Outdoor and UV-B Laboratory Weathering Resistance of Geosynthetics

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ABSTRACT: Nowadays limited data are available to show correlations between tests conducted with natural outdoor exposure vs. accelerated weathering tests on geosynthetics. This paper compares the results obtained after one year of outdoor exposures in Italy at the 45° parallel with tests conducted in laboratory using a UV-B fluorescent lamp apparatus up to 3000 hours of exposure. The performances of seven different types of geosynthetics have been compared with those of virgin specimens by means of change in tensile properties.

1 INTRODUCTION

Most of the geosynthetics, mainly geotextiles and geogrids, are often buried in the soil and exposed to sunlight only for few days during the installation period. Some others, such as geomembrane liners for dams and canals, are often permanently exposed without any external protection.

The actual stabilization of geosynthetics against the effects of the outdoor exposure is a common query among civil engineers and polymer scientists.

Polymers are all susceptible to be attacked by light, oxygen, heat and water, resulting in product brittleness, cracking, crazing, color change, aging, strength loss and sometimes failure of the product to perform its functions (Tisinger, 1991). Thus any specific product and/or chemical formulation shall be designed to solve the degradation problems associated to weathering exposure.

2 WEATHERING TESTING ON GEOSYNTHETICS

The accelerated test methods utilizing artificial light sources provide the advantages of reducing the testing period and of providing repeatable results thus allowing an easy quality control and assessment (Brennan, 1987). However doubts are often raised about the reliability of the collected information in relationship with full scale outdoor exposure. Of course testing geosynthetics in the environmental conditions of the site is usually the ideal solution, however this is often impracticable due to the variability of exposure conditions and time constraints. Thus, it is important to develop a realistic but at the same time severe test that will represent the worst weathering conditions and will shorten the testing time.

When a geosyntethic is exposed in the outdoor, it is subjected to cycles of sunlight exposure (day and night), wet and dry conditions (rain and dew), temperature changes (heat and cold). These conditions may have a synergetic effect, thus leading to a more severe aging and deterioration.

The crucial factors for a successful laboratory weathering test are:

- to simulate cycles of irradiation in the UV spectrum of the sunlight or at least the UV-A (315 ÷ 380 nm) and UV-B (280 ÷ 315 nm) range. In fact the wave length that produces the maximum damages for the polymers used in the geosynthetic industry is between 300 and 370 nm, varing between polymer types (Grossman, 1981);
- to obtain cycles of moisture by heat condensation and not by water immersion of the specimens;
- to accelerate the tests by increasing the testing temperature thus reducing the required activation energy to break the polymeric molecules.

To obtain the above conditions in laboratory, a QUV fluorescent condensation tester equipped with UV-B type lamps has been selected. The UVB-313 fluorescent lamps simulate the shortest wave lengths found in the sunlight at the earth's surface that are responsible for most polymer damages, having however minimal emission below 290 nm. The typical spectral irradiance of the fluorescent UV-B lamps compared with solar light is shown in Fig. 1. The cycles for performing the tests have been selected in accordance to ISO 4892-3 and ASTM G53 test methods and consisted in 4 hours UV exposure at 60°C and 4 hours of condensation at 50°C.

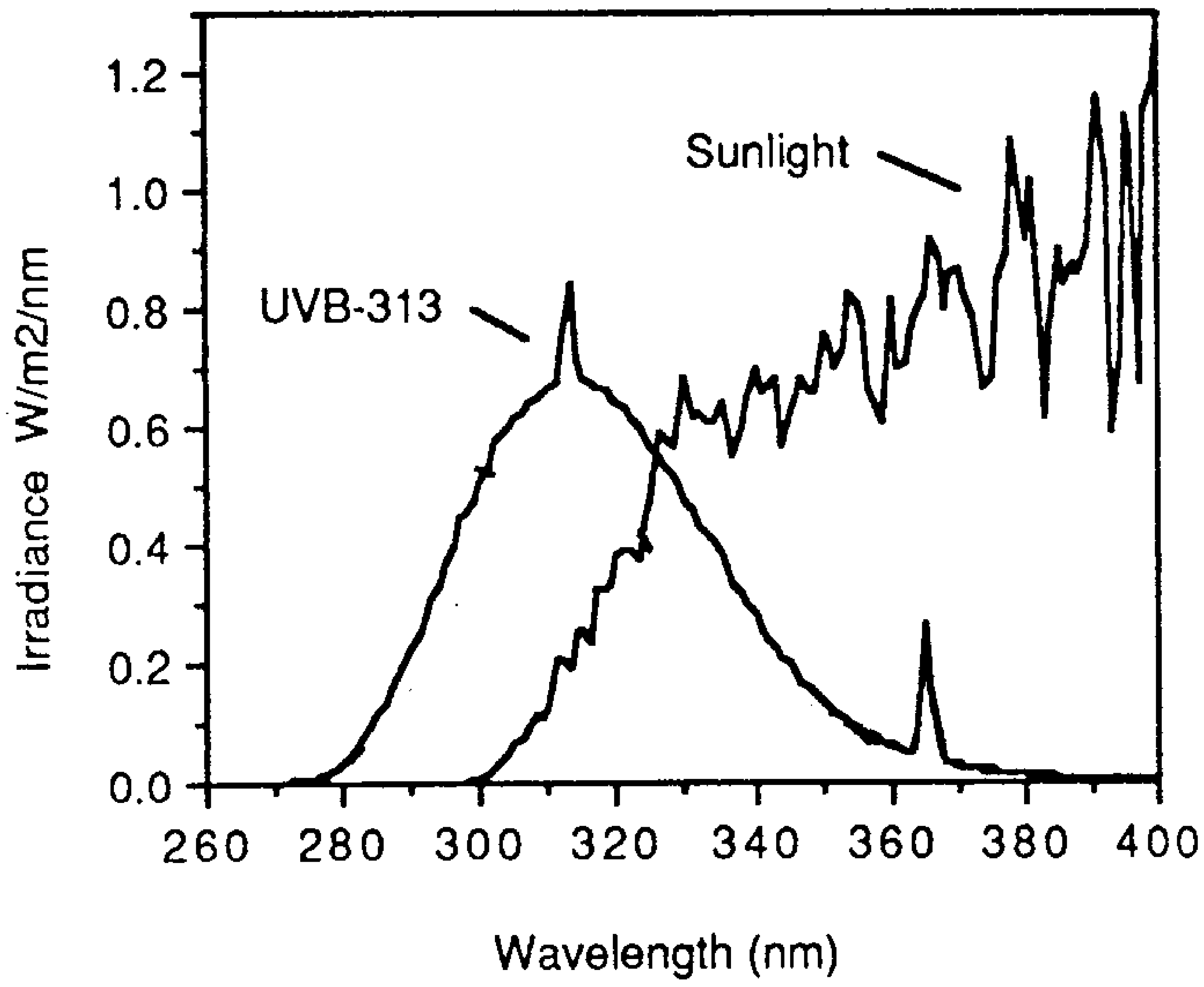

Fig. 1: UVB-313 lamp and sunlight spectrum (from Brennan, 1987).

To verify the correct interpretation of the environmental conditions, the results obtained by exposure in the UV-B device have been compared to the ones exposed in the outdoor at the 45° parallel in Milan, Italy. At this location the typical annual solar irradiance is 120 Kcal/cm^2/year. It has been deliberately chosen to install the tests specimens flat on a gravel bed, thus simulating a typical geosynthetic application. The horizontal position of the specimens allows them to be exposed all the day long and ensures temperature and humidity conditions similar to the ones encountered during the service life of the products.

It has been decided to monitor the variation of product characteristics by measuring the residual tensile properties, such as the peak tensile strength, the strain at peak and the secant modulus at 5% strain. The outdoor exposure has started in May /June 1993 and have been scheduled to be performed after 0, 1.5, 3, 6, 12 and 24 months of outdoor exposure corresponding respectively to 0, 1080, 2060, 4120, 8640 and 17280 hours. The tests for UV-B laboratory exposure have been performed at 1000, 2000, 3000 hours. The tensile tests have been carried out in accordance to the testing standards and parameters listed in Table 1 and Figure 2.

It has been decided to test the geotextiles using a narrow-width specimen and geogrids using a single rib specimen since it is not practicable to perform laboratory weathering tests on wide-width specimens due to space limitation in the testing apparatus. To the Authors' knowledge, this is the first time that geotextiles, geogrids and geomembranes are tested together and their resistance to weathering is directly compared.

Moreover, limited data were available with 3000 hours UV-B exposure tests, while shorter duration tests, for geotextiles only, have been already published (Koerner and Koerner, 1990).

Table 1: Tensile test parameters

	Geotextiles	Geogrids	Geomembranes
Test method	ISO 5081	GRI-GG1	ASTM D 638
Specimen shape	Rectangular	Single rib (min 3 junc.)	Type 4 dumb-bell
bo (mm)	50	-	6
ho (mm)	200	200^ / 250*	64
hr (mm)	80	80^ / 100*	25
Test speed (mm/min)	50	50	50
Note: ^ Biaxial geogrid		* Uniaxial geogrid	

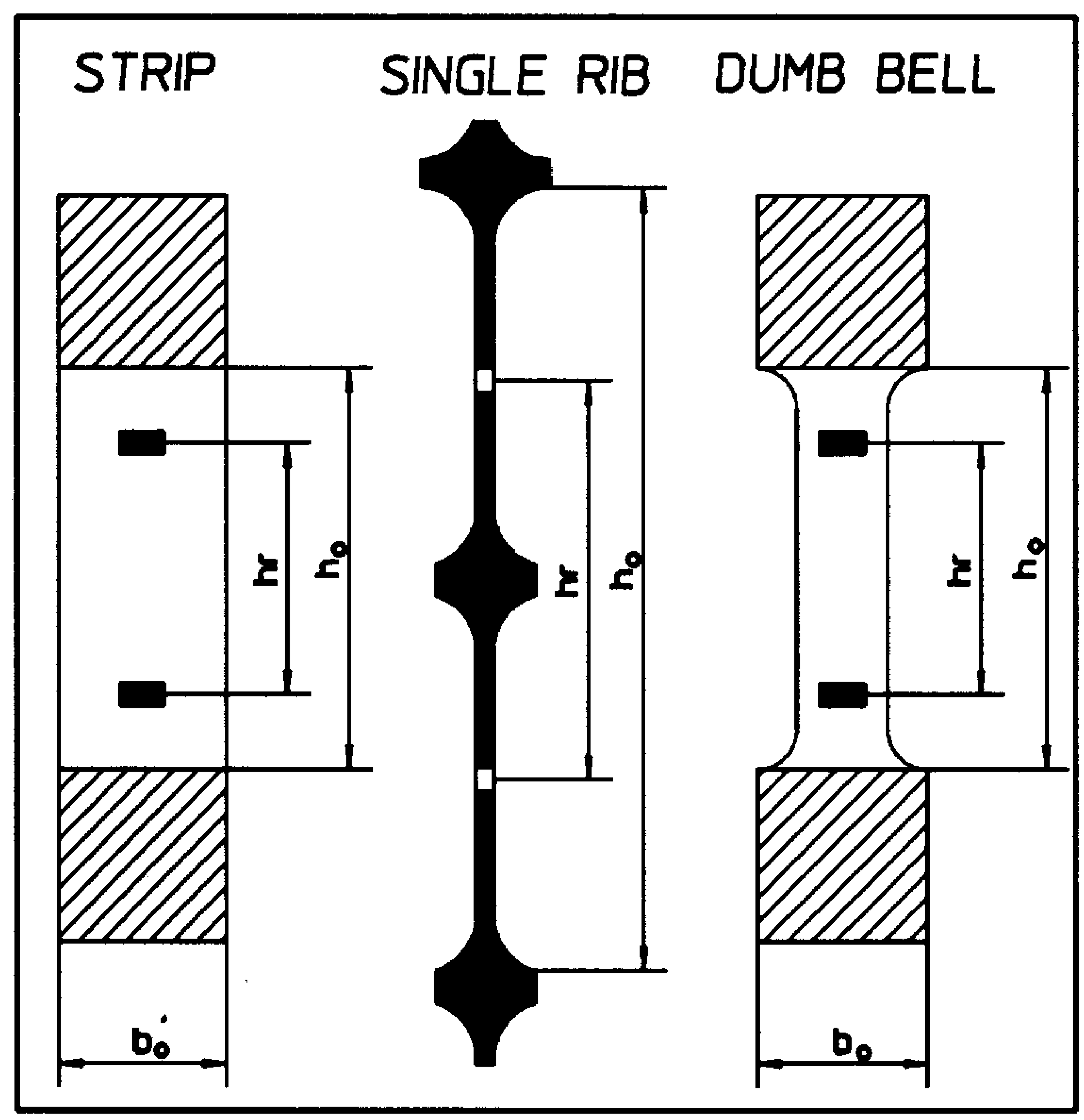

Fig. 2 : Specimens shapes and dimensions: respectively for Geotextiles, Geogrids and Geomembranes.

3 GEOSYNTHETICS TESTED

The main characteristics of the geosynthetics tested are summarized in Tables 2 and Table 3. It has been decided to select a representative group of geosynthetics including several types of polymer composition, manufacturers, product type and typical suggested applications.

Table 2: Geosynthetic products

Code	Brand name	Polymer type
GT-PT	Bidim S 300	PET
GT-PP	Polyfelt TS 700	PP
GG-PP1	Tenax LBO 101 SAMP	PP
GG-PP2	Tenax LBO 301 SAMP	PP
GG-PE	Tenax TT 401 SAMP	PE
GM-PV1	Sibelon C	PVC
GM-PV2	Trocal A	PVC
GM-PE	Carbofol	HDPE

Table 3: Geosynthetic type and physical characteristics.

Code	Geosynthetic type	μ (g/m²)	Thickness (mm)
GT-PT	Nonwoven geotextile	300	2.7
GT-PP	Nonwoven geotextile	280	2.6
GG-PP1	Biaxial geogrid	160	0.8÷3.0
GG-PP2	Biaxial geogrid	350	1.5÷4.0
GG-PE	Uniaxial geogrid	770	1.6÷4.3
GM-PV1	Geomembrane	3900	3.0
GM-PV2	Geomembrane	1920	1.5
GM-PE	Geomembrane	1900	2.0

4. TEST RESULTS AND CONCLUSIONS

The tensile test results have been reported in Figure 3 and 4.

Regarding the comparison of results between laboratory and outdoor testing we may conclude the following:

- For geotextiles, the UV-B testing device produces a different speed in the reduction of tensile strength and tensile strain; for the strength the correlation with outdoor exposure seems quite evident, while for the strain further testing is required to define this correlation.

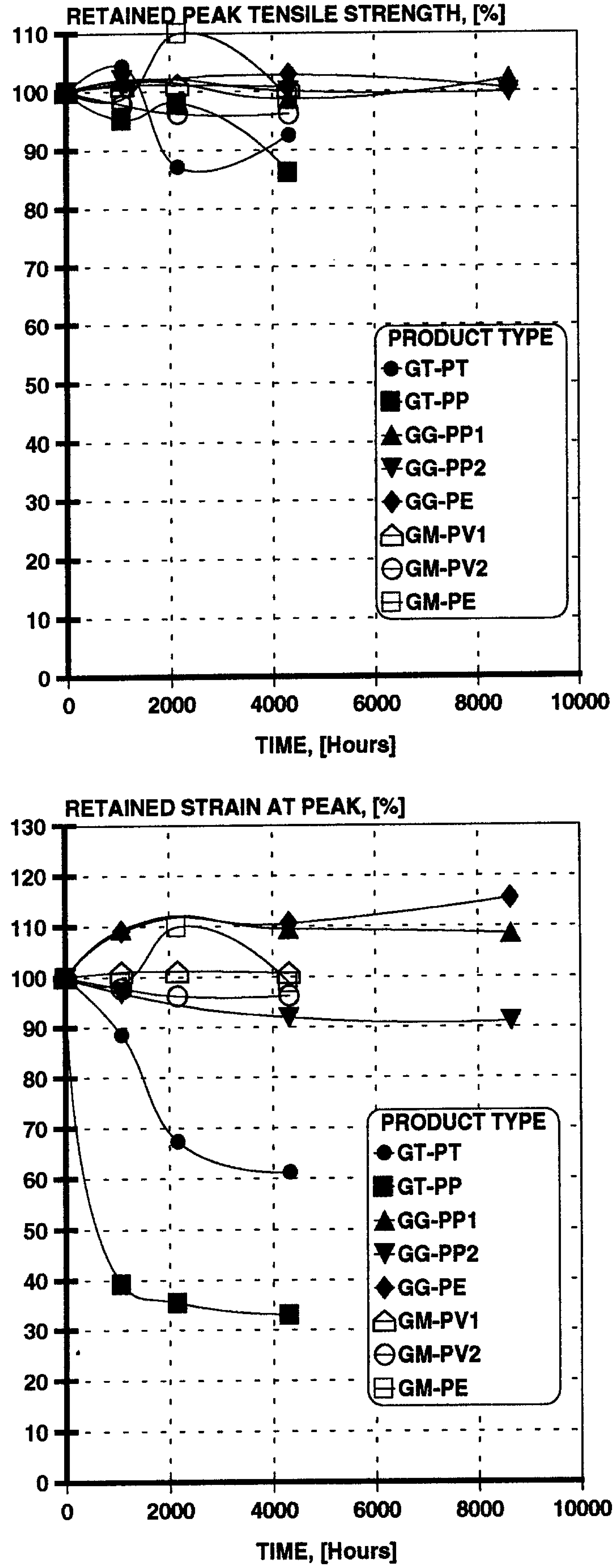

Fig. 3: Tensile test results after outdoor exposure.

- In particular, 1000 hours of UV-B exposure produce considerably more loss in peak tensile strength than 6 months (4120 hours) of exposure to outdoor weathering but less reduction in strain at peak.
- 2000 hours of UV-B exposure have been enough to almost destroy completely the PP and PET geotextiles.

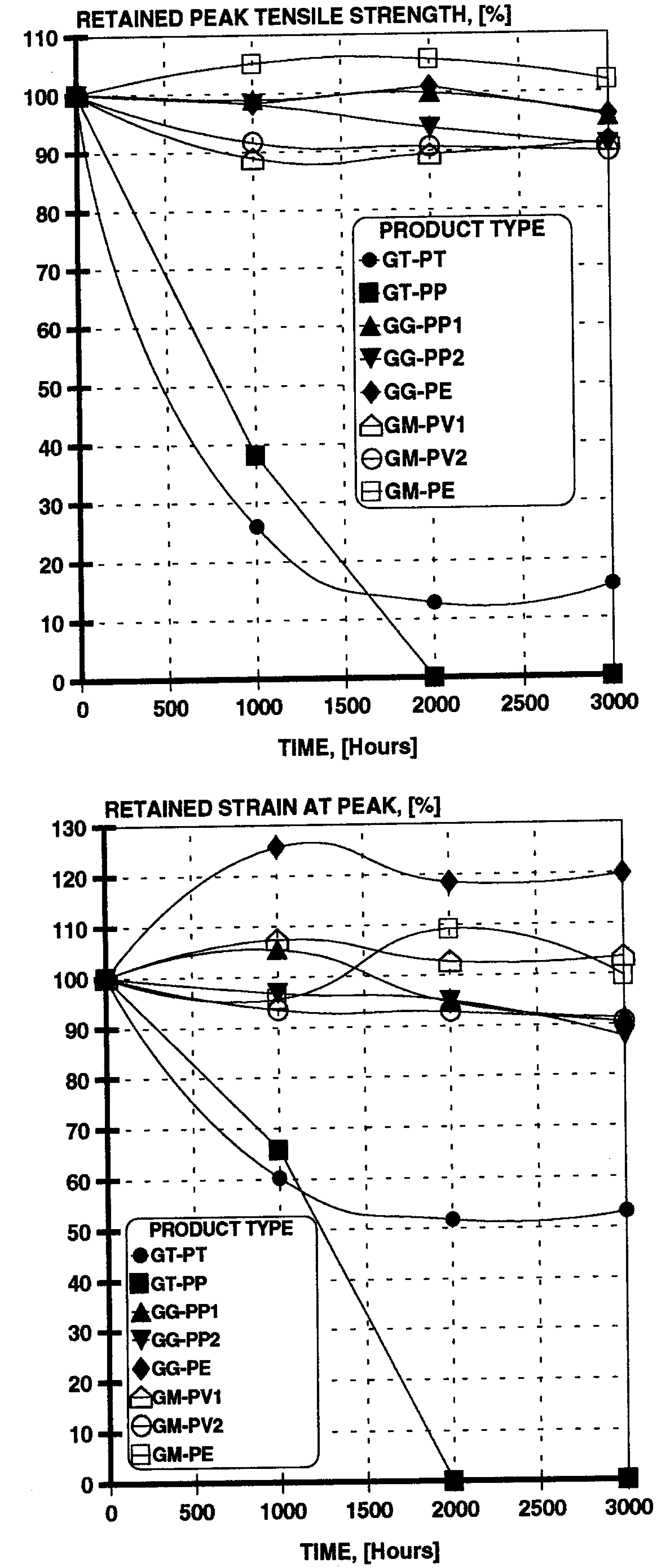

Fig. 4 : Tensile test results after UV-B laboratory weathering.

- Greater correlations or similarities can be seen for geogrids and geomembranes even if it is felt that the outdoor exposure length is still limited, compared with the 1000 hours UV-B tests.
- Overall a good correlation has been found in the product ranking while the absolute values show rather poor correlation.

Regarding the behaviour of the different products, the following conclusions may be drawn:
- more than polymes and additives, the most important parameters influencing the resistance to weathering seem to be the geometrical properties and in particular the dimensions of the elements composing the geosynthetics since the weathering usually affects only a thin surfacial thickness, (see also Wrigley, 1987). Thus properties such as fiber diameter for geotextiles, rib thickness for geogrids, sheet thickness for geomembranes are key index for assessing UV resistance.
- For geotextiles, the variation in tensile strain at peak after 6 months of outdoor exposure clearly indicates polymer embrittlement and aging with loss up to 70% of the initial strain. For the same exposure, the loss of the peak tensile strength has been approximately 15%. Thus peak tensile strength is not always a good index for assessing geosynthetic aging. The tensile modulus being a ratio of strain and strength is a much better index for identifing product modifications (up to 370%).
- On the contrary, thicker and solid products such as geogrids and geomembranes have shown variation in tensile peak properties not greater than 20% and variation in tensile modulus lower than 10%, for both outdoor and laboratory exposure. Moreover for these products lower reductions than geotextiles are present and properties seem to stabilize after 1000 hours of laboratory exposure. Thus aging seems not proportional to the exposure time and the conclusions that may be drawn are that changes occur only in the surfacial thickness and do not propagate inside with the same rate of speed.

5. ACKNOWLEDGEMENT

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