DURABILITY EVALUATION OF GEOMEMBRANE LINERS BY OUTDOOR EXPOSURE TEST FOR 10 YEARS

T. HARADA*, S. IMAIZUMI**, I. NISHIZAKI°, M. TAKAHASHI*AND T. KASHIWAGI*

** Marine/Civil Engineering Products Development Dept. Bridgestone Corporation*
*** Energy and Environmental Science Graduate School of Engineering, Utsunomiya University*
° Materials & Geothecnical Engineering Research Group, Public Works Research Institute

SUMMARY: Polymer geomembrane liners are light-weight and hard to be deteriorated, and therefore are used in various civil structures such as final landfills, agricultural ponds, etc. However, durability evaluation of geomembrane liners is mainly conducted by accelerated weatherability test, thermal deterioration test and other acceleration tests, and systematic evaluation based on actual outdoor exposure test is rarely done because it needs enormous amount of time. We conducted, for the purpose of obtaining basic data on chemical durability of geomembrane liners, long time outdoor exposure test for about 10 years at four locations in Japan on various types of geomembrane, mainly thermoplastic elastomer liners, and also conducted follow-up test on the variation in fundamental dynamic properties and surface status. For a part of geomembrane liners, we conducted tests on the variation in strength at the joint portion. As a result, no significant performance decrement was observed on the geomembrane liners, and it was confirmed that the liners have sufficiently large residual performance.

1. INTRODUCTION

Geomembrane liners are used as an important structure of the sealing work of final landfills. On the other hand, there is a concern that damage in the geomembrane liners of the final landfills and resultant leakage of contaminated water would aggravate neighboring environment.

We reckoned the need of evaluation for the durability of the geomembrane liner itself, and conducted a long term outdoor exposure test for about 10 years. In a partial area, due to a delay in starting the test, the length of test is less than 10 years. However, we summarized the data we are possessing at present, and reported as follows in this paper.

Proceedings Sardinia 2005, Tenth International Waste Management and Landfill Symposium
S. Margherita di Pula, Cagliari, Italy; 3 - 7 October 2005

2. OUTLINE OF OUTDOOR EXPOSURE TEST

2.1 Purpose of outdoor exposure test

The final landfills of the waste are installed all over the country of Japan, and various types of geomembrane liners are used as the sealing bottom liners. The geomembrane liners are laid down at the bottom and all over the side surface of a disposal site for prevention of contact between underground water and waste materials. During the reclaiming period, the liners are exposed to the solar radiation and wind and weather. We considered these conditions, and conducted outdoor exposure test with a view of the following purposes:

- Durability evaluation on outdoor exposure of various geomembrane liners
- Evaluation of the effect given by the exposure site to the durability of geomembrane liners
- Durability evaluation of the joint portion of geomembrane liners
- Comparison between accelerated exposure test and outdoor exposure test
- Understanding of residual performance and life estimation

2.2 Selection of outdoor exposure site

Considering the difference in weather conditions, we conducted outdoor exposure test at four locations all over the country of Japan. (Figure 1)

Table 1 shows the weather data of each installation site. This data was compiled on the basis of yearly mean atmospheric temperature for the past 20 to 30 years and the yearly mean sunshine duration from the open data of Meteorological Agency.

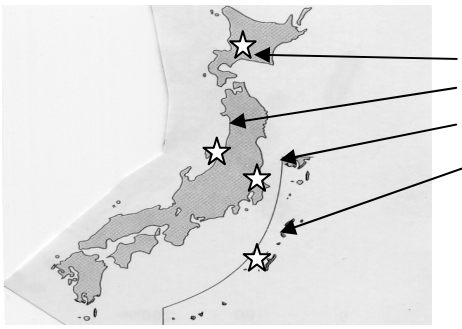
2.3 Outdoor exposure test specimen

We conducted outdoor exposure test on three types of geomembrane liners These liners are made black by adding carbon black and stabilization agent to the raw material polymer, and durability to outdoor exposure is taken into consideration.

- Thermo-plastic olefin elastomer (in this paper called TPO)
- Polyvinyl chloride (in this paper called PVC)
- High density polyethylene (in this paper called HDPE)

Table 1. Weather data around the installed site

Area	Yearly mean atmospheric temperature	Yearly mean sunshine duration
Hokkaido (Rikubetsu)	4.4□	1534 hrs
Niigagta (Takada)	13.3□	1596hrs
Tsukuba	14.0□	I964 hrs
Okinawa (Nago)	22.5□	1759 hrs



Rikubetsu-Cho, Asyorogun, Hokkaido (cold area)
Arai-shi, Niigata-prefecture (heavy snowfall area)
Tsukuba-shi, Ibaragi-prefecture (temperate pastoral area)
Oogimi-mura, Okinawa-prefecture (subtropical, coastal area)

Figure 1. Outdoor exposure test locations

Table 2. Types of test specimens, and installation locations

Installation location	Okinawa	Tsukuba	Niigata	Hokkaido
TPO	○,□	○,□	○,□	○,□
PVC	○	○	○	○
HDPE	○	○		○

○liner □joint portion

Figure 2. Outdoor exposure test in Okinawa

2.4 Method of outdoor exposure test

Types of test specimens and installation locations are shown in Table 2.
The test specimen is fixed on a wooden panel, which is attached to an exposure table facing south with an angle of 5°. Figure.2 shows the situation directly after starting the outdoor exposure test conducted in Okinawa area.

2.5 Recovery of test specimen

The target periods for outdoor exposure were one year, two years, three years, five years and 10 years. After elapsing these periods, respectively, we removed the test articles, and evaluated concerning the evaluation items listed in chapter 3.

3. EVALUATION ITEMS OF OUTDOOR EXPOSURE TEST SPECIMENS

We conducted test on the following evaluation items. All the test specimens were evaluated under the same conditions.

3.1 Tensile strength and elongation after fracture

- Test method: According to JIS K6251 Tensile test method for vulcanized rubber
- Shape of test specimen: Dumbbell No. 3 type
- Pulling speed: 500mm/minute

3.2 Hardness

- Test method: According to JIS K6253 Hardness test method for vulcanized rubber
- Measuring apparatus: Durometer type A

3.3 Strength of joint (shearing/ peeling)

- Test method: Conducted in accordance with JIS K6854 Testing methods for strength properties of adhesives.
- Shape of test specimen: Strip specimen of 25mm in width
- Pulling speed: 50mm/minute

3.4 External appearance (Observation of exposed surface)

- Test method: Comparative observation by digital video microscope

4. DYNAMIC PROPERTIES TEST RESULTS OF OUTDOOR EXPOSED TEST SPECIMEN

4.1 Change in dynamic properties of various types of geomembrane liners

We followed up the change in the dynamic properties of the geomembrene liners at four installation sites. Among the remaining four installation sites, Okinawa was highest in yearly mean atmospheric temperature, and longer in yearly mean sunshine duration, and larger change in the dynamic properties was expected. Figures.3 thru 4 show the results of follow-up in Okinawa for about 10 years. Figure.3 shows the retention ratio of elongation and tensile strength, and Figure. 4 show the secular variation in hardness.

From Figure. 3, it is known that, even after exposure for 10 years, there was no significant reduction in the elongation on each liner, and the liners showed the retention rate of 80 to 90% or over, respectively. Figure.3 also shows no significant reduction in tensile strength by outdoor exposure for about 10 years. Figure. 4 shows increase in the hardness of PVC liner with time, but other liners showed no increase in the hardness. This may be due to elution of plasticizer contained in the PVC liner.

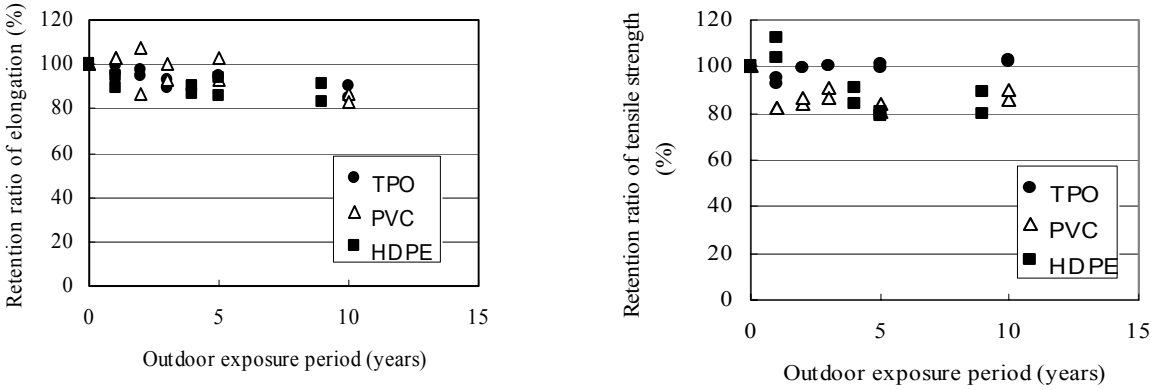


Figure 3. Change in dynamic properties in Okinawa

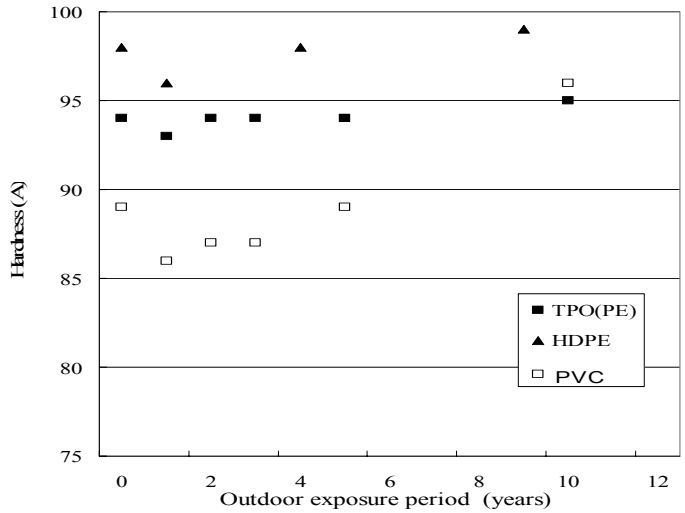


Figure 4. Change in Durometer hardness in Okinawa

These results of outdoor exposure test in Okinawa indicates that change in the dynamic properties by 10-years outdoor exposure was small, and the liners have sufficiently high performance with the retention rate of 80 to 90% or over. It can be said that damage to the geomembrane liners by ultraviolet rays and heat during outdoor exposure for about 10 years was small.

4.2 Outdoor exposure locations (Evaluation of the effect of weather conditions)

The land of Japan is long from north to south, and considerable difference in weather conditions is observed. We conducted the outdoor exposure test on two types of geomembrane liners, TPO liner and PVC liner, at four locations indicating large difference in weather conditions.

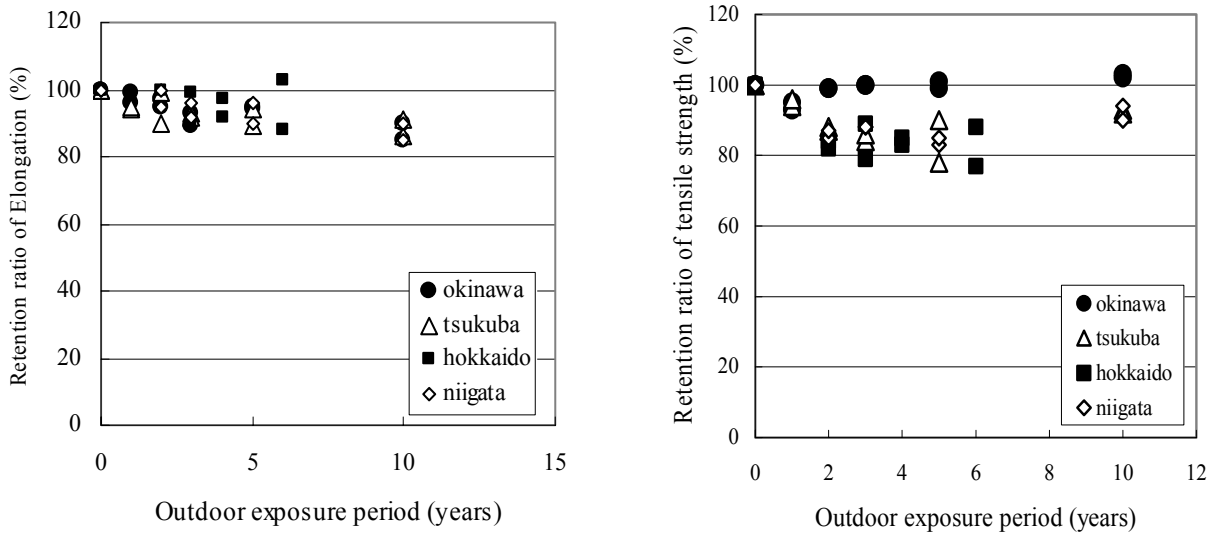


Figure 5. Change in dynamic properties of TPO liner

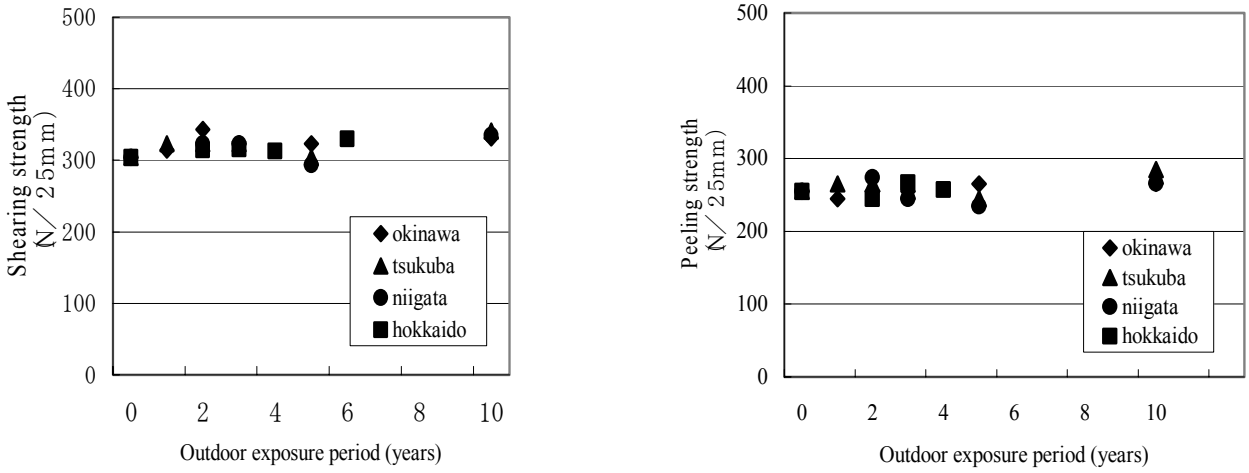


Figure 6. Change in joint strength of TPO liner

Figure 5 shows the change in elongation and tensile strength of TPO liners subjected to outdoor exposure test at four locations in Japan.

No regional difference was observed in the data of other areas. Tensile strength showed some what larger change in tensile strength compared to that of elongation , but regional difference was not clear.

Though some reduction was noted in the dynamic properties, no clear regional difference was observed. This is true also in Okinawa where the mean atmospheric temperature is the highest. The reason may be that since the change in physical properties was small, the regional difference in physical properties was not clear.

4.5 Durability of joint

The joint and surrounding portion of the liner are subject to high temperature when fused by heat. We therefore evaluated simultaneously the durability of the joint. Figure.6 shows the change in shearing strength and peeling strength of TPO liners.

The result of outdoor exposure for 10 years was that: stable joint strength was observed, without reduction of shear strength and peel strength, as shown in Figure. 6.

5. OBSERVATION OF OUTDOOR EXPOSURE TEST SPECIMEN

5.1 Observation of outdoor exposed surface

In the evaluation of dynamic properties described above, reduction rate was small and the regional difference among exposure locations was not clear. This indicates that the dynamic properties of the exposed geomembrane liners are on the level not depending on the domestic weather conditions when the exposure period is only 10 years. We then checked the specimen more minutely for examining the degree of deterioration. Figure.7 shows micrograph of the surface of three types of geomembrane liners exposed for about 10 years in Okinawa. Figure.8 shows the micrograph of the PVC liners exposed for about 10 years in Okinawa and Tsukuba. (The surface of the specimen was magnified to 100 magnifications for observation.).

In Figure.7, PVC liner shows very small cracks on the surface, but cracks are not clear on other liners. Figure.8 shows that the deterioration status of surface layer differs clearly owing to the difference in outdoor exposed location.

TPO HDPE PVC

Figure 7. State of outdoor exposed surface (Okinawa)

okinawa (10years) tsukuba

Figure 8. Regional difference appeared on PVC liner

When Okinawa and Tsukuba are compared, deterioration proceeds quickly in Okinawa, and crack status is not equal, and this seems to be the difference in weather conditions.

The status of initial deterioration which was not clear in the evaluation of dynamic properties was clarified through observation of outdoor exposure surface. We considered that, if combining the both, more accurate judgment and service life estimation would become possible concerning the durability of the geomembrane liners.

6. COMPARISON BETWEEN OUTDOOR EXPOSURE TEST AND ACCELERATED EXPOSURE TEST

6.1 Outline of the comparison of exposure tests for TPO liner

We conducted outdoor exposure test (Okinawa) and accelerated exposure test for TPO liner. In the accelerated exposure test, we used the sunshine weather meter, black panel controlled to 83degree centigrade, and the rain fall cycle of 18 minutes/120 minutes.

6.2 Results of accelerated exposure test by sunshine weather meter

Change in the elongation in accelerated exposure test is shown in Figure.9. As shown in Figure. 9, the results of accelerated exposure test indicate a trend similar to that of outdoor exposure test results shown in Figure.10.

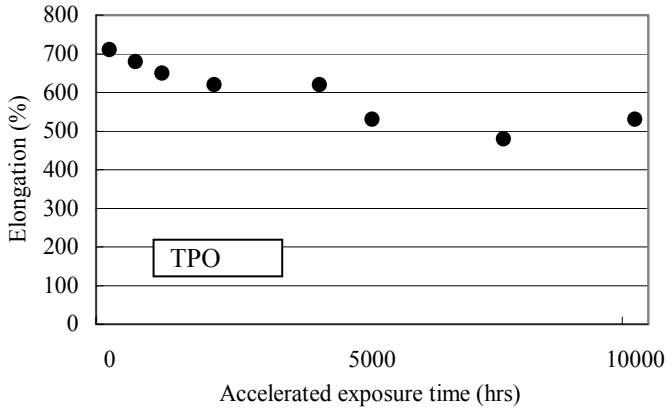


Figure 9. Change in the elongation in accelerated exposure test

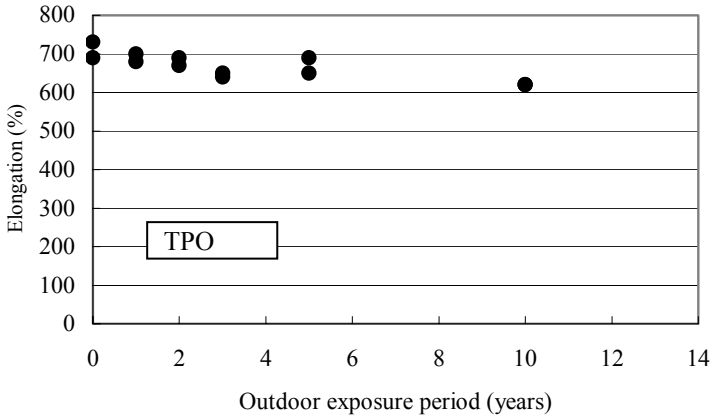
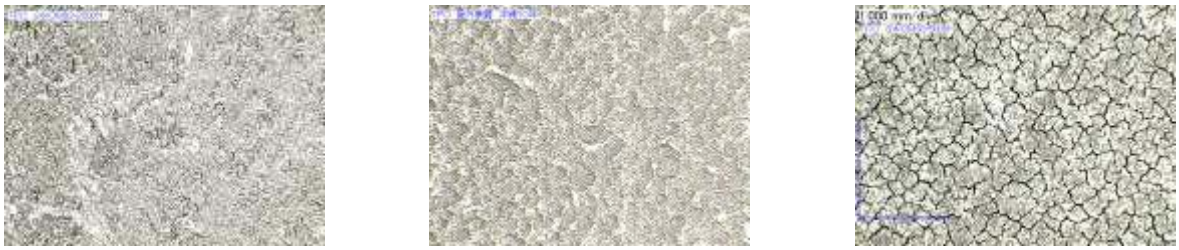


Figure 10. Change in the Elongation in outdoor exposure test

6.3 Correspondence between outdoor exposure test and accelerated exposure test

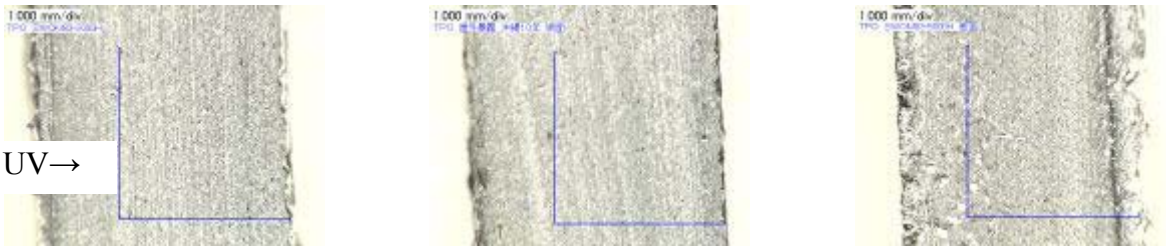
From the change in elongation shown in Figures.9 thru 10, it is known that the value of elongation is 620% for TPO liner 10 years after outdoor exposure. The accelerated exposure time corresponding to elongation, based on the correspondence with the accelerated test results shown in Fig. 9, is 2000 to 5000 hours for TPO liner. These data indicates that approximately 3000 hours can be taken as a measure for the service life in Okinawa for 10 years, provided the same accelerated exposure test conditions as those adopted this time are applied.

Based on these results, we compared the surface of TPO liner after outdoor exposure and the surface after accelerated exposure. Figure.11 shows the exposed surfaces of TPO liner. The left shows the surface subjected to 2000 hours of accelerated exposure, the middle the surface subjected to outdoor exposure for 10 years in Okinawa, and the right the surface subjected to 5000 hours of accelerated exposure. The state of the surface subjected to 10 years of outdoor exposure resembles the surface of accelerated exposure for 2000 hours, and accelerated exposure for 5000 hours indicates too much deterioration. Figure.12 shows the sectional photograph of TPO liner. The left photo shows the state after 2000 hours of accelerated exposure, and the middle photo after 10 years of outdoor exposure in Okinawa, and the right photo shows the state after 5000 hours.



indoor accelerated (2000hrs) | outdoor exposure (10years) | indoor accelerated (5000hrs)

Figure 11. Exposed surface of TPO liner



indoor accelerated (2000hrs) | outdoor exposure (10years) | indoor accelerated (5000hrs)

Figure 12. Cross section of TPO liner

Similar to the observation from the surface, it can be said that the state after 10 years of outdoor exposure in Okinawa resembles the state after 2000 hours of accelerated exposure.

Based on the above-mentioned examination, we obtained a prospect that the state after 10 years of outdoor exposure can be estimated by accelerated exposure test of 2000-3000 hours. We will further continue our analysis of weather data and exposure test specimen, thereby contributing to the life estimation and understanding of remaining performance of the geomembrane liners.

7. SUMMARY

- The dynamic properties of various geomembrane liners are stable, and deterioration due to exposure for about 10 years is limited to approximately 20%. This indicates that the geomembrane liners have sufficiently large residual performance.
- Outdoor exposure tests were conducted at four locations in Japan, and no significant regional difference was noted in the variation of dynamic properties. Through observation of the exposed surface, faster deterioration was noted on the specimen tested in Okinawa where the mean atmospheric temperature is high and mean sunshine duration is also long. However, Penetration in the cross-section direction was very small.
- The durability of the joint portion was evaluated. The jointing performance was quite stable, and continued data for 10 years was obtained.
- Through observation of the surface and cross-section, it became possible to provide judgment on minor deterioration.
- Through combined use of the follow-up of dynamic properties and appearance observation, the relation between outdoor exposure and accelerated exposure has been clarified. To be concrete, it was known that the outdoor exposure for 10 years in Okinawa corresponds to about 2000-3000 hours of accelerated exposure.

REFERENCES

Katawaki and Nishizaki; Long-term exposure test of new polymer materials for civil engineering (1), Material of Public Works Research Institute, May 1993

Materials Life Society, Japan; International symposium on weatherability (1)

Final landfills engineering system research group; 1999 year study report of design group, p3-13 to 23