Long-Term Outdoor Exposure Test of Geosynthetics

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ABSTRACT

The variations of natural environment and weather conditions impact the service life and long-term performance of installed geosynthetics. To understand the degradation behaviour of these polymer materials in outdoor environment, this study conducted long-term outdoor exposure test for eight different geosynthetics in the middle of Taiwan for 12 months of exposure in sunlight. Test results indicated that the geogrid showed virtually no reduction in strength throughout the observation period. However, long-term sunlight truly damaged the tensile strength properties of all geotextiles tested despite the types of the materials. The values of retained strength and elongation for all geotextiles generally decreased with the elapsed exposure time. Nonwovens geotextiles presented worse performance than wovens. Test results presented herein are valuable to the applications of geosynthetics in Taiwan. However, correlations with other studies should be developed to promote more potential applications of such empirical local information.

1. INTRODUCTION

Geosynthetics have been used widely for numerous geotechnical engineering applications worldwide. However, their outdoor service life is remaining questionable. Many factors affect the material's lifetime such as sunlight, temperature, oxidation, hydrolysis, chemical, and biological etc. Decrease of safety performance due to various surrounding environments occurs when geosynthetics are applied in the construction field. Therefore, it is important to consider how serious the effects of outdoor environments may have to cause the degradations of property for the materials being used.

Among the outdoor harmful impacts, sunlight is an important cause of degradation for geosynthetics, which is made from polymers and very sensitive to ultraviolet from sunlight. Photo-degradation and thermal-degradation due to sunlight is well known to occur in polymer materials. The degradation is caused and initiated by photons of light or energy of thermal breaking the polymer's chemical bonds. Several studies show that different types of polymer materials and chemical bounds have different sensitivity to the energy of a photon (wavelength).

Many researches have been conducted to explore the long-term performance of photo-degradation for polymer materials. There are two tests that have been commonly used for this purpose. Outdoor exposure test is more trustworthy but requires much time (Lodi et al. 2008, Dierickx and Van Den Berghe 2004, Suits and Hsuan 2003, Grubb et al. 2000, Grubb et al. 1999). The accelerated exposure test is more efficient but difficult to interpret the complex correlation between the test result and actual weather condition (Rios-Soberanis et al. 2013, Bratton 2013, Liew and Brown 2012, Yang and Ding 2006, Suits and Hsuan 2003).

The outdoor exposure test is exposing specimens to the natural sunlight and weather conditions. ASTM D5970 has provided a standard procedure for conducting the outdoor exposure test for geotextiles. It also gives recommendations for the evaluation of photo-degradation at a particular site. However, because in-situ natural weather conditions vary, it is difficult to compare the test results from different sites. The intensity of total global solar radiation and solar UV radiation especially shall be measured during the testing for comparisons of different types of exposure testing results (Suits and Hsuan 2003).

For the real performance of photo-degradation, global solar radiation (UV radiation), temperature, and relative humidity are very important influence factors in UV degradation of polymer materials. Although the accelerated exposure test provide rapid test results for the comparison of relative durability for different materials, it is not useful for the same material on different sites due to the possible differences of UV radiation, temperature, relative humidity and other weather factors (Lodi et al. 2008).

Geosynthetics in Taiwan have seldom been tested for their degradation under local natural environment. It is important to evaluate the long-term performance of geosynthetics installed in such a warm, humid, and rainy subtropical region. This study conducted outdoor exposure tests to observe the effect of environmental conditions for eight different geosynthetics in Taiwan for 12 months. The retained tensile strength properties of tested materials for each condition were then evaluated as percent strength change after the exposure test. The reported results might contribute valuable answers to the above questionable conditions.

2. EXPERIMENTAL PROGRAM

2.1 Materials

The experiments were performed on eight different geosynthetics. One geogrid, three different woven geotextiles, and four different nonwoven geotextiles were evaluated in outdoor exposure test up to 12 months. As shown in Figure 1, each type of woven and nonwoven geotextiles was prepared in five duplicates with each piece cut to a dimension of 18cm wide and 30cm long. Geogrid was prepared in a dimension of 120cm wide and 240cm long. Table 1 presents the characteristics of the tested materials in this study. All materials are commercial products from three manufacturers and have been widely used for different geotechnical applications in Taiwan. As can be seen in Table 1, test materials were specifically selected for a wide range of characteristics to observe the effect of long-term exposure on different materials.

Figure 1. Set up of outdoor exposure test.

Table 1. The characteristics of tested materials.

Characteristics	Type of Material	Manufacture	Mass (g/m2)	Thickness (mm)	Tensile strength (kN/m)	Elongation (%)
GG1	PET coating PVC	geogrid	--	--	77.5	11.6
GT1	PP	woven	286.9	0.82	59.6	22.4
GT2	PP	woven	485.9	1.21	75.2	18.1
GT3	PP	woven	852.7	2.17	231.2	26.0
NW1	PP staple fibers	Needle punched + Heat bonded	483.0	2.59	21.2	61.0
NW2	PP staple fibers	Needle punched + Heat bonded	180.0	1.16	14.2	39.4
NW3	PET Continuous filament	Needle punched	230.2	2.12	15.7	58.0
NW4	PET Continuous filament	Needle punched	338.7	2.92	10.8	56.3

2.2 Test location

The test site is located in Wuchi, Taichung City, Taiwan (24° 14' 25.51" N, 120° 30' 29.47" E, 7m elevation). It is in the central area of the island where there is sufficient sunlight throughout the year. All samples were set up on the rooftop to expose themselves to the air totally (Figure 1). The experiment was commenced on 9 November 2010 for one year.

2.3 Experimental program

The outdoor exposure test was performed according to ASTM D5970. All test samples were attached to wooden frames oriented 45° from the horizontal. The surface of all wooden frames were prepared free from any paint and any shade. They were placed in a manner such that no heat or sunlight was reflected on their surface from surrounding buildings. All samples were facing the equator at designated location and representative samples were taken for exposure times of 1, 2, 4, 8 and 12 months. When the predetermined exposure time was reached, one of the five samples for each type of geosynthetic was removed from the wooden frame and sent to laboratory for further examinations of their tensile strength and mass per unit area.

The tensile strength test for geogrid was performed according to ASTM D6637 method A, and those for woven and nowoven geotextiles were according to ASTM D5035. A percent strength retained and a percent elongation retained in terms of tensile test was calculated after several exposure time (1, 2, 4, 8 and 12 month).

3. RESULTS AND DISCUSSION

3.1 Weather information

The weather information was obtained from the Wuchi weather station (24° 15' 31" N, 120° 30' 54" E, 31.73 m elevation) which is close to the test site. Table 2 presents the weather information during the exposure period. Global solar radiation varied with seasons and higher amounts all concentrated in summer. The total solar radiation in Wuchi was 5,358.9 MJ/m^2.

3.2 Retained strength properties

After the designated exposure time was reached, representative samples for each type of geosynthetics were taken to the laboratory for further examinations. Figures 2 and 3 show the test results for the percent strength retained and the percent elongation retained with the elapsed exposure time.

As can be seen in Figure 2, the geogrid showed virtually no reduction in strength throughout the 12 months of exposure in sunlight. However, the values of retained strength for all geotextiles generally decreased with the elapsed exposure time. The strength of nonwovens presented a greater reduction than those of wovens. NW1 and NW2, PP staple fibers geotextiles, appeared to have the worst results. The retained strength dropped to 10 to 20% of their initial condition after an exposure time of 12 months. NW3 and NW4, PET continuous filament geotextiles, have shown somewhat better results with a strength reduction of 40 to 70%. The retained strength of PP woven geotextiles exhibited much stronger performance than those of nonwovens. The greatest decrease was about 30% of its initial strength for GT3 whereas GT1 and GT2 only have shown little reduction in strength. Compared with GT1 and GT2, GT3 has the highest initial strength. However, test results indicated that the geotextile with a higher strength in an exposed environment does not favorably warrant it has a better performance. In average, the rate of strength reduction was about 6.67% per month for nonwovens and 1.67% per month for those of wovens. When exposed in outdoor environment, the nonwoven geotextiles presented about 4 times faster in strength reduction than woven geotextiles.

Figure 3 shows the relationships of retained elongation with the elapsed exposure time. Generally, the tendencies were similar to those shown in Figure 2. However, nonwoven geotextiles immediately dropped their retained elongation within the first two months whereas woven geotextiles did not initiate their reductions until 4 months of exposure. Again, nonwovens showed the worst decrease with an averaged retained elongation only about 50% of their original values. For wovens, GT3 presented the greatest reduction among all samples tested.

Table 2. The weather information during the exposure period.

Exposure time (month)	Average Temp. (°C)	Mean RH (%)	Amount of rainfall (mm)	Global solar radiation (MJ/m^2)
1 (2010.12)	20.2	74.8	12.7	280.7
2 (2011.01)	15.7	60.0	27.7	266.1
3 (2011.02)	14.5	82.3	39.3	249.2
4 (2011.03)	14.7	75.5	27.2	355.0
5 (2011.04)	17.6	75.1	8.5	398.2
6 (2011.05)	23.3	78.6	69.1	449.2
7 (2011.06)	25.9	77.0	51.1	557.3
8 (2011.07)	28.9	76.9	139.9	499.4
9 (2011.08)	28.9	74.8	42.2	482.7
10 (2011.09)	28.8	75.6	11.6	423.9
11 (2011.10)	26.5	77.9	83.7	411.3
12 (2011.11)	24.3	77.9	83.7	411.3

The outdoor exposure test results indicated that long-term sunlight truly damaged the tensile strength properties of all geotextiles tested despite the types of the materials. The differences of reductions were probably because of fiber types, weaving structures, and amount of UV stabilizers etc. The PET geogrid has virtually no degradation for an exposure in outdoor environment for 12 months. It can be attributed to the protection of PVC coatings on the surface of geogrid. Based on the studies, suitable protections are mandatory for geotextiles to be used in outdoor environment. Woven materials are also preferable for those applications exposed in sunlight. The test results collected in this study are valuable for the applications of those geosynthetics in the markets.

This research clearly indicates that the outdoor exposure test can closely reflect natural weathering conditions and provide the most accurate local useable information. However, uncontrollable weathering variables limit the possibility of reproducible data among different sites. Longer test durations also frequently lead the engineers to the selection of an accelerated weathering method. Further studies are recommended to develop correlations of test results with other investigations to promote additional potential applications of such empirical local information.

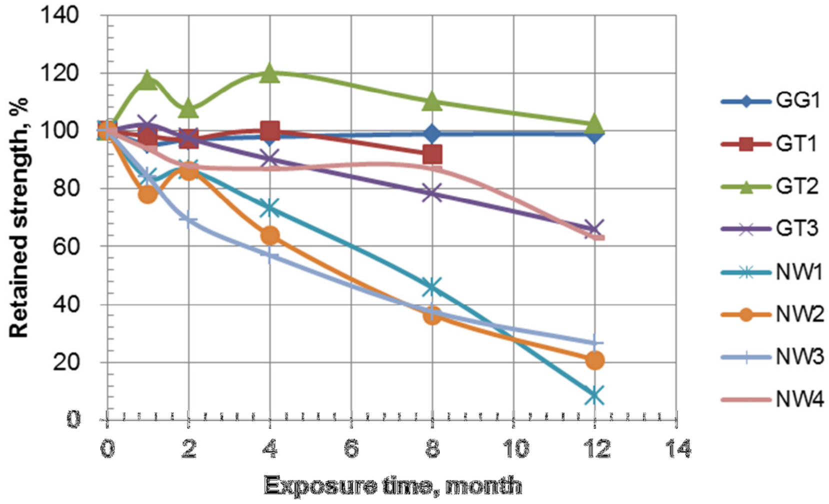

Figure 2. Retained strength after outdoor exposure.

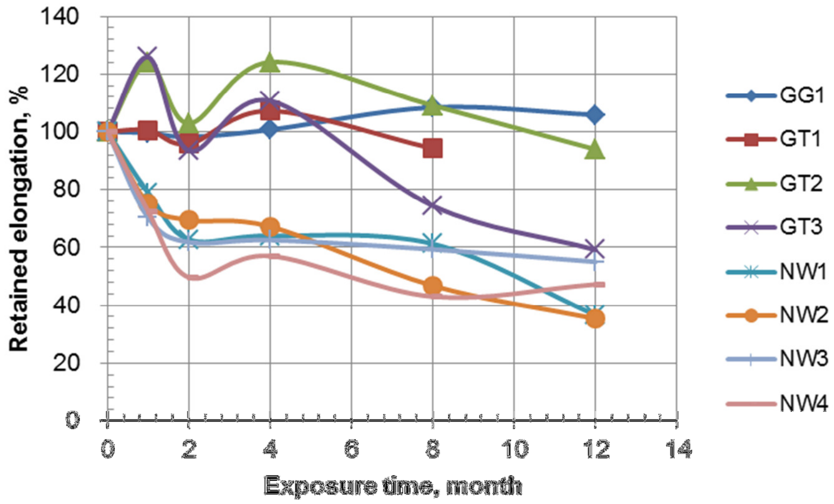

Figure 3. Retained elongation after outdoor exposure

4. CONCLUSIONS AND RECOMMENDATION

The effects of outdoor environment on geosynthetics are important. This research conducted long-term exposure tests on geotextiles and geogrid to evaluate their possible degradations under local conditions. Based on the study, the following recommendations and conclusions can be drawn:

1. The PET geogrid showed little reduction in strength throughout the 12 months of exposure in sunlight. It can be attributed to the protection of PVC coatings on the surface of geogrid.

2. The values of retained strength and retained elongation for all geotextiles generally decreased with the elapsed exposure time. The strength of nonwovens presented a greater reduction than those of wovens. It also appears that the geotextile with a higher strength in an exposed environment does not favorably warrant it has a better performance.

3. For nonwoven geotextiles, the retained strength of PP staple fibers geotextiles dropped to 10 to 20% of their initial condition after an exposure time of 12 months whereas PET continuous filament geotextiles have shown a little stronger results.

4. When exposed to outdoor environment, the nonwoven geotextiles presented about 4 times faster in strength reduction than woven geotextiles. Nonwoven geotextiles also immediately dropped their retained elongation within the first two months whereas woven geotextiles did not initiate their reductions until 4 months of exposure.

5. The outdoor exposure test results indicated that long-term sunlight truly damaged the tensile strength properties of all geotextiles tested despite the types of the materials. The differences of reductions were probably because of fiber types, weaving structures, and amount of UV stabilizers etc.

6. Test results presented herein are valuable to the applications of geosynthetics in Taiwan. However, correlation database with other studies should be developed to increase more potential applications of such empirical local information.

REFERENCES

ASTM D5970. Standard Test Method for Deterioration of Geotextiles from Outdoor Exposure, *American Society for Testing and Materials*, West Conshohocken, Pennsylvania, USA.

ASTM D5035. Standard Test Method for Breaking Force and Elongation of Textile Fabrics (Strip Method), *American Society for Testing and Materials*, West Conshohocken, Pennsylvania, USA.

ASTM D6637. Standard Test Method for Determining Tensile Properties of Geogrids by the Single or Multi-Rib Tensile Method, *American Society for Testing and Materials*, West Conshohocken, Pennsylvania, USA.

Bratton, D.C. (2103). Estimating the lifetime of exposed geomembranes using thin-film samples and accelerated UV aging, *Geosynthetics '13*, IFAI, SLong Beach, California, USA, 170-179.

Dierickx, W. and Van Den Berghe, P. (2004). Natural weathering of textiles used in agricultural application, *Geotextiles and Geomembranes,* 22: 255-272.

Grubb, D.G., Cheng S.C.J. and Diesing III, W.E. (1999). High altitude exposure testing of geotextiles in the Peruvian Andes, *Geosynthetics International,* 6 No.2: 119-144.

Grubb, D.G., Diesing III, W.E., Cheng S.C.J. and Sabanas R.M. (2000). Comparison of geotextile durability to outdoor exposure conditions in the Peruvian Andes and the Southeastern USA, *Geosynthetics International,* 7 No.1: 23-45.

Lodi, P.C., Bueno, B.S., Costa, C.L.M. and Zornberg, J.G. (2008). Degradation of geotextiles after weathering exposure, *The First Pan American Geosynthetics Conference & Exhibition*, Cancun, Mexico, 612-616.

Liew, W. and Brown, D.N. (2012). Predicting long-term performance of exposed geosynthetics in geotechnical applications, *Second Pan American Geosynthetics Conference & Exhibition*, GeoAmericas 2012, Lima, Peru.

Rios-Soberains, C.R., Rodriguez-Laviada, J., Mendez-Alpuche, A.A. and Herrera-Gongora, M.A. (2013). Analysis of mechanical properties degradation on geotextiles after artificial weathering exposure, *Geosynthetics and Modern materials in Coastal protection and Related applications*, Department of Ocean Engineering, IIT Madras, Chennai, India.

Suits, L.D. and Hsuan, Y.G. (2003). Assessing the photo-degradation of Geosynthetics by outdoor exposure and laboratory weatherometer, *Geotextiles and Geomembranes,* 21: 111-122.

Yang, X. and Ding, X. (2006). Prediction of outdoor weathering performance of polypropylene filaments by accelerated weathering tests, *Geotextiles and Geomembranes,* 24: 103-109.