DEGRADATION OF HDPE AND PVC GEOMEMBRANES EXPOSED TO HEAT

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ABSTRACT: HDPE and PVC geomembranes are sensitive to changes in their properties when in contact with high temperatures. ASTM D 794 is used to assess the consequences of hot temperature on polymeric geomembranes. This paper presents results of mechanical tests in HDPE and PVC geomembranes that were exposed to heat in conventional oven. Geomembranes of two thicknesses were tested: 1.0, 2.0 mm (PVC) and 0.8, 2.5 mm (HDPE). Mechanical and physical properties were evaluated. The results obtained show, for example, that after 30 months of exposure, the PVC geomembranes (1.0, 2.0 mm) were more rigid and stiffer than fresh samples. The HDPE geomembranes, on the other hand, when exposed to heat presented increases in deformation. MFI tests showed some level of degradation of the geomembranes.

1 INTRODUCTION

All polymers are susceptible to degradation when exposed to UV-radiation, heat, water and oxygen. The lifetime of a material is de-termined by UV-radiation (photochemical degradation) and thermal oxidation, or a combination of these factors (van Zanten, 1986). Several properties of polymeric geomembranes are sensitive to changes in temperature. When they are exposed to heat changes in their physical, mechanical and chemical properties can occur. The time and level of severity will determine the degree of those changes.

This paper brings an analysis of degradation of the Poly Vinyl Chloride (PVC) and High Density Poly Ethylene (HDPE) geomembranes when exposed to conventional oven after 6, 12 and 18 months. Mechanical and physical properties were evaluated. OIT tests were also performanced to evaluate the level of oxidation degradation occurred on the HDPE geomembranes.

2 THERMAL DEGRADATION

Increases in temperature cause loss of volatile substances as solvents and plasticizers. The ASTM D794 deals with the effects of heat on the plastics. The rupture due to heat is defined as a change in the appearance, weight, dimensions or other properties that may alter the material to a degree that it is no longer acceptable for the service in question. Not only does temperature act as an accelerator, but it may also affects the fiber structure by stabilizing or reducing the inner stress. Another consequence of temperature is the increase of material crystallinity associated with an increase of density. Thus, temperature is an important parameter in the aging process due to its capability to influence the reaction rate, mechanical (strength and elongation), and abrasion properties. It must be emphasized that the temperature in the sample may be significantly higher than in the surroundings due to the material thickness and opacity.

Various properties of the geomembranes are directly dependent on the temperature range within which they are used or handled. A high temperature can lead to: (1) decrease in the bending stiffness; (2) reduction in resistance to chemicals; (3) increase in the speed of creep and, (4) increase in process of thermo-oxidation. On the other hand, a lower temperature leads to: (1) increase in the bending stiff-ness; (2) formation of condensation, which can cause problems especially during welding with solvents and adhesives and, (3) shrinkage in hard PE membranes due to high coefficient of (linear) expansion (van Santvoort, 1994). In the presence of thermal or radiation energy the oxidation degradation is triggered or accelerated (Rowe and Sangam, 2002). In order to prevent this problem, anti-oxidants are embedded within the material, they stop the chemical reaction; another procedure is to eliminate oxygen from the material and then cover the geomembrane. A complete and great review on the process of oxidative degradation can be found in the papers of Rowe & Sangam (2002) & Hsuan and Koerner (1998).

2.1 *Oxidation Time Induction (OIT) Tests*

OIT is the time required for the geomembranes test specimen to be oxidized under a specific pressure and temperature. Since the antioxidants protect the geomembrane from oxidation, the OIT value indicates the amount of antioxidant remaining in the test specimen (Hsuan & Koerner, 1998).

The method ASTM D3895 (Standard Oxidative Induction Time – Sdt-OIT) uses a differential scanning calorimeter (DSC) with a specimen test cell that can sustain a 35 kPa gauge pressure. The specimen is heated from room temperature to 200ºC at a heating rate of 20ºC/min under a nitrogen atmosphere. At 200ºC an isothermal condition is maintained for 5 min and the nitrogen gas is changed by the oxygen gas. The test is finished when an exothermal peak occurs (oxidation of material). The minimum OIT value required is 100 minutes. The Figure 1 illustrates a test performanced in a HDPE geomembrane. The OIT value obtained was 8,11 minutes.

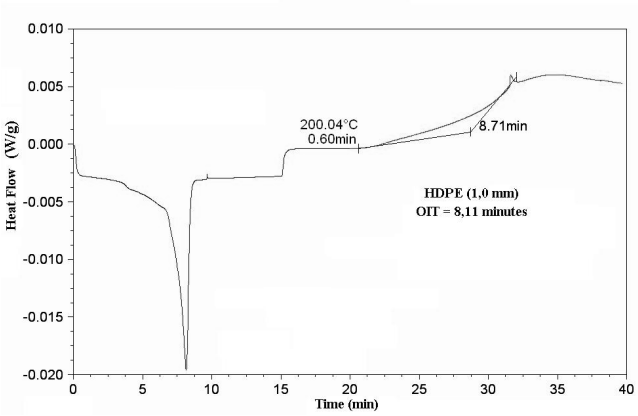


Figure 1. OIT test (HDPE geomembrane – 1,0 mm)

3 MATERIALS AND METHODS

The analyses were performanced after 6, 12, 18 and 30 months of exposure to heat in a conventional oven. The tests were conduced as specified in ASTM D794 and D5721. Geomembranes of two thicknesses were tested: 1.0, 2.0 mm (PVC) and 0.8, 2.5 mm (HDPE). The samples were exposed to the heat at 85°C in an oven conventional. The Standard Specification GM13 (Test Properties, Testing Frequency and Recommended Warranty for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes) recommends the temperature at 85°C to evaluate the OIT after 90 days of exposure under effects of heat. Mechanical and physical properties were evaluated and compared to intact samples. The OIT tests were performanced in accordance to ASTM D3895. The Figure 2 shows the samples in the oven conventional.

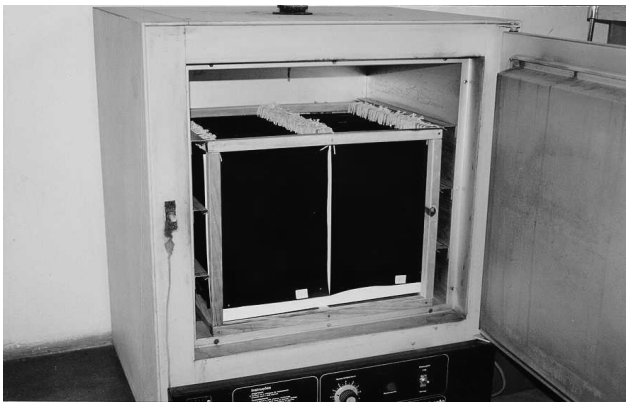


Figure 2. HDPE and PVC geomembranes in the conventional oven

4 TEST RESULTS AND DISCUSSION

The Figure 3 shows the variations of mechanical properties for both HDPE and PVC geomembranes. Results of OIT tests are presented in Table 1.

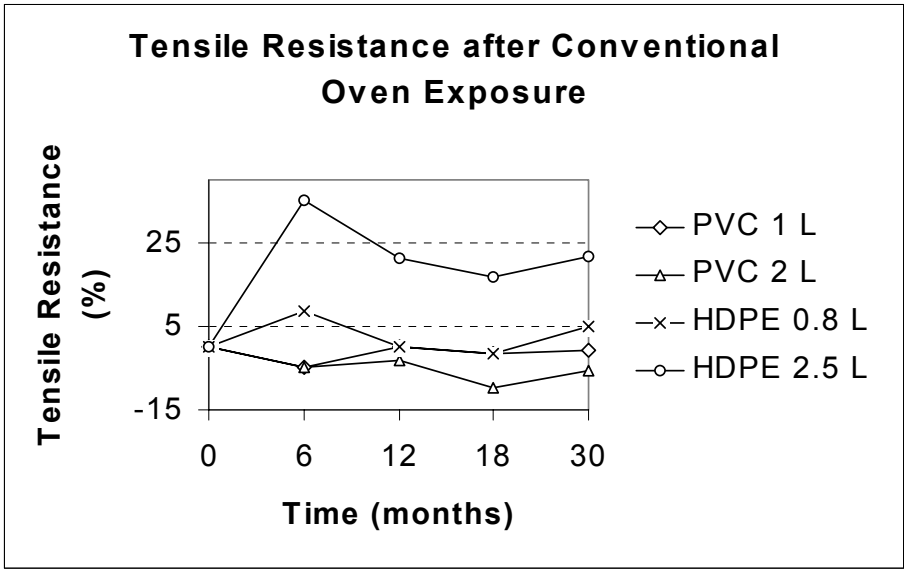
Table 1. Results of OIT tests

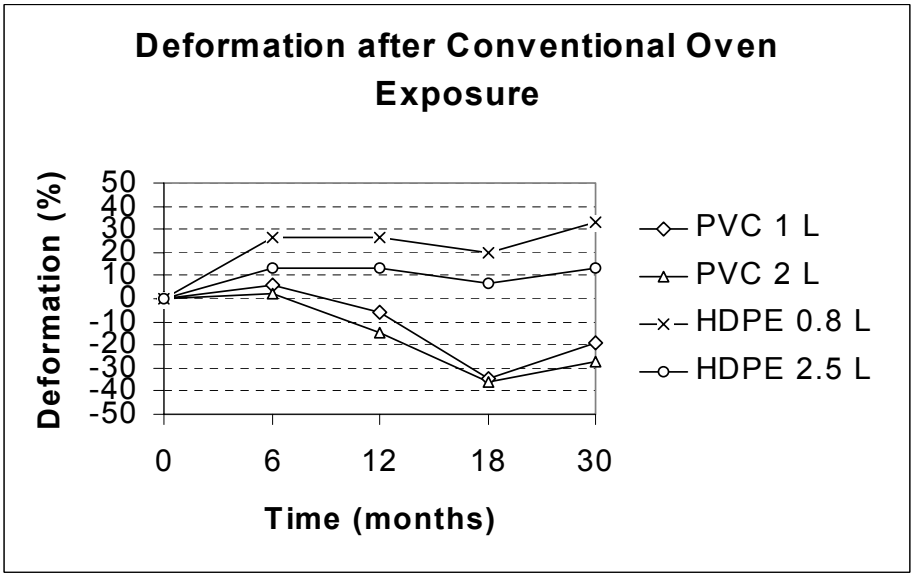
Exposure	HDPE (mm)	OIT (min)
Intact	0,8	12,55
	2,5	10,05
Conventional Oven	0,8	1,68
	2,5	0,96

PVC geomembranes presented a generalized tendency. Some increase in deformability occurs at the initial periods. However, decreases were verified after the final period. After 18 months, the variations observed were of 30 to 45% (decrease). In spite of reduction at the last period, the variations were 20 to 30%. Conversely, the HDPE showed tendency of increase in deformability. The final variations obtained were of 15 to 32% (increase).

Regarding to stiffness, the PVC geomembranes showed some decrease at the first period but increases were noted until 18 months. At this time the increase reached 40% (PVC 1L). At the last period the values decreases to values nearest to the initial values. HDPE geomembranes (0,8 mm) showed the largest variations. Initially it was observed an increase to all the samples. However, the stiffness shows decreases until the final period. Despite of decreases in stiffness to the HDPE (2,5 mm) after 6 and 18 months, some increases were noted at the final period.

The OIT tests presented shorter values (intacts and exposed samples). The HDPE exposed presented OIT values nearest to zero. These values already expected due to several condition of exposure. According to Hsuan & Koerner (1998) the high temperatures employed in the Std-OIT test may bias the test results for certain types of antioxidants, such as HALS antioxidants. HALS antioxidants have a maximum effective temperature below of 150°C.





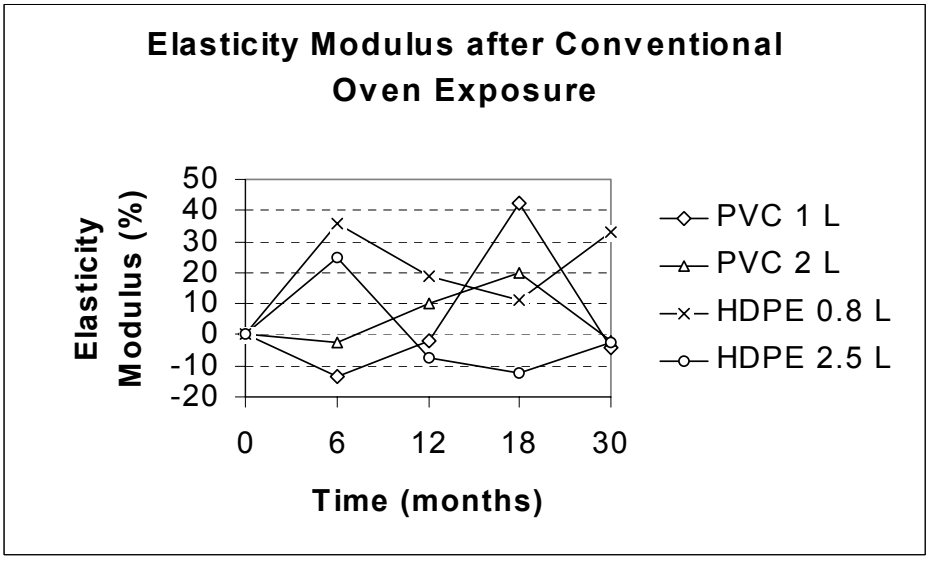


Figure 3. Variation of tensile properties after exposure to heat in a conventional oven

5 CONCLUSIONS

PVC geomembranes showed some decrease in deformability and some increase in tensile resistance and stiffness (specially in the smallest thicknesses). HDPE geomembranes presented increase of deformability and decrease of stiffness after the periods of analyses. The OIT values were inexpressive but the Std-OIT test may be unable to evaluate certain antioxidants packages. In this sense, the HP-OIT (High Pressure) test is more desirable.

6 REFERENCES

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