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Durability evaluation of geomembrane liners by outdoor exposure experiments for 10 years

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ABSTRACT: Polymer geomembrane liners are hydraulically impervious and deterioration resistant therefore are used as bottom liners in waste landfills. However, the durability evaluation of geomembrane liners is mainly based on accelerated weatherability test. Systematic evaluation based on actual outdoor exposure experiment is rarely done because it needs enormous amount of time. We have conducted, for the purpose of obtaining basic data on the durability of geomembrane liners, long-term outdoor exposure experiment lasting about 10 years at four locations in Japan on various types of geomembranes, mainly thermoplastic elastomer liners. In addition, we also conducted follow-up test on the variation in fundamental mechanical properties and surface status. 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 for evaluation of the durability of the geomembrane liner itself, and conducted long-term outdoor exposure tests for 10 years.

2 OUTDOOR EXPOSURE EXPERIMENT

We conducted outdoor exposure test on three types of geomembrane liners. These liners are made black by adding carbon black and stabilization agents to the raw material. Table 1 shows the mechanical properties of these liners.

Table 1. Mechanical properties of liners.

Liners properties	TPO	HDPE	PVC
Durometer hardness (shore A)	94	98	88
Tensile strength (kN/m^2)	115.6	320.1	178.3
Elongation (%)	710	820	260

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

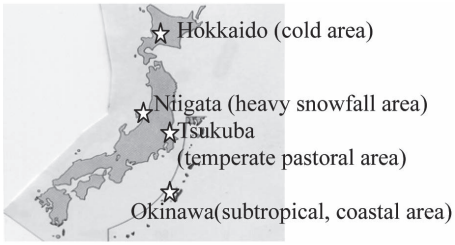


Figure 1. Outdoor exposure test locations.

Table 2 shows the typical weather data for each installation site.

Table 2. Weather data around the installed site.

Area	Yearly mean atmospheric temperature	Yearly mean sunshine duration
Hokkaido	4.4°C	1534 h
Niigata	13.3°C	1596 h
Tsukuba	14.0°C	1964 h
Okinawa	22.5°C	1759 h

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 disclosed data of Meteorological Agency.

The test specimen is fixed on a wooden panel, which is attached to an exposure table facing south with an angle of 5°C Figure 2 shows the situation

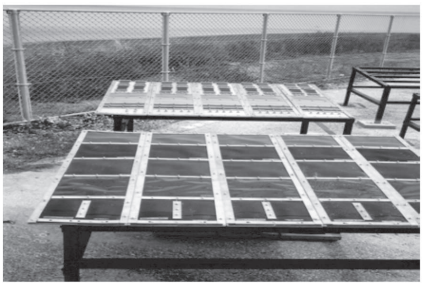


Figure 2. Outdoor exposure test in Okinawa.

directly after starting the outdoor exposure test conducted in Okinawa area.

3 RESULTS OF OUTDOOR EXPOSURE EXPERIMENTS

We followed up the change in the mechanical properties of the geomembrene liners at four installation sites. Among the remaining 4 installation sites, Okinawa was highest in yearly mean atmospheric temperature, and longer in yearly mean sunshine duration, and larger change in the mechanical properties was expected. Figures 3 to 5 show the change in mechanical properties tested in Okinawa. Figure 3 shows the big increase in durometer hardness of PVC liner.

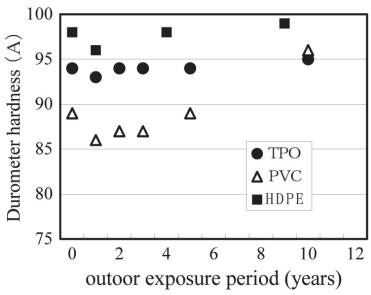


Figure 3. Change in durometer hardness in Okinawa.

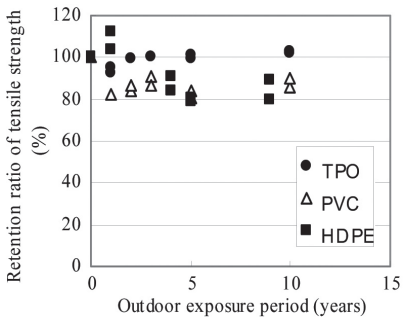


Figure 4. Change in tensile strength in Okinawa.

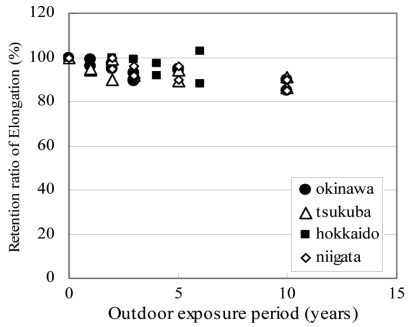


Figure 5. Change in elongation in Okinawa.

From Figures 4 to 5, it is known that, even after exposure for 10 years, there were no significant reduction in the tensile strength and elongation on each liner, and the liners showed the retention rate of 80% or over, respectively.

These results of outdoor exposure test in Okinawa indicate that the change in the mechanical properties during the 10 years outdoor exposure was relatively small. Hence, the liners performed well with the retention rate of 80% 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.

Figure 6 shows the change in elongation of TPO liners subjected to outdoor exposure test at four locations in Japan. No regional difference was observed in the data.

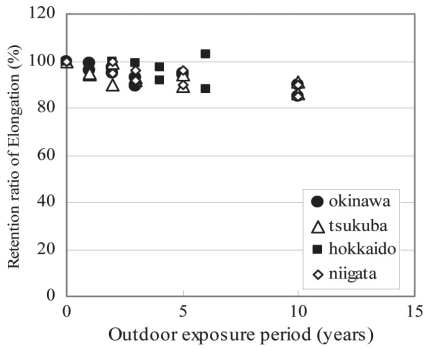


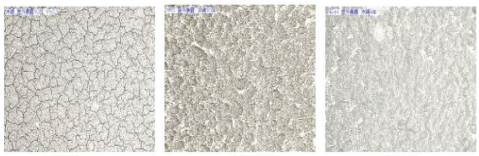
Figure 6. Change in elongation of TPO liner.

4 OBSERVATION OF EXPOSURED SURFACE

In the evaluation of mechanical properties described above, reduction rate was small and the regional difference among exposure locations was not clear. This indicates that the mechanical 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. (The surface of the specimen was magnified to 100 magnifications for observation.)

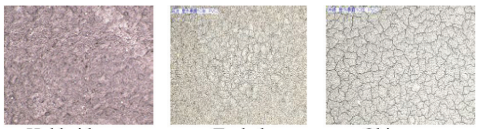


TPO HDPE PVC

Figure 7. State of outdoor exposed surface (Okinawa).

In Figure 7, PVC liner shows very small cracks on the surface, but cracks are not clear on other liners. Figure 8 shows the micrograph of the PVC liners exposed for about 10 years in Okinawa, Tsukuba, and Hokkaido. Figure. 8 shows that the deterioration status of surface layer differs clearly owing to the difference in outdoor exposed location.

From Figure 8, deterioration proceeds quickly in Okinawa, and crack status is not equal, and this seems to be the difference in weather conditions.



Hokkaido Tsukuba Okinawa

Figure 8. Regional difference appeared on PVC liner.

The status of initial deterioration, which was not clear in the evaluation of mechanical properties were clarified through observation of exposed 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.

5 COMPARISON BETWEEN EXPOSURE TEST AND INDOOR ACCELERATED EXPOSURE TEST

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 83°C, and the rain fall cycle of 18 minutes/120 minutes.

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.

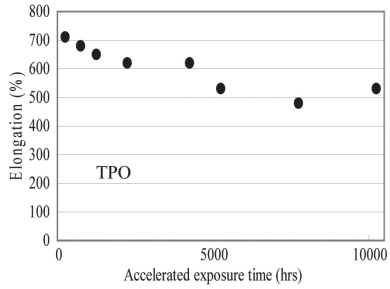


Figure 9. Change in the elongation in indoor test.

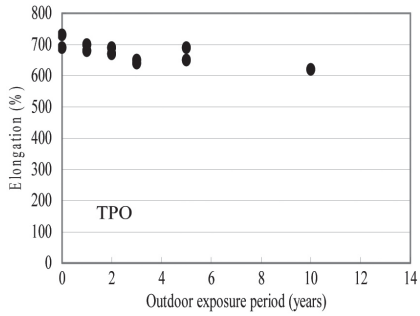
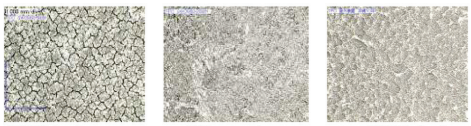


Figure 10. Change in the elongation in outdoor exposure test.

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. 8, is 2000 to 5000 hours for TPO liner. These data indicates that approximately little more than 2000 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 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. 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 little more than 2000 hours.



(2000 hrs) (10 years) (5000 hrs)

Figure 11. Exposed surface of TPO liner.

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.

6 SUMMARY AND CONCLUSIONS

The mechanical 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 mechanical properties. But, 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 shallow.

Through observation of the surface, it became possible to provide judgment on minor deterioration.

Through combined use of the follow-up of mechanical properties and observation of the exposed surface, 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 little more than 2000 hours of accelerated exposure.

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