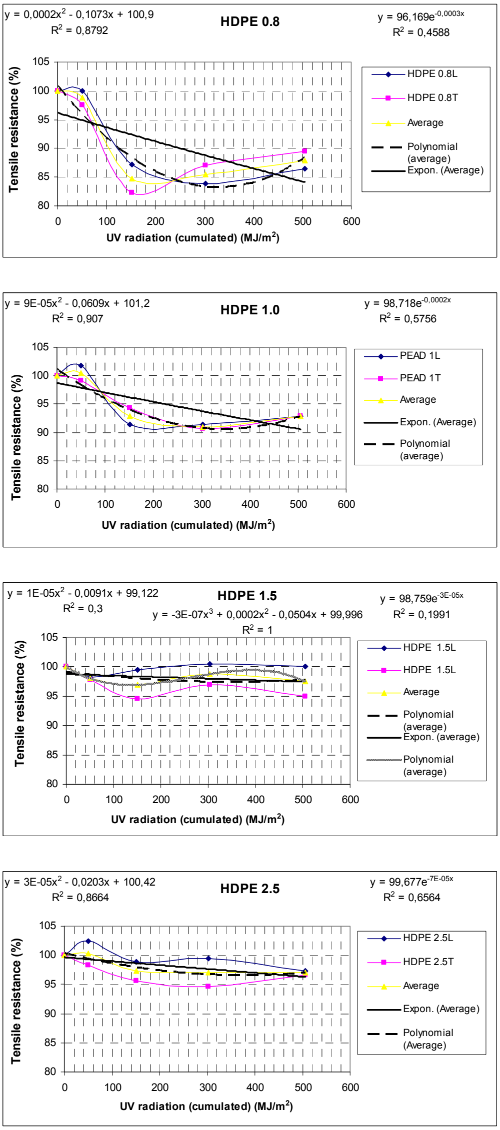


(a)

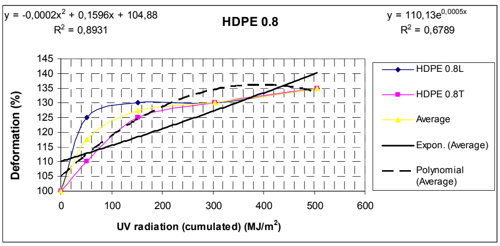


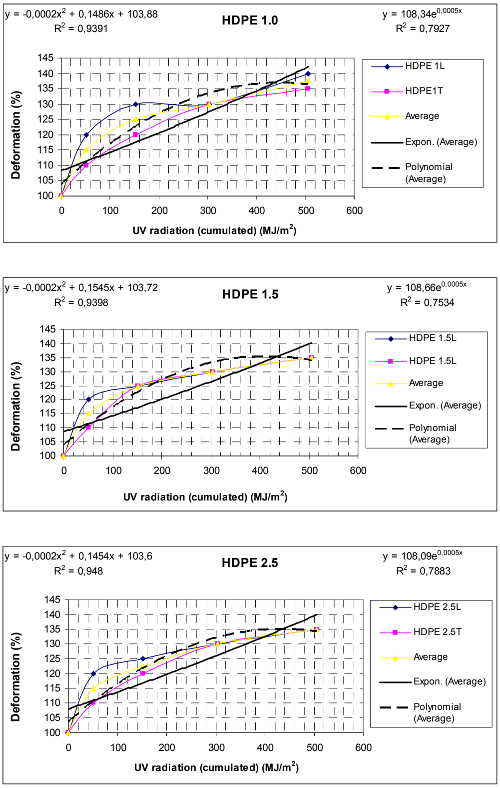
(b)

Figure 1. Tensile properties versus cumulated UV radiation (weathering) (a) tensile resistance (b) deformation.



(a)





(b)

Figure 2. Tensile properties versus cumulated UV radiation (laboratory) (a) tensile resistance (b) deformation.

It should be noted that the behavior of the geomembranes can be adjusted by polynomial and exponential equations considering both resistance and deformation. However, the exponential adjustments were not adequate to both weathering and laboratory exposure. The polynomial adjustments showed a good correlation. In this sense, the laboratory material behavior could be extrapolated to larger field periods (see Lodi et al. 2008, for instance). However, there is the need to know how to use global radiation parameters. Moreover, a statistical treatment can be desirable to understanding the correlations between outdoor and laboratory exposure. Besides that we must take in account that the UV laboratory exposure is very harmful to the GMs resulting many times in unrealistic results.

4 CONCLUSIONS

After the exposures small variations were noticed to physical and mechanical properties.

Mathematical adjustments were presented to both exposures performed. The polynomial adjustments presented good correlation concerning the resistance and deformation to weathering and laboratory exposures. So, the laboratory results showed good correlation to the field results. An evaluation more detailed can be used to extrapolate the laboratory values to larger periods in outdoors exposures.

ACKNOWLEDGEMENTS

The authors are thankful to Geosynthetics Laboratory at São Carlos (EESC-USP), Engineering Civil Department at Ilha Solteira (UNESP) and to FAPESP for the financial support.

REFERENCES

ASTM D638. Standard Test Method for Tensile Properties of Plastics, American Society for Testing and Materials, West Conshohocken, Pennsylvania, USA.

ASTM D792. Specific Gravity and Density of Plastics by Displacement, American Society for Testing and Materials, West Conshohocken, Pennsylvania, USA.

ASTM D1435. Standard Practice for Outdoor Weathering Plastics, American Society for Testing and Materials, West Conshohocken, Pennsylvania, USA.

ASTM D3776. Mass per Unit Area, American Society for Testing and Materials, West Conshohocken, Pennsylvania,

ASTM D5199. Measuring Nominal Thickness of Geotextiles and Geomembranes, American Society for Testing and Materials, West Conshohocken, Pennsylvania, USA.

ASTM D5970. Standard Practice for Deterioration of Geotextiles from Outdoor Exposure. American Society for Testing and Materials, West Conshohocken, Pennsylvania, USA.

ASTM G154 Standard Practice for Operating Fluorescent Light Apparatus for Exposure of Nonmetallic Materials, American Society for Testing and Materials, West Conshohocken, Pennsylvania, USA.

GM11 (GRI Test Method). Accelerated Weathering of Geomembranes using a Fluorescent UVA Condensation Exposure Device.

Lodi et al. 2008. Analysis of mechanical and physical properties on geotextiles after weathering exposure. *Proc. of EuroGeo 4 - 4th European Geosynthetics Conference, 2008, Edimburgo*, CD Rom.