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Durability standards for geosynthetics: The tests for weathering and biological resistance

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ABSTRACT: This paper describes the application of three new European prestandard methods on the resistance of geosynthetics to weathering and to microbiological attack and on the methods used for the detection of degradation. From the weathering results it is deduced that all three methods currently in general use for artificial weathering are satisfactory and comparable with natural weathering. Radiation doses of 10 and 50 MJ/m² are proposed as the basis for determining the maximum time for which materials may be exposed on site. The soil burial test can be used to screen out natural fibre based geotextiles but to test long-term biological resistance it is necessary to perform the test for longer. Mechanical testing supported if necessary by visual observation is sufficient for the evaluation of degradation. Intercomparison tests of both methods are in progress and an analysis of numerical accuracies will be made only when these are complete.

1. EUROPEAN STANDARDS

Test methods for durability can be screening tests to exclude products without a certain minimum level of durability, or they can attempt to predict the degradation over the whole service life of the geosynthetic. This paper will describe two examples of European standard test methods: those for resistance to weathering and for biological resistance.

All geosynthetics are likely to be exposed to sunlight and weather during construction on site, and must therefore have a limited resistance to weathering. In service most materials will be covered by soil, while those which remain exposed during their entire life will need a far greater degree of resistance. After some discussion within CEN TC189 Working Group 5, Geotextiles, it was agreed that the weathering test would be aimed at ensuring sufficient resistance during construction only, similar to a German procedure (FGSV 1994) for relating the performance during testing to the time the material may be exposed before it is covered. In the FGSV procedure, the material is exposed in a Global-UV apparatus for 360 h:

retained strength	exposure time on site
>80%	two months
60-80%	two weeks
<60%	one week

Special methods would then be necessary for testing geotextiles for continuous exposure.

All polymers are susceptible to degradation due to weathering, principally due to the effect of ultraviolet radiation, and most commercial materials contain stabilisers to reduce this effect. Testing can be by exposure to natural or artificial radiation. Artificial radiation has the advantage that not only can testing be accelerated by increasing mean irradiance level and temperature and eliminating the cycles of night and day, winter and summer, but equally important is that the exposure parameters can be controlled. The maximum global irradiance is 1090 W/m² of which 74 W/m² lies in the ultraviolet range with wavelengths below 400 nm and 412 W/m² in the infrared range above 800 nm (data from Table 4 of CIE Publication No 85, 1989). In Europe the corresponding maximum values are about 80%, or 60 W/m² in the ultraviolet range. The total radiant exposure per year has a maximum of 7.5 GJ/m² in Arizona and reaches values of 3 to 6 GJ/m² in Central and Southern Europe.

The methods for artificial weathering of polymers have been developed and established over many years and are set down in international standard ISO 4892. There are three types of equipment in current use in Europe: one uses a xenon arc which approximates to the spectrum of natural sunlight; two use fluorescent tubes which approximate to the actinic portion of the spectrum of natural sunlight in the ultraviolet region only, but has the advantages that the equipment is cheaper. All methods include control of specimen temperature, measurement of radiant exposure (dose), and the inclusion of a water spray cycle, since humidity is known to have a significant effect.

The European prestandard for weathering was written to define the methods of ISO 4892 more precisely for geotextiles. Very few geotextiles had actually been tested under controlled conditions. A test programme was therefore set up with the objectives of:

- selecting one of the three different methods for artificial weathering
- comparing artificial with natural weathering
- providing a database of measurements on a range of geotextiles
- testing the validity of the prestandard with respect to geotextiles

and if possible to recommend suitable times during which the material may be exposed.

Biological degradation differs in that so far there has been no evidence of any such degradation in artificial geotextiles. Only those based on natural fibres degrade, as is the intention. Biological degradation cannot be accelerated beyond the selection of optimum soil conditions and temperature; try to accelerate it further and the microorganisms will be destroyed. Methods for soil burial are established and the European Prestandard (prENV12225) was based on work by Raschle (1983); a corresponding method is now being added to ISO 846/DIS (1995). As with weathering, experience was lacking, and a test programme was initiated with the objectives of :

- testing the validity of the prestandard with respect to geotextiles
- providing a database of measurements on geotextiles
- recommending a test duration

Testing was performed under the European Standards, Testing and Measurement Programme (see acknowledgements) of which J H Greenwood is the general coordinator. The weathering tests were performed under the leadership of P Trubiroha at BAM and the soil burial tests under the leadership of P Franke at LGA.

2. WEATHERING TESTS

Natural weathering tests and artificial weathering tests using the Global-UV equipment were performed by BAM, Berlin, artificial weathering tests using the Atlas Weatherometer and the QUV equipment by EMPA, St Gallen, Switzerland.

The materials chosen for the weathering tests (Table 1) were representative of a wide range of geotextiles including both woven and nonwoven materials. Unstabilised materials were included to find out if the test could differentiate between them and the stabilised materials.

Table 1. Geotextiles used in weathering tests

TGC	woven PP, 190 g/m², black, HALS and graphite stabilised tape yarns with $CaCO_3$ fillers
TGA	woven PET/PA, 450 g/m², white, multifilament yarns. Tested in PA weft direction.
THC	woven PET, 260 g/m², white, multifilament yarns
TFB	nonwoven needlepunched PP, 200 g/m², grey, staple fibres, no UV stabilisers
TGB	nonwoven thermally bonded PA/PET, 130 g/m², grey, no UV stabilisers, filaments, CC type
TGL	nonwoven needlepunched PET, 200 g/m², grey, no UV stabilisers, filaments
TFN	nonwoven needlepunched HDPE, 300 g/m², black, assumed UV stabilised, staple fibres
TGJ	nonwoven thermally bonded PE/PP, 180 g/m², white, UV stabilised filaments, CC type

Test specimens were 400 x 50 mm. To reduce scatter specimens of woven material were cut 70 mm wide and before tensile testing warp yarns were removed from the edges to leave a predetermined number of yarns over a width of approximately 50 mm. The specimens were cut from strips to contain the same yarns. They were then allocated to the various exposure times to ensure a precise comparison. Specimens of nonwovens were specially selected by weighing as described by Schröder et al (1996).

For exposure test specimens were placed between two stainless steel grids with mesh widths of 16-20 mm and wire diameters of 1.2-2.0 mm. In the QUV apparatus the specimens were backed by a steel plate to prevent the spray leaking from the apparatus. Only one short side of a specimen was fixed in order to allow the specimen to shrink. Precautions were taken to prevent one material becoming contaminated by the spray water running off another material.

All artificial weathering tests were performed to three radiant exposures: 10, 50 and 100 MJ/m², referring to wavelengths below 400 nm. The parameters were as follows:

Atlas Weatherometer Ci65a (xenon lamp), :
  Continuous radiation exposure
  102 min dry at black standard temperature (BST) of 65 ± 3°C and 45% relative humidity
  18 min water spray
  Exposure time to reach 100 MJ/m² : 500 h (55 W/m²),

QUV (Type I (340) fluorescent lamp):
  Intermittent radiation exposure
  5 h dry at BST of 60 ± 3°C, with radiation exposure

1 h water spray, without radiation exposure, at approximately 25°C
Exposure time to reach 100 MJ/m²: 864 h (32 W/m²)

Global- UV (fluorescent UV lamp combination):
Continuous radiation exposure
5 h dry at BST of 50 ± 1°C and 10 ± 5% relative humidity
1 h water spray at 20 ± 3°C
Exposure time to reach 100 MJ/m²: 646 h (43 W/m²)

Natural weathering was performed to ISO 877: 1994 Method A on the roof of a 40 m high building in Berlin and at a natural weathering station in Bandol, southern France. The angle of exposure was 45°. The radiant exposures H (λ < 400 nm) in Berlin were:

28 MJ/m²	winter 1994/1995	134 days
44 MJ/m²	spring 1995	59 days
72 MJ/m²	summer 1995	76 days
147 MJ/m²	spring/summer 1995	182 days
176 MJ/m²	autumn 1994 to autumn 1995	317 days

and in Bandol:

154 MJ/m²	spring/summer 1995	147 days

Evaluation was performed generally in accordance with the tensile test methods listed in the standard tests for evaluation following durability testing, prENV 12226. Specimens of the woven materials TGC, THC and TGA were reduced to 44, 56 and 22 yarns respectively, the gauge length was 200 mm, and the crosshead speeds 100 mm/min for woven materials and 200 mm/min for nonwovens. The preloads for TGC, THC and TGA were 20 N, 10 N and 5 N respectively and for all other materials 1 N except when the tensile strength was < 10 N when the preload was 0.2 N. Visual inspection as required by prENV 12226 provided no additional information on the degradation and is therefore not reported. Measurements of change in mass and dimensions were performed in some cases but provided no useful additional information. The results of the tensile tests are presented as percentage retained strengths in Table 2. For current purposes retained strength is used without subtracting one standard deviation as set out in FGSV (1994).

The ranking of materials based on these results is shown in Table 3.

All six artificial weathering tests and the four natural weathering tests with doses of 50 MJ/m² or more show a comparable ranking of change of tensile strength, with few exceptions:

Table 2. Retained strengths following artificial and natural weathering

Code		TFN	TGJ	TGC	TGL	TGA	THC	TGB	TFB
Polymer		HDPE	PE/PP	PP	PET	PA	PET	PA/PET	PP
nonwoven/woven		nw	nw	w	nw	w	w	nw	nw
stabilised/unstabilised		stab	stab	stab	unstab			unstab	unstab
H MJ/m²	Exposure type	Retained strengths in %							
10	Weathero-meter	105	101	99	87	94	61	67	82
	QUV	116	103	98	95	92	64	73	86
	Global-UV	119	104	99	86	93	72	86	88
50	Weathero-meter	112	98	87	53	68	36	45	5
	QUV	120	98	97	69	65	38	33	8
	Global-UV	116	94	97	56	71	38	43	27
100	Weathero-meter	103	104	89	36	75	31	30	2
	QUV	105	86	92	45	56	19	21	0
	Global-UV	116	71	95	50	34	29	19	3
28	Natural weathering, Berlin	119	95	98	87	81	84	85	94
44		117	93	87	84	84	59	71	75
72		108	83	74	69	66	42	40	33
147		102	69	62	55	51	28	20	8
176		109	54	60	50	44	28	18	12
154	Natural weathering, Bandol	95	66	56	52	73	26	45	2

Table 3. Ranking of materials based on retained strengths following artificial and natural weathering

Code		TFN	TGJ	TGC	TGL	TGA	THC	TGB	TFB
Polymer		HDPE	PE/PP	PP	PET	PA	PET	PA/PET	PP
nonwoven/woven		nw	nw	w	nw	w	w	nw	nw
stabilised/unstabilised		stab	stab	stab	unstab			unstab	unstab
H MJ/m²	Exposure type	Rank based on retained strength (1 = high)							
10	Weathero-meter	1	2	3	5	4	8	7	6
	QUV	1	2	3	4	5	8	7	6
	Global-UV	1	2	3	7	4	8	6	5
50	Weathero-meter	1	2	3	5	4	7	6	8
	QUV	1	2	3	4	5	6	7	8
	Global-UV	1	3	2	5	4	7	6	8
100	Weathero-meter	2	1	3	5	4	6	7	8
	QUV	1	3	2	5	4	7	6	8
	Global-UV	1	3	2	4	5	6	7	8
28	Natural weathering Berlin	1	3	2	5	8	7	6	4
44		1	2	3	4	5	8	7	6
72		1	2	3	4	5	6	7	8
147		1	2	3	4	5	6	7	8
176		1	3	2	4	5	6	7	8
154	Natural weathering Bandol	1	3	4	5	2	7	6	8

1. TFN
2 and 3. TGC and TGJ
4 and 5. TGL and TGA
6 and 7. TGB and THC
8. TFB

Figures 1 and 2 are two of the eight diagrams that compare the natural with the artificial weathering for individual materials. They demonstrate the variation between the results of three artificial weathering methods, which differs for each material and is generally less than the variation in the results of the two natural weathering stations. Considering that the 28 and 42 MJ/m² exposure stages started in the cold season, they show that the results of the artificial weathering generally track the results of natural weathering, and it was noted that they are generally non-conservative for black materials (TGC and TFN) and conservative for the remaining white and grey materials. At 10 MJ/m² the variation is greater because the relative reductions in strength are small. An analysis of numerical accuracies will be made only when the intercomparison trials are complete.

A similar analysis was made for retained elongation at break which showed broader variations than for retained strength. TGB showed the greatest reduction in strength, followed by TFB and THC.

It was concluded that all three artificial weathering methods may be considered valid for geotextiles.

The results, which will be published in full, provide a useful database for the weathering performance of geotextiles. As a result of the work, doses of 10 and 50 MJ/m² were proposed for a system of ranking materials for exposure on site similar to but not identical with FGSV (1994).

3. SOIL BURIAL TESTS

In the soil burial test specimens of geotextile are buried in a microbially active soil. There is no need to inoculate the soil with specific bacteria or fungi; all relevant species are assumed to be present already and those which benefit from the nutrients in the geotextile, if any, will multiply and accelerate the attack. The soil must be allowed to stabilise and condition before the specimens are placed in it. A sample of untreated cotton is used to test soil: if the tensile strength of the cotton strips is less than 25% of the original tensile strength after a seven day exposure the soil is regarded as biologically active. A good quality horticultural compost should be sufficient.

Previous tests have shown that moisture content and temperature must be controlled (Raschle 1993). Moisture content is to be maintained at 60% of the moisture holding capacity, defined by a saturation test, while temperature was to be maintained at 28°C.

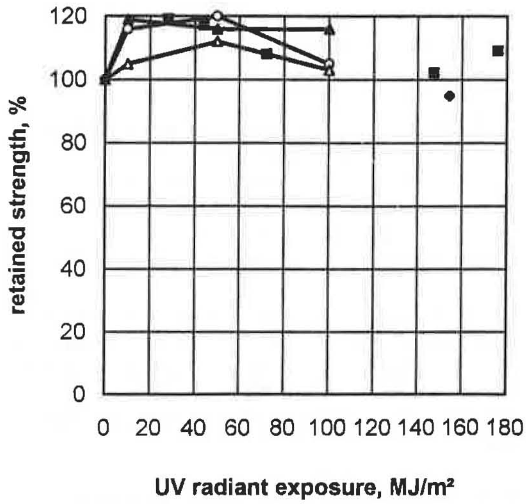


Fig 1
Results of natural and artificial weathering for material TFN

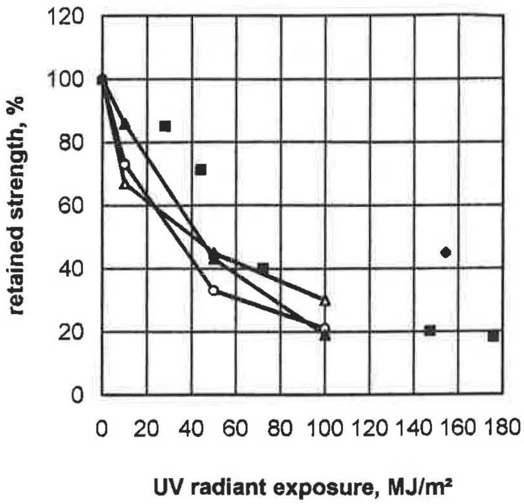
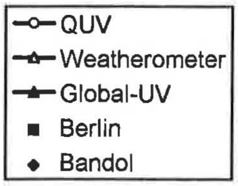


Fig 2
Results of natural and artificial weathering for material TGB



Symbols used in Figs 1 and 2

For these tests the following geotextiles were chosen:

Table 4. Materials used for soil burial tests

TFC	nonwoven needlepunched HDPE
TGJ	nonwoven thermally bonded PP/PE, 180 g/m²
TGQ	nonwoven needlepunched PET
TFB	nonwoven needlepunched PP, 200 g/m²
TFP	nonwoven needlepunched PP
TGH	nonwoven thermally bonded PP
THA	biodegradable sheet

The biodegradable sheet was chosen to provide a material deliberately intended to degrade. TFB and TGJ were common to both the weathering and soil burial tests. Specimens were prepared in a manner similar to the weathering tests.

Testing was divided between two laboratories, LGA in Germany and Euro Laboratories in England, with the biodegradable sheet tested by both parties. LGA used "Einheitserde ED 73" with 20 specimens in each of two 200 litre fibre cement boxes. The biological activity of the soil was determined by using the cotton control in samples of soil in separate glass jars, and checked by measuring the total viable count (number of microorganisms per gram). The containers were covered with black polyethylene foil with ventilation openings since this provides a cheaper method of maintaining the moisture content than does containment of the boxes in a controlled humidity environment. The temperature was maintained at 25 ± 3°C, wider than the 28 ± 1°C set out in the original standard, since such a tight tolerance is not necessary to achieve maximum biological activity. Specimens were 300 x 50 mm in size and were selected in the same manner as that used in the weathering tests.

Euro Laboratories used "John Innes No 2" soil in 50 litre plastic containers with lids allowing ventilation and maintained at 28 ± 2°C.

Regular measurements by LGA showed that during the test (ie excluding the soil conditioning period) the moisture content of the soil averaged 60% of its maximum holding capacity, with a range from 55 to 66%. The total viable counts measured by both parties, 4×10^5 to 5×10^6, were regarded as normal. The cotton strip test, however, gave variable results. Geotextile testing was started by LGA when the cotton strip test was satisfied but in subsequent tests the cotton strip test was not always satisfied, indicating that the biological activity of the soil was not uniform.

Testing continued for 16 weeks. As with the weathering tests, evaluation was restricted to visual observation and measurement of tensile properties.

The results are shown in Table 5:

Table 5. Results of the soil burial test. Statistically significant reductions are shown **bold**

Code	Material	% retained strength	% retained elongation at break
TFC	needlepunched HDPE	127	**87**
TGJ	thermally bonded PP/PE	102	93
TGQ	needlepunched PET	110	**80**
TFB	needlepunched PP	107	102
TFP	needlepunched PP	106	101
TGH	thermally bonded PP	99	132
THA (LGA)	biodegradable sheet	**88**	**79**
THA (Euro Labs)	biodegradable sheet	101	106

The only statistically significant reduction in strength was observed on the nominally biodegradable sheet, and that by LGA only. In three cases there was a significant reduction in elongation at break and in several cases a significant increase in strength, which is assumed to be due to the effect of humidity. Only the cotton cloth degraded .

Both laboratories had some difficulty with the draft method and some detailed modifications have been made to the prestandard.

The results show that it is possible by this method to identify, and thus screen out, natural fibre based textiles such as cotton from artificial polymers. It is not, and cannot be, an accelerated test for biological resistance, since it operates in real time. 16 weeks is too short for any other purpose. The only form of acceleration is the deliberate selection of a biologically active soil and of optimum test parameters, but the degree of acceleration which this represents compared with a particular soil in practice would have to be tested experimentally. The only means of assessing long-term resistance is to perform long-term tests. This method is suitable and 17 month tests are in progress.

Intercomparison tests using similar materials, but with the addition of a further vegetable fibre geosynthetic, are in progress and will be completed by the end of 1996.

4. CONCLUSIONS

- All three artificial weathering methods may be considered valid for geotextiles, the variation between them being no greater than the variation between natural weathering stations.
- Ultraviolet radiant exposures of 10 and 50 MJ/m² are proposed as the basis for determining the maximum time for which materials may be exposed on site.

- Artificial weathering was conservative for the white and grey materials tested and non-conservative for the black materials.
- The 16 week soil burial test can be used to identify, and thus screen out, natural fibre based textiles from artificial polymers. To test long-term biological resistance it is necessary to perform the test for longer.
- Mechanical testing supported if necessary by visual observation is sufficient for the evaluation of degradation.
- Intercomparison tests of both methods are in progress and an analysis of numerical accuracies will be made only when these are complete.

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