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Outdoor Exposure Tests of Geotextiles

Expériences d'exposition à la lumière de divers géotextiles

Several geotextiles were exposed in 3 different locations. All specimens in a test series were started at the same time and samples withdrawn at 4 to 8 week intervals up to 52 weeks (or failure). Grab strength and elongation of exposed and unexposed controls were measured.

Geotextiles exposed in Florida degraded faster than in Arizona - in most tests. Degradation in North Carolina tended to be slower - but there was considerable variations in this respect between fabrics.

The eleven fabrics tested could be divided into three main groups: the poor performers that must be protected from the sun except for short installation periods; the intermediate performers with only minor strength loss during protracted installation delays and suitable for short life silt fences, temporary walls or very shades locations. The long term performers can be considered for more severe exposure for temporary applications. No geotextile should be left exposed to light for permanent installations.

La résistance et l'allongement de rupture de l'éssai d' arrachement sont mesurés pour les géotextiles exposés à la lumière pour divers intervalles, en trois emplacements de divers climats.

La dégradation est la plus vite en Floride, moins dans l'Arizona et la plus lente dans la Caroline du Nord - dans la plupart des tests. Mais on a constaté des variations sensibles dans les divers géotextiles et même dans les séries de tests.

Les géotextiles testés sont séparés dans trois catégories de rendement: (a) médiocre: les textiles doivent être protégés contre le soleil - excepté pendant une période courte pour l' installation (b) intermédiaire: les textiles qui peuvent demeurer exposés à'la lumière pendant une installation prolongée et sont utilisables pour des usage temporaires (silt fence, mur provisoire etc.) (c) long terme: les textiles qui peuvent être considerérs pour des expositions plus rigoureuses et semi permanentes.

Pour les applications permanentes aucun geotextile ne doit rester exposé à la lumiere indéfiniment.

1 INTRODUCTION

In late 1977, the first samples of geotextiles were sent to Arizona and Florida testing laboratories for outdoor exposure tests. Fadeometer tests had shown poor reproducibility and their relevance to outdoor performance had been frequently questioned.

Correlation between indoor and outdoor tests continues to be hotly debated and it is generally recognized that there are many factors that can and do affect exposure results. Even if indoor tests cannot be relied on for outdoor performance predictions, they can be used for screening or rough comparisons between different fabrics.

2 EXPERIMENTAL DETAILS

2.1 Sample Size and Exposure Angle

The sample size was .3m x .3m and they were mounted at 45° angle south exposure using two samples of each fabric for each exposure time: one with the machine direction (MD) parallel with the horizontal plane, the other with the transverse direction (TD) parallel to that plane. At each exposure time, one sample of each fabric and orientation was withdrawn and cut into four .1m x .15m grab test specimens and tested in the MD direction. The two 50mm x 300mm off-cuts from either side were stored in the dark and retained for additional tests and observations.

Ten specimens of the machine direction (MD) and ten of the transverse direction (TD) were tested without being exposed outdoors. Earlier results had shown that although different strengths may be found in the MD and TD, the percent loss of strength was essentially the same in both directions. All data here reported are the averages for both directions: for exposed specimens and controls.

2.2 Test Locations, Times and Weather Records

Three different locations were used. The Florida (FL) and the Arizona (AZ) locations are commercial firms for exposure testing. In North Carolina (NC) exposure racks were placed on the roof of the Monsanto Research Building and for most fabrics the tests there compared well with the Florida tests, although degradation in N.C. appeared somewhat slower. Not all the fabrics were used in all the test series, but there was considerable duplication and overlap of fabrics and test location. Each test series included a sample of B1 (polyester Bidim® C-22* off the same roll to act as a control to make relative fabric performances independent of variations between different test series. This was a .150 kg/m^2 material. Table I lists a brief description of all the fabrics tested in the various series.

It is known that degradation of the polymers depends on light duration and intensity of relevant wave lengths and such additional factors as temperature, presence of water (liquid or vapor) or other atmospheric components (ozone, nitrous oxides, hydrocarbons, etc.). Further, the strength loss of fabrics depends on the polymer degradation as well as on additional factors such as the fabric structure and the rate at which degraded layers are removed and new layers exposed to the actinic rays.

*Footnote: Bidim® is a registered trademark of Monsanto Company for polyester nonwoven fabrics.

This process can be affected by precipitation (type, total amount or rate of application) and wind (speed, direction and whether combined with rain or dust).

There are several ways in which the energy in the sunlight received by the fabrics can be measured. All stations recorded the total sun hours. Some also used the energy recorded in Langleys - either as total Langleys or as U.V. Langleys. Analysis of our test results did not establish significantly better agreement between different times of the year whether related to sun hours, Langleys or any other reported weather parameter. It was therefore decided to give all our results merely as total times (in weeks) left exposed. This simplifies the charts and does not introduce any important errors.

TABLE 1 FABRIC DESCRIPTION AND GRAB TEST RESULTS OF CONTROLS

Fabric Code	μ* kg/m²	Polymer, Construction	Color †	Grab F_G, kN MD	Grab F_G, kN TD	Grab ε_G, % MD	Grab ε_G, % TD
B1	.150	PE,C,N,NW	GREY	.658	.560	74	83
B2	.270	PE,C,N,NW	GREY	1.041	1.133	64	67
B6	.160	PE,C,N,NW	WHITE	.534	.455	72	89
CO	.270	PP,C,N,NW	BUFF	1.170	.791	110	158
F2	.360	PP,S,N,NW	WHITE	.734	1.205	129	112
M4	.150	PP,C,B,NW	WHITE	.525	.511	127	124
T4	.135	PP,C,B,NW	GREY	.609	.484	60	69
T6	.200	PP,C,B,NW	GREY	1.112	1.023	58	69
S4	.125	PP,S,B,N,NW	GREY	.436	.502	51	52
S5	.170	PP,S,B,N,NW	GREY	.498	.703	60	67
M5	.140	PP,C,W,SF	BUFF	.823	.925	21	18
A3	.105	PP,C,W,SF	BUFF	.609	.418	21	16
P8	.260	PP,C,W,MF	BLACK	2.063	1.325	26	32
L8	.235	PP,C,W,MF	BLACK	1.965	1.125	27	32
P5	.175	PP,C,W,MF	BLACK	.712	.832	22	25

† Key: B = heat bonded, C = continuous filament, MF = monofilament, N = needled, NW = nonwoven, PE = polyester, PP = polypropylene, S = staple fibers, SF = slit film, W = woven

* Mass per unit area

2.3 Grab Tests: Strength and Elongation

Standard test procedures were used (ASTM D-1682): .15m x .10m specimens, 50mm x 50mm and 25mm x 25mm rubber lined clamp faces, 5mm/sec head speed. The maximum load and elongation (expressed as a percentage of the original, 75mm, gauge length) were recorded and all strip charts retained.

2.4 Microscopic Investigation

Three needled fabrics, i.e. B1, CO (continuous filaments), and F2 (staple) were observed in the scanning electron microscope (SEM) before and after exposure for 12 weeks at the Miami test site. Fiber appearances are shown in Plate I. For that exposure time the percentage strength and elongation loss can be determined from the data plotted in Figs. 1 and 3. B1 and CO both had about 45 to 50% strength retention and 70% retained elongation at break, although the appearance of the polyester fibers (B1) under the SEM was essentially unchanged, while the polypropylene fibers had undergone very significant changes. Comparing CO and F2: the latter had only 10% retained strength and 55% retained elongation at break and yet the appearance of the circumferencial cracks of the former were much longer, deeper, and more numerous. Thus, the more severe cracking of the CO was accompanied by a smaller loss in strength and elongation at break than the very badly degraded, seriously changed F2.

3 RESULTS

3.1 Reproducibility of Tests, Polyester Fabrics

The control B1 fabric was included in all test series and was used to compare repeatability of tests. Figs. 1A & 1B show the grab strengths and elongations retained - expressed as a percentage of the unexposed controls.

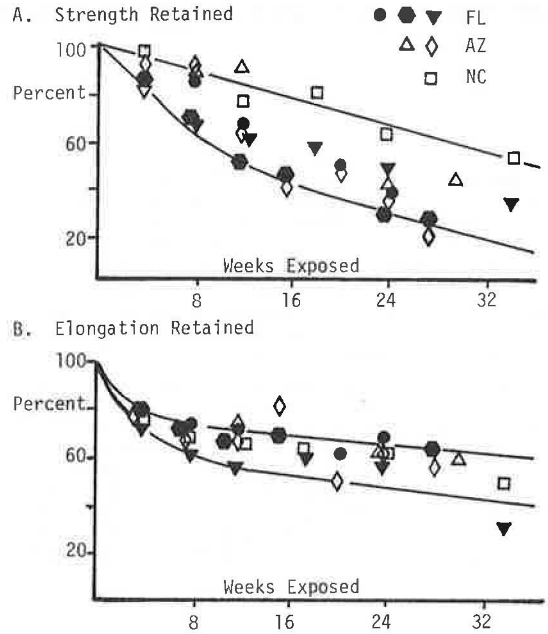

Fig. 1 Grab Strength and Elongation Retained vs. Exposure Time. Polyester Fabric B1; various test sites.

It is clear that considerable differences between different runs were observed. The two Florida test series were similar but differences reported from Arizona for the two test series were much greater: one gave degradations similar to the Miami tests while the other degraded more slowly.

Variations from site to site in the breaking elongation were less than for the grab strength but followed the same pattern. The breaking elongation rapidly decreases in the first 2-4 weeks of exposure and then continues at a much slower rate.

Figs. 1A & 1B show lines (drawn by eye) representing the upper and lower limits of the observations in these tests at different locations and seasons and roughly correspond to North Carolina and Florida rates. All results reported below (when not expressly stated otherwise) will be the actual or expected performance in North Carolina.

3.2 Comparisons Between Different Polyester Fabrics*

Tests were run at the Florida test site in the summer of 1978. The agreement between B1 and B6 was very good and shows that the small amount of carbon black in the grey product had no significant effect on the U.V. resistance. This was in keeping with expectations. Similarly, the better resistance to U.V. of the thicker B2

*Footnote: All polyester fabrics tested were made by essentially the same process.

was as expected and showed a significant effect of the shielding action of the upper layers on the remaining strength of the fabric. The grab test data for the three polyester fabrics are shown in Fig. 2.

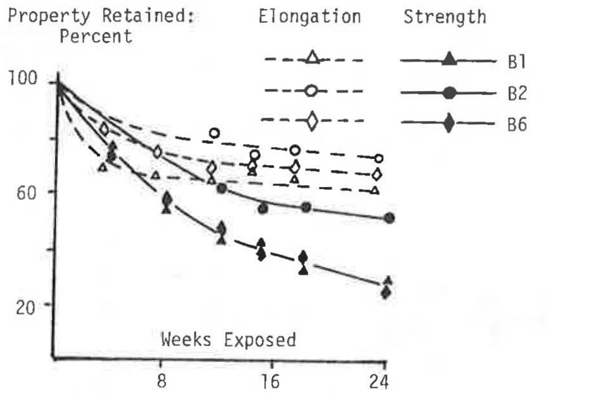

Fig. 2 Grab Strength and Elongation Retained vs. Exposure Time. Needled polyester fabrics (FL).

3.3 Needled Polypropylenes: Fabrics CO and F2

The behavior of these fabrics are shown in Fig. 3 Fabric CO tested in Florida and Arizona gave very similar results although the Florida site was more rapid. The fabric F2 showed slower strength loss in North Carolina and an initial delay period. Both fabrics showed similar losses in elongation with exposure times: At first a rapid decrease to 70% of the original, then a plateau at that level lasting from 4 to 20 weeks, and then a very sudden drop as the strength reaches 10% of the original. This course of degradation is made clearer by the surface changes observed in the microscope and already described in 2.4. Both fabrics appeared dusty (with broken filaments) after a few weeks exposure.

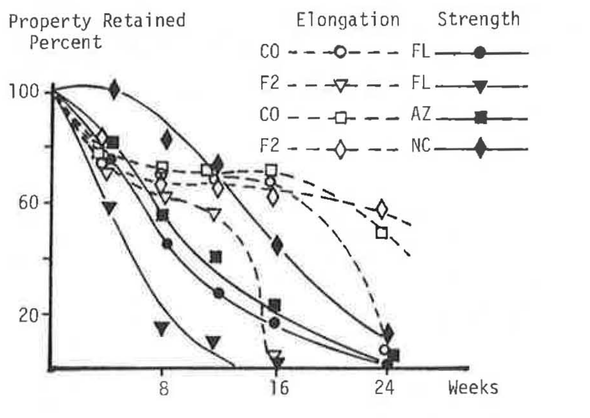

Fig. 3 Grab Strength and Elongation Retained vs. Exposure Time: Needled polypropylene, CO & F2.

3.4 Needled and Bonded Fabrics: P4 and P5

Both these fabrics have a smooth and a fuzzy side, hence tests were run on both faces. The strengths and elongations after exposure did not show significant differences that could be related to which of the surfaces had been exposed.

Fig. 4 shows the very poor light stability of P4 & P5. As had been seen with B1 and F2, the Florida location gave much more rapid deterioration where these fabrics were essentially useless after 3 to 4 weeks and had almost disappeared after 8 weeks. In North Carolina deterioration proceeded at about half the rate but even there the fabrics had lost 70% of the strength and 30% of the elongation after 8 weeks exposure.

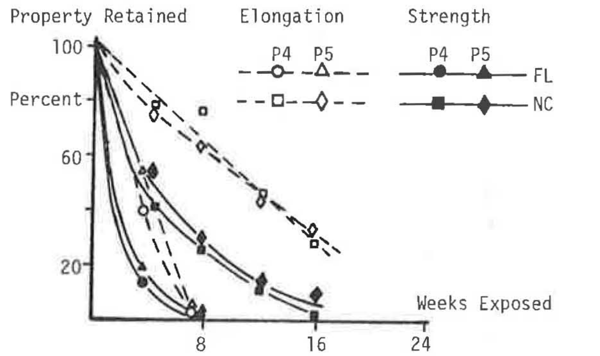

Fig. 4 Grab Strength and Elongation Retained vs. Exposure Time. Needled/bonded polypropylene fabrics.

Fig. 5 shows the results of the bonded polypropylene fabrics. Fabric M4 gave very good reproducibility of fabric strength loss at the Florida and Arizona sites. The material has very poor resistance to sunlight, being essentially useless after 8 weeks, having lost 50% of strength and elongation in only 4 weeks.

Fabrics T4 and T6 were tested in Florida, Arizona and T6 also in N.C. T4 showed minor differences between the Florida and Arizona locations. The initial effect of sunlight was to cause a small increase in strength and little loss in elongation possibly due to cross linking. Subsequent degradation was rapid and the fabric can be considered useless after 14 to 18 weeks.

Fabric T6 showed an approximately linear decrease in grab strength up to about 14 to 18 weeks. Additional exposure caused accelerated deterioration - although this also corresponded with the summer months. As previously noted the Florida location was more severe than the North Carolina site. The fabric was too brittle to handle after 16 weeks in Florida or 30 weeks in North Carolina.

3.6 Woven Geotextiles: Monofil Fabrics P8, L8 and P5

The woven monofil geotextiles are heavy duty fabrics composed of high denier filaments of thickness comparable to the width. They are very stiff, usually black and of very uniform construction. They have been in use in geotechnical applications such as shore protection and drainage for some time. The exposed fabrics, all heavily loaded with carbon black, showed excellent strength retention (Fig. 6A) and only small loss in breaking elongation (Fig. 6B). The fabrics P8 and L8 showed some 20% decrease in grab strength and elongation, while P5 actually increased in strength and elongation but not significantly.

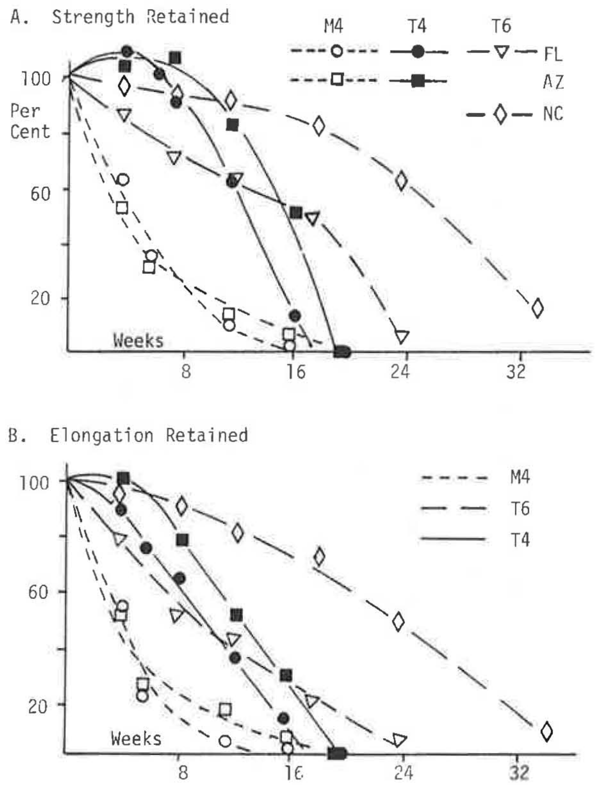

Fig. 5 Grab Strength and Elongation Retained vs. Exposure Time. Bonded Polypropylene Fabrics.

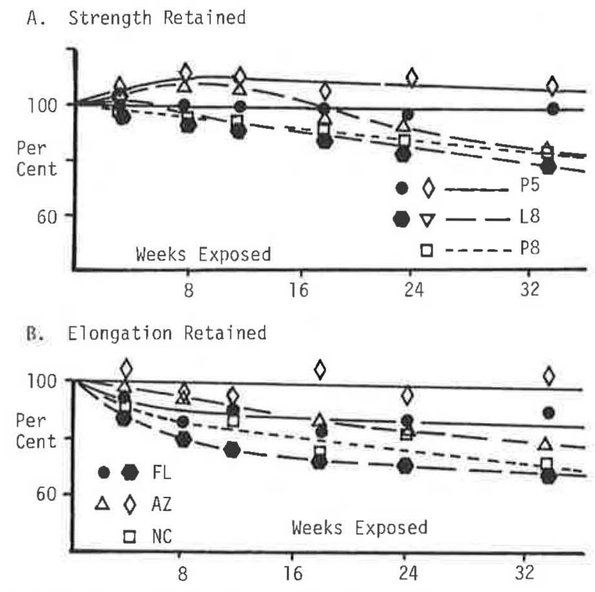

Fig. 6 Grab Strength and Elongation Retained vs. Exposure Time. Woven Popylene Monofils.

3.7 Woven Geotextiles: Slit Film Fabrics M5 and A3

These fabrics are woven from comparatively thin, wide ribbons produced by slitting polypropylene film and folded randomly during weaving. They are typically more flexible and more irregular in appearance due to the uneven folding of the ribbons. They have come into use in the geotextile field more recently and developed from fabrics used for sandbags, bale wraps or carpet backing. Exposure tests on fabric M5 showed good performance in Arizona but only fair in Florida where it started to deteriorate rapidly after 18 weeks exposure (Fig. 7). The other fabric A3 resembled M5 in appearance and construction but performed poorly even in North Carolina. It was too brittle to handle after about 16 weeks.

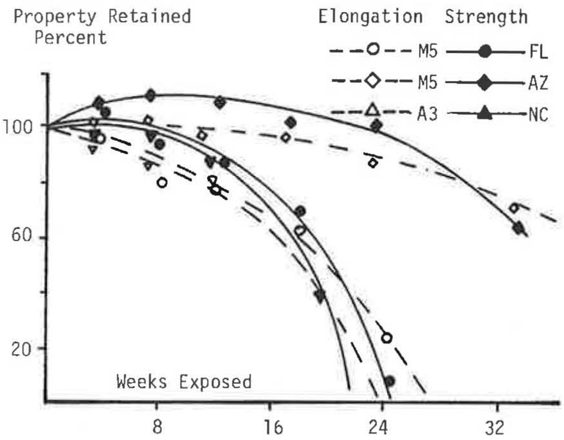

Fig. 7 Grab Strength and Elongation Retained vs. Exposure Time. Woven Slit Film Fabrics.

4 SUMMARY

4.1 Comparative Fabric Performances

Comparisons of fabric performance can be carried out in several ways, namely to compare relative resistance to degradation of different fabrics based on their unexposed properties or the absolute values of strength and breaking elongation. Comparison on a cost basis is also possible but since prices depend on so many factors, such comparisons will be excluded here.

4.1.1 Percent Property Retained

By plotting the relative values, it is easier to show visually the similarities between fabrics, to give better insight into the degradation processes, and to eliminate differences due to fabric weight or directionality of properties. It is also easier to use interpolation and proration of data generated in different locations and test series. Fig. 8 represents actual or expected performance in North Carolina. Those fabrics not tested there had constant multipliers applied to test reresults obtained elsewhere, bearing in mind the time of year, location and the performance of the control B1 polyester fabric. Based on 50 to 70% strength retention, the tested fabrics fall into three main groups: the poor performers, the intermediate performers, and the long-term performers.

1. Poor performers are here exemplified by the polypropylene geotextiles M4, P4 and P5. After 8 weeks of North Carolina exposure, their strength was less than one half the original values. Strength loss started at quite

small exposure times and it is presumed that no inhibitors were present in the polymer.

2. Intermediate performers here include most of the fabrics tested. They retain 80% of their original strength for 8 to 20 weeks, North Carolina exposure, and at least 70% of the original elongation to break. The fabrics included in this group are the polypropylene fabrics of woven slit film, heat bonded, or needled construction. All were too brittle to handle after 24 weeks exposure.

3. Long-term performers are exemplified by the woven monofil polypropylene fabrics L8, P5, P8, and the needled polyester geotextiles. The loss in strength of these was gradual and no sudden accelerated decay was observed up to 52 weeks exposure. They retained at least 50% of the strength and 60% elongation for one year.

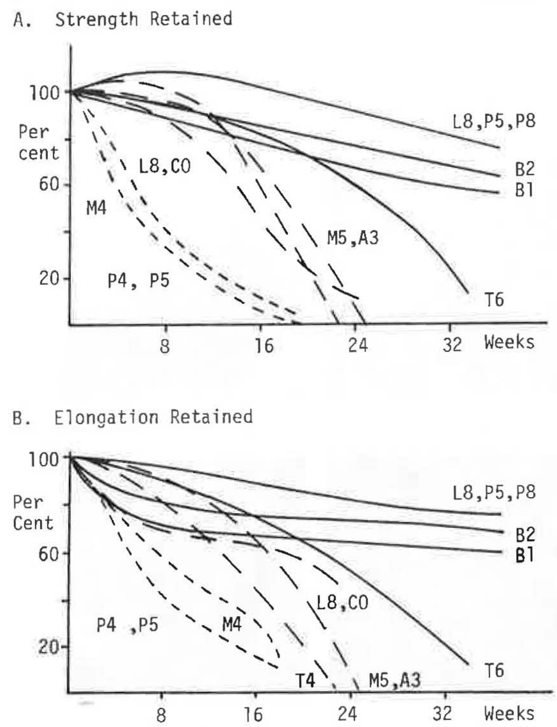

Fig. 8 Grab Strength and Elongation Retained vs. Exposure Times. NC performance.

4.1.2 Absolute Fabric Performance

The actual values of fabric strength and elongation to break are, of course, fundamental in the selection of a suitable geotextile for an engineering project and hence they are critical parameters for performance criteria and specifications.

For the average absolute values*, 3 broad regions can again be distinguished:

1. The poor performers include the same fabrics as before and are normally not suitable for exposure to direct sunlight except for the short periods during installation.

*Footnote: When comparing absolute values, it must be borne in mind that many of the fabrics tested are very anisotropic (see Table I) and this factor will alter rankings for specific applications.

2. The strengths retained for intermediate performers are shown in Fig. 9. They include a heat bonded fabric T4, a woven slit film fabric M5, and the needle bonded fabrics (CO and F2), all made from polypropylene fibers. Their original grab strengths of 0.6 to 1.2 kN are reduced to below 0.5 kN in 12 to 18 weeks exposure. At the same time, the breaking elongations, shown in Fig. 10, originally ranging from 26 to 130% are all reduced to about 20% after 14 to 18 weeks exposure: Exposure to sunlight during installation procedures lasting up to 12 weeks may result in considerable embrittlement and significant strength loss. However, applications such as: silt fences, silt curtains in rivers, temporary fabric walls could be considered.

3. Long-term performers are also shown in Figs. 9 & 10 and they include heatbonded polypropylene fabric T6, needled polyester fabrics B1, B2, and B6, and woven polypropylene monofil fabrics (P8, L8, P5 and P3). The geotextile T6 degraded most rapidly, both in strength and elongation loss. On the basis of grab strength alone, the woven monofil fabrics continued to outperform all other fabrics. However, because of their very low initial breaking elongation, a 30% loss of breaking elongation, means that their total grab elongation at break is 20% or less. For many applications, this would be considered unacceptably low. The needled polyester fabrics with their initial breaking elongation of near 60% are the only fabrics which retain more than 40% breaking elongations after long-term exposure to sunlight.

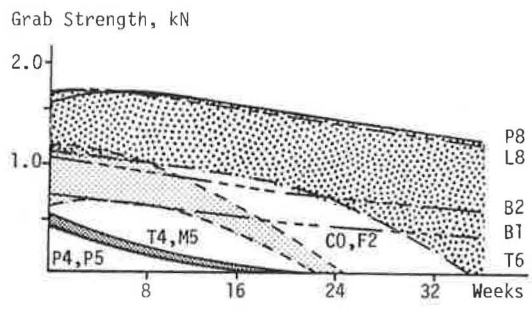

Fig. 9 Average Grab Strength vs. Exposure Time. Poor, Intermediate and Long Term Performers.

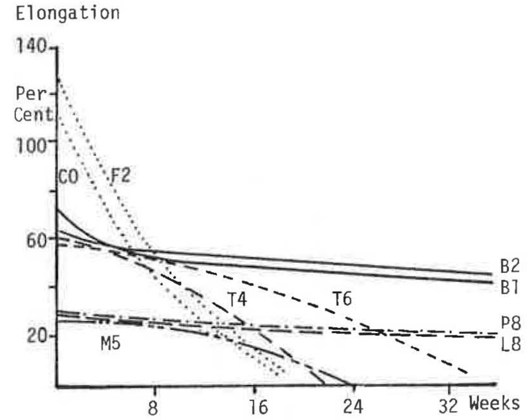

Fig. 10 Average Grab Elongation vs. Exposure Time. Intermediate and Long Term Performers.

Long-term performers can be expected to be suitable for more critical silt fences, silt curtains, and prolonged exposure in shade areas or high latitude climates.

For permanent installation, no geotextile should be left exposed to sunlight.

4.2 Predictions for Actual Fabric Performance

While the comparison of different fabrics is relatively straightforward, predictions of the expected behavior of fabrics in field situations is far from simple. It is clearly impracticable to do long exposure tests in every situation where geotextiles may be used, hence estimates, however approximate, are the only other course.

It is possible to estimate whether the expected degradation will be more or less severe than the data collected in the field tests by combining the information contained in curves such as Figs. 8 or 9 for the fabric in question and local information on:

1. Expected sun hours
   - Local weather data for the appropriate season
   - Reduction due to shading, snow cover, mud
2. Energy of sunlight
   - Fabric configuration and angle of exposure
   - Angle of incidence of sunlight
   - Increase due to altitude or proximity of reflecting areas
3. Additional weather information
   - Frequency of strong winds, sand or rain storms, snow, ice
   - Average temperatures and relative humidity
4. Possibility of atmospheric pollution

While such considerations are useful in general their limitations are exemplified by our own comparisons of data from the Arizona and Florida sites: Although of similar latitude and number of sun hours, the Florida site is normally more severe, but one series in Arizona showed similar degradation. The reason is not clear and may have been due to exceptional weather conditions (sandstorm, hail) or atmospheric pollution.

4.3 Pointers for Specifications

While individual engineers can make allowances for some of the factor outlined above, such an approach is unacceptable for performance criteria or specifications. Hence, the problem is to strike a balance between performance required in severe situations and the additional costs incurred for unneeded performance in the average or minimal situation.

Typically, strength loss with exposure times shows a low rate at low exposure times and a much more rapid rate after a given time interval. If the specification is set too low, a higher than expected exposure would produce severe strength loss in the fabric; if set too high, it may eliminate many fabrics that would perform well in the vast majority of situations. A uniform rate of degradation as shown by the polyester fabrics greatly reduces the risk of a serious failure due to light degradation, if the design otherwise follows sound practice.

At this stage, few specifications address the subject of sunlight exposure. One Department of Transportation requires a grab strength retention of 90% after 30 days' exposure and is obviously aimed at eliminating only the very poor performers, which might represent a risk if construction is slow or interrupted.

Specifications for projects requiring longer exposure will be much more difficult to set. The choice of grab testing was based on convenience and is only one type of measurement and may not be appropriate for specific applications.

5 CONCLUSIONS

Although laboratory testing of U.V. and light resistance of geotextiles can be precisely specified and controlled, it is at least equally important to measure actual outdoor performance. The data presented here give a clear indication of the wide variations observed - not only between fabrics but between test locations and repeat exposure tests. Therefore great caution must be used when predicting geotextile performance from limited outdoor or indoor tests. Additional parallel exposure testing and laboratory U.V. tests are needed to arrive at useful standard test methods and specifications for the diverse applications of geotextiles.

Plate I SEM Views of Fabrics B1, F2 and CO Exposed for 12 Weeks (Florida).