MECHANICAL AND THERMAL PROPERTIES OF HDPE AND PVC GEOMEMBRANES AFTER UV EXPOSURE

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Abstract: This paper evaluates the effects of UV degradation in PVC and HDPE geomembranes which were exposed after 6 months in accelerated condition (laboratory) and after 6, 12, 18 and 30 months in outdoor exposure. The laboratory tests were performed using a weatherometer assembled at EESC-USP in accordance to ASTM G154. The outdoor exposure was evaluated according to ASTM D1435 and D5970. Physical and tensile properties were evaluated and compared to intact material. Tests were carried out according to ASTM standards. PVC and HDPE geomembranes were tested: 0.8 and 2.5 mm (HDPE) and 1.0 and 2.0 mm (PVC). Concerning the UV exposure (laboratory) another thicknesses of HDPE were tested: 1.0 and 1.5 mm (black smooth) and 1.0 mm (white textured). MFI and OIT tests were carried out on the HDPE geomembranes. The results show variations differentiated for the mechanical properties (tensile resistance, deformation and elasticity modulus) after each period to both conditions. In spite of HDPE become more ductile to both conditions of exposure, the results obtained from accelerated tests were not allowed to establish an adequate standard of comparison.

Keywords: geomembrane, laboratory test, weathering, OIT tests.

INTRODUCTION

According Suits & Hsuan (2003) sunlight is well recognized as being a dominant degradation factor in many polymers including those used in geosynthetics. When solar radiation strikes the polymer surface (note that this only applies to exposed geosynthetics), photons with energy similar, or higher, than the chemical bond strength of the polymer cause a series of reactions that can lead to polymer chain scission and eventual degradation of polymer properties. In this sense, outdoor conditions may cause drastic variations in the properties of geosynthetic material due to the effects of temperature and ultraviolet (UV) radiation.

Evaluation of the effects of outdoor exposure is very important since the geosynthetics may be exposed to the combined influence of sunlight, rain, temperature, and oxygen. In this way, UV degradation can arise and the type of aging is caused by the UV content of the sunlight. One important aspect in evaluating the durability of geosynthetics in outdoor applications are the accelerated laboratory tests which may be used to establish relations between outdoor and laboratory tests.

In this sense, this paper evaluates PVC and HDPE geomembranes (GM) that were exposed to both accelerated laboratory (6 months) and outdoor conditions (6, 12, 18 and 30 months). Tensile properties were evaluated and MFI and OIT tests were also used to verify the oxidative degradation on HDPE GMs.

MATERIAL AND METHODS

PVC and HDPE geomembranes were evaluated in two conditions: outdoor exposure and laboratory exposure. In the laboratory the analyses were performed after 1.5 and 6 months. It was used an equipment (Figure 1) assembled at the laboratory of the Engineering School of São Carlos (EESC-USP), Brazil. In this sense, recommendations of the ASTM G154 were used like a guide. It was used UV-B lamps (40 W) with the cycle of 4 hours UV at 60 ± 3°C followed by 4 hours condensation at 50 ± 3°C.

(a) (b)

Figure 1. UV Exposure: (a) lamps details (b) geomembranes samples exposed to UV radiation

The outdoor exposure was evaluated according to ASTM D1435 and D5970. The samples were putted on a panel that was built in that way so the GM receives the direct incidence of the sun for the entire day. Figure 2 show samples exposed to weathering.

PVC and HDPE geomembranes were tested: 0.8 and 2.5 mm (HDPE) and 1.0 and 2.0 mm (PVC). Concerning the UV exposure (laboratory) another thicknesses of HDPE were tested: 1.0 and 1.5 mm (black smooth) and 1.0 mm (white textured).

Physical and tensile properties were evaluated and compared to intact material. Tests were carried out according to ASTM standards: ASTM D5199 (Measuring Nominal Thickness of Geotextiles and Geomembranes), ASTM D3776 (Mass Per Unit Area), ASTM D792 (Specific Gravity and Density of Plastics by Displacement) and ASTM D638 (Standard Test Method for Tensile Properties of Plastics).

OIT and MFI tests were performed in HDPE geomembranes after the last period to verify the oxidative degradation. These tests were performed only in geomembranes evaluated in laboratory exposure. The ASTM specifications were used: ASTM D1238 (Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer Endurance of the Geomembrane under Examination) and ASTM D3895 (Test Method for Oxidative-Induction Time of Polyolefins by Differential Scanning).

Figure 2. Weathering exposure of geomembranes

TESTS RESULTS AND DISCUSSION

Concerning the physical properties, small variations (nearest to 0.5 to 1%) were verified to all geomembranes exposed. Figure 3 and 4 show results from tensile tests of PVC and HDPE that were exposed to UV radiation in laboratory.

Analyzing the variations suffered for the PVC it is verified that, initially, the two analyzed thicknesses had varied of similar form being that the lesser thickness (1.0 mm) slightly more was affected. After 45 days, the PVC presented reduction of the tensile strength with increase of its deformability and consequent reduction of its rigidity. This reduction in the modulus of elasticity was more expressive for the thickness of 1.0 mm (35%). After 6 months small reductions in the tensile strength and deformability occurred. The rigidity increased 10% for the lesser thickness and decreased 10% for the highest thickness. Thus, after 6 months the variations suffered for the PVC had practically been inexpressive regarding the fresh samples. The referring samples to the first period had presented bigger variations that the samples evaluated after 6 months. Under the action of the heat and rays UV, the waited behavior of the PVC it would be of an increase of its rigidity with consequent reduction of its deformability. However, analyzing the effect of the first period, it is verified that the behavior was total inverse: occurred decrease of its rigidity and increase of its deformability. After 6 months, the behavior is more coherent with the effect caused for action UV and the process of condensation. The increase of the deformability in the first period was not so expressive: only 10% for the PVC 1L. The highest variation occurred for the elasticity modulus (lesser thickness). These results can reflect the difficulties of attainment of this parameter being able to mask some results.

Regarding the HDPE, it is verified that after 45 days its behavior is characterized by a few minor variations in the tensile strength and the deformability. The rigidity showed a high variation only for the lesser thickness (0.8 mm) presenting values of up to 60% of increase in the property. Thus, one evidences that the material presented increase of rigidity with consequent reduction of deformability only for the lesser thickness after 45 days of analysis. The highest thickness practically did not modify its properties. After 6 months, the lesser thickness does not vary its tensile strength, but present increase both of rigidity (30 and 50%) and deformability (27%) in the longitudinal direction. When a high increase of the elasticity modulus occurs, this must come followed of significant changes in the deformability and/or the tensile strength. These increases in the rigidity observed for the HDPE (0.8 mm) can only reflect the uncertainties of determination of the property. In other words, the occurred variations for the material after 6 months had not been so sharp a time that the tensile strength and the deformability had not varied significantly. For the highest thickness, the behavior is characterized by small increases in the tensile strength and the deformability.

The variation of the rigidity was inexpressive and, considering itself the uncertainties of this parameter, can be inferred that the material became more ductile than the fresh samples.

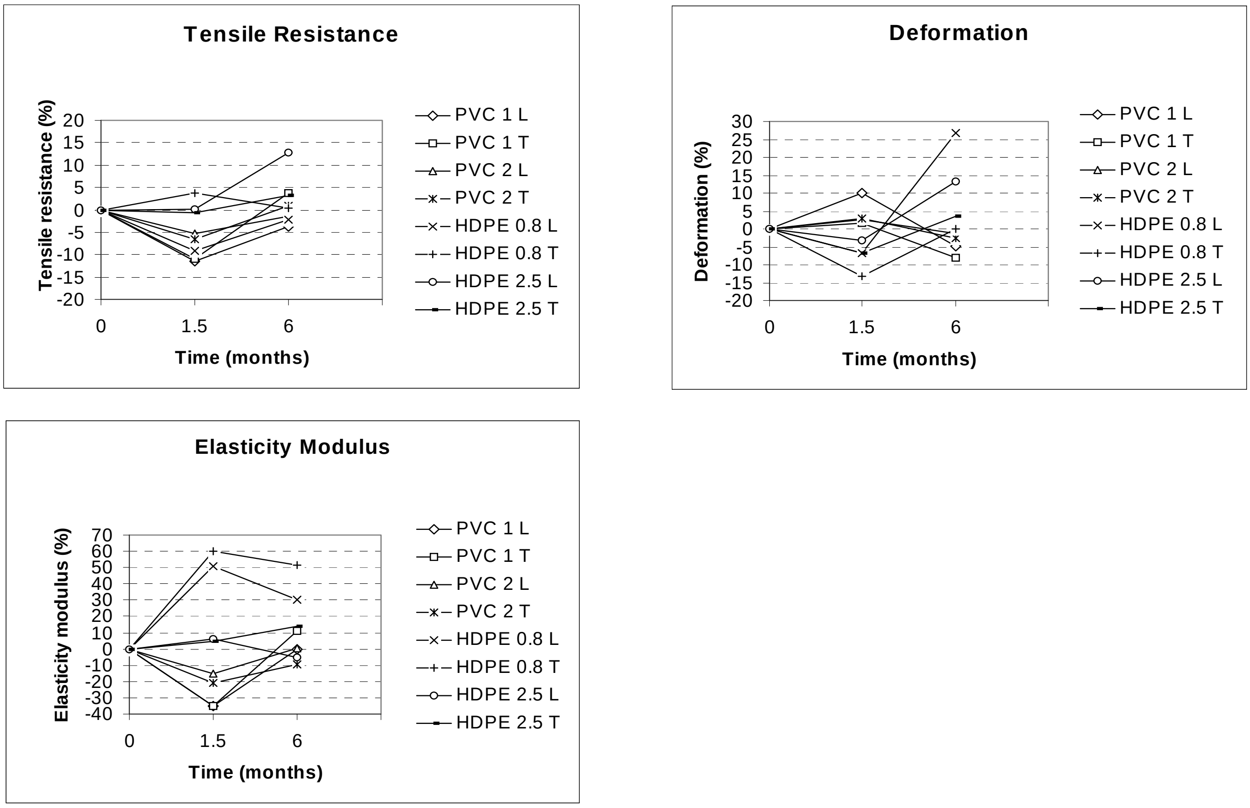

Figure 3. Tensile properties of PVC (1.0 and 2.0 mm) and HDPE (0.8 and 2.5 mm) geomembranes after 1.5 and 6 months of UV exposure

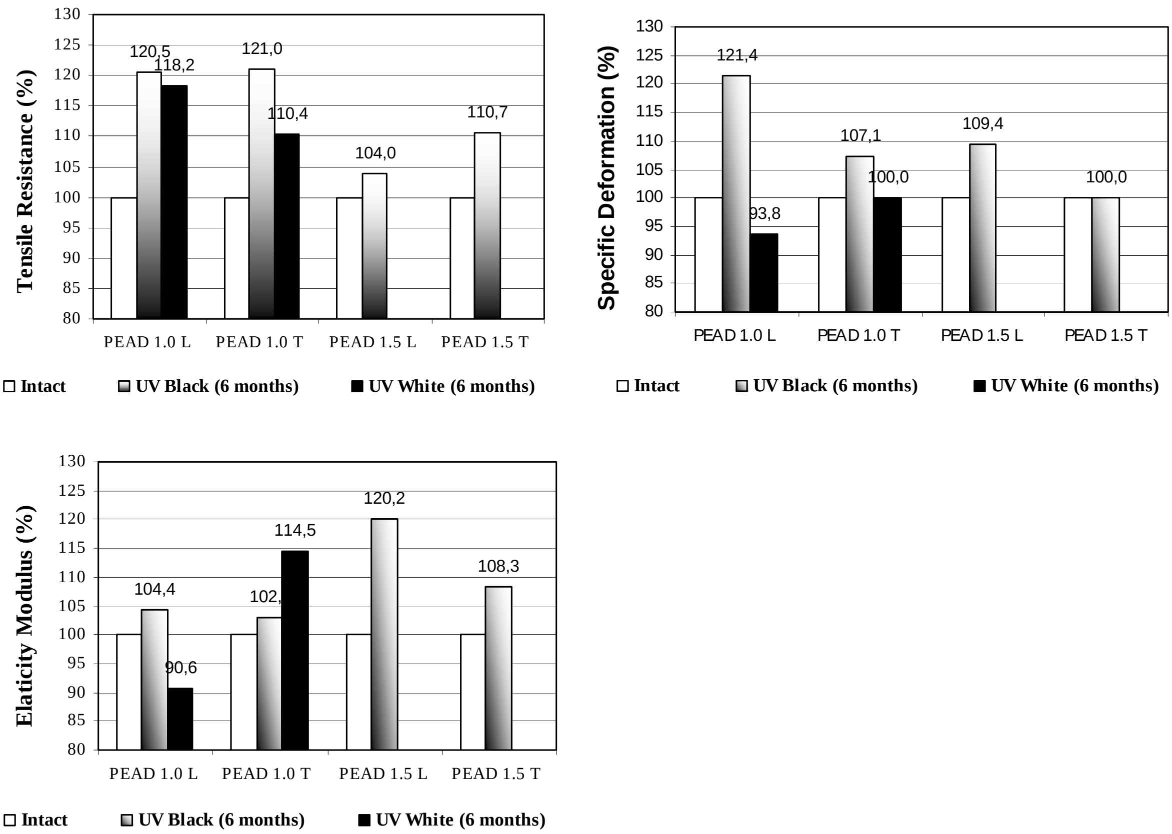

Figure 4. Tensile properties of HDPE (1.0 and 1.5 mm; 1.0 white) geomembranes after 6 months of UV exposure

Concerning the HDPE (1.0 and 1.5 mm) a similar behavior was observed after 6 months of exposure. Some increases were verified in tensile resistance and deformability. Concerning the tensile resistance the average increases were by 20% (1.0 mm), 7% (1.5 mm) and 14% to HDPE textured. The deformability presented some oscillation of 14% to HDPE (1.0 mm). On the other hand, variations to HDPE (1.5 mm) and the textured HDPE were not expressive. The same trend was verified to the elasticity modulus. In this sense, the HDPE became more ductile. The white textured geomembrane presented small variations on its behaviour. The deformability and stiffness remain the same values what implies in a great efficiency against the UV rays.

Figures 5 and 6 show the results from weathering exposure after 6, 12, 18 and 30 months. In general, PVC geomembranes showed changes including alterations in tensile resistance, loss of deformation, and increases in stiffness. After 18 months, increases in deformation and elasticity were very evident for PVC geomembranes (1.0 mm thickness were more affected). In the last time, the highest decrease in deformation was about 8% (1.0 mm). The samples became more rigid and stiffer than fresh samples. HDPE geomembranes showed some variations (increases) occurring in deformation, which were more significant after 30 months. Some oscillations in elasticity had been also observed. Here again, the lesser thicknesses had been affected (0.8 mm). The behavior was characteristic of a ductile material.

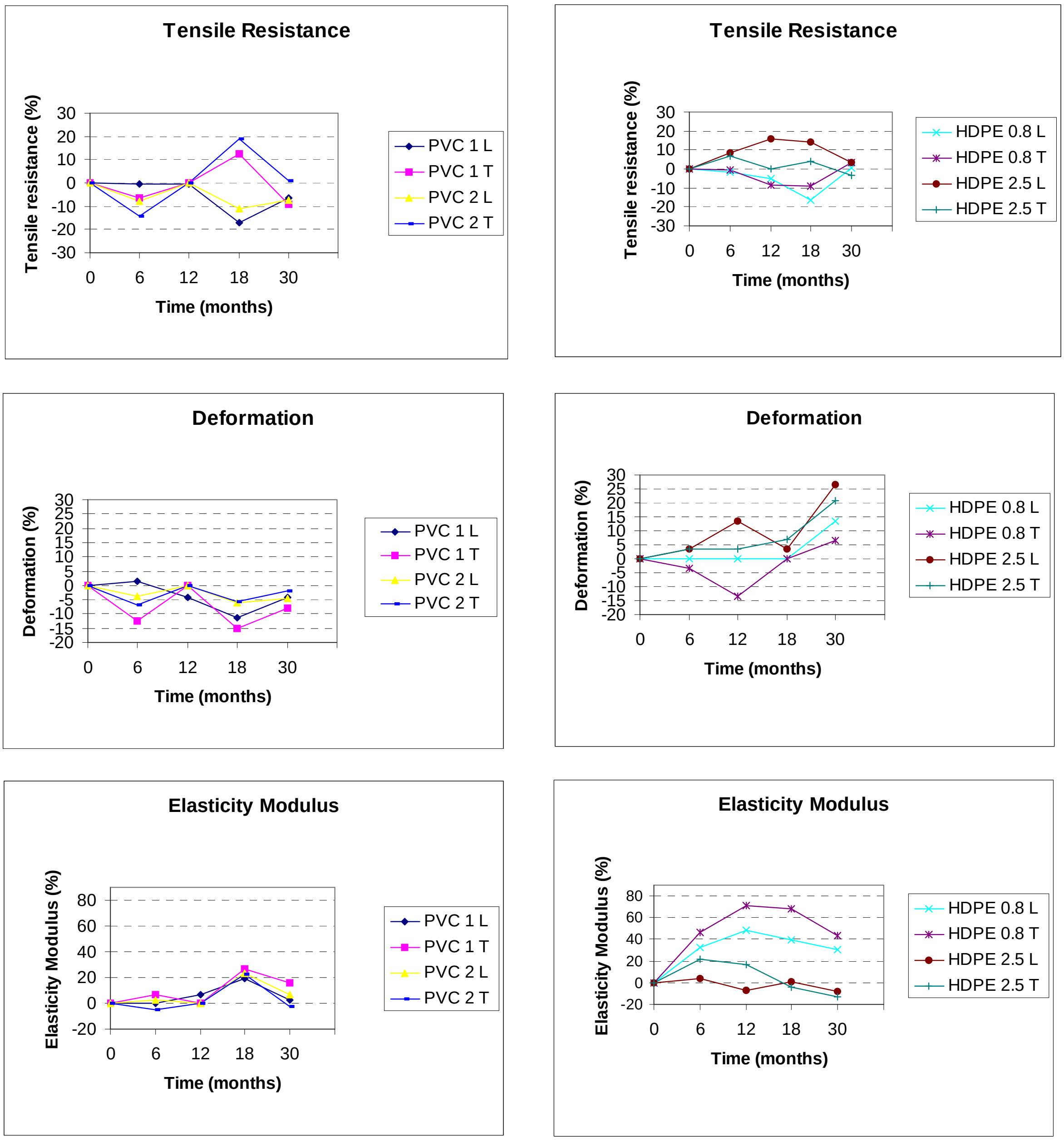

Figure 5. Tensile properties of PVC (1.0 and 2.0 mm) and HDPE (0.8 and 2.5 mm) geomembranes after 6, 12, 18 and 30 months of UV exposure (outdoor exposure)

MFI and OIT tests results are presented in Table 1 and 2, respectively. The analyses were performed only to HDPE GM exposed in laboratory. Concerning the MFI values, the table 1 shows the variation of the values of the exposed samples compared to the values of the fresh samples.

Table 1. MFI tests results

Condition	HDPE (mm)	MFI (g/10 min)	Variation (%)	Probably meaning
Intact	0.8	0.1778	-	-
	1.0	0.1710	-	-
	1.5	0.1530	-	-
	2.5	0.1460	-	-
	1.0 (W*)	0.1680		
Exposed	0.8	0.1691	(-) 4.89	CL
	1.0	0.1650	(-) 3.50	CL
	1.5	0.1484	(-) 3.00	CL
	2.5	0.1433	(-) 1.85	CL
	1.0 (W*)	0.1633	(-) 2.80	CL

*W = white GM; (-) decrease; CL = Crosslink

Table 2. OIT tests results

Condition	HDPE (mm)	OIT (min)
Intact	0.8	12.55
	1.0	11.50
	1.5	12.00
	2.5	10.05
	1.0 (W*)	100.00
Exposed (UV lab)	0.8	6.99
	1.0	11.00
	1.5	10.00
	2.5	12.24
	1.0 (W*)	65.68

*W = white GM

The MFI results obtained show that all HDPE geomembranes presented decrease in MFI values. However, these values are not so expressive: the biggest value observed was 4.89%. The white GM presented the lowest value: 2.80%. Decreases in MFI value are an indication of crosslink in polymer (crosslink after exposure is always an indicative of superficial degradation). This is a good fact since the level of degradation was not so critical.

The intact white GM presented the minimum OIT value required (100 minutes) and showed a good value after the exposure (65.68 minutes). The OIT tests values were very low to all intacts and exposed samples (black HDPE). The minimum value required was not achieved.

Comparing the results obtained from both laboratory and outdoor exposure, it was not possible to establish an adequate standard of comparison since the laboratory results had not supplied good resulted.

In the laboratory exposure the variations suffered for the PVC after 6 months had practically been inexpressive regarding the fresh samples. Concerning the HDPE, the variation of the rigidity was inexpressive. In general, the HDPE became more ductile than the fresh samples.

After outdoor exposure, the PVC samples became more rigid and stiffer than fresh samples. HDPE geomembranes showed some variations (increases) occurring in deformation, which were more significant after 30 months. In spite of HDPE became more ductile to both laboratory and outdoor exposure, results obtained can reflect the difficulties of attainment of the elasticity modulus, for example.

Of course it needs to be considered that many factors can also have affected the behavior of the samples such as: type of lamp (UV-B), time of exposition, temperature, relative humidity, etc.

CONCLUSIONS

PVC and HDPE geomembranes were evaluated in two kinds of exposure: laboratory and outdoor. The GMs presented variations in its physical and mechanical properties to both exposure conditions.

Concerning the laboratory exposure, the variations suffered for the PVC had been inexpressive in relation to the fresh samples after 6 months of exposure to radiation UV. On the other hand, the HDPE became more ductile than fresh samples and the HDPE white textured were more effective against the UV effects. MFI test showed some levels of superficial degradation (crosslink) in HDPE geomembranes. OIT tests showed shorter values to intact and exposed samples. However, the Std-OIT test may be unable to evaluate certain antioxidants packages.

After outdoor exposure, PVC GMs became more rigid and stiffer than fresh samples. HDPE geomembranes showed some variations (increases) occurring in deformation and became more ductile.

It was not possible to establish an adequate standard of comparison between the results obtained from both conditions of exposure. It must be taken into account that many factors can also affect the behaviour of the GMs in laboratory exposure (irradiation level, type of lamps, temperature, time of exposure, etc).

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