Evaluation of physical properties of aged geomembranes taken from landfill sites in Japan

Shimaoka, T. & Nakayama, H.
Kyushu University, Japan
Hirai, T. & Hironaka, J.
Mitsui Chemicals Industrial Products Ltd., Japan
Katsumi, T.
Kyoto University, Japan
Ueda, S.
Taiyo Kogyo Ltd., Japan
Kanou, H.
Mitsuboshi Belting Ltd., Japan

Keywords: geomembrane, landfill, durability, field sample

ABSTRACT: Geomembrane liners in landfills fulfill the important role of avoiding groundwater and soil pollution by preventing leakage of leachate. In order to maintain the effectiveness of the liners for a long time, they should be tolerant against physical and chemical factors prevailing in the environment under which they are used. However, due to the lack of durability data obtained from the field samples, little is known about the actual durability of liners in landfill sites. In this study, 66 geomembrane samples in total, which comprise 27-year-old PVC, 24-year-old TPO, 18-year-old EPDM, 12-year-old HDPE, etc., were taken from six different landfill sites, one test site of landfill liners, and one test site of pond liners. Tensile tests were carried out along both the Machine (MD) and Transverse (TD) direction, and retention ratio of tensile strength (=amount of change/initial × 100), retention ratio of extension at break (=amount of change/initial × 100), and retention ratio of thickness were obtained. Using the above results, the changes in the physical properties of the liners were evaluated.

1. INTRODUCTION

In Japan, nearly 30 years have passed since the order on the technology standard of municipal solid waste (MSW) landfills and industrial waste landfills (Joint Ordinance by Prime Minister's Office and Ministry of Health and Welfare), which called for the installation of a barrier system, was issued in 1977. However, there is little quantitative information on the durability of geomembranes. It can be said that there is no information whatsoever about the durability of geomembranes in the landfill sites.

This study aims to take samples of aged geomembranes from the field and obtain information that contributes to the elucidation of factors that affect the durability of geomembranes and mechanisms underlying their degradation on the basis of the results obtained from tensile tests, etc.

2. FIELD STUDY

2.1 *Sites being investigated*

Degradation of geomembranes is considered to differ according to regional factors such as air temperature and amount of solar radiation. Accordingly, municipal solid waste landfills in

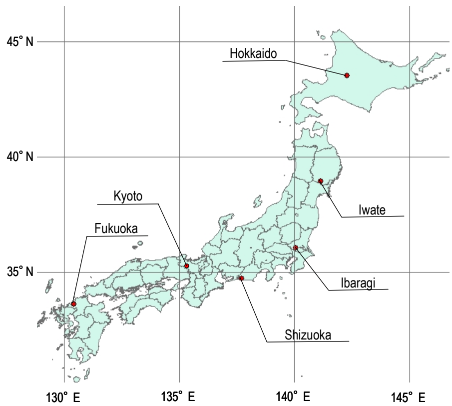

Fig.1 Sampling location of aged geomenbranes

Table 1 Investigated municipal solid waste landfills and a irrigation pond

Prefecture	Facilities	Geomenbrane materials	Elapsed time (years)	Protection geomat
Hokkaido	Municipal solid waste landfill site	PVC	11	Not installed
Iwate	Municipal solid waste landfill site (1)	HDPE	8	Installed
	Municipal solid waste landfill site (2)	EPDM	25	Not installed
Ibaragi	Irrigation pond at National Institute for Rural Engineering (NIRE)	TPO, PVC, EPDM	18～27	Not installed
Kyoto	Landfill simulator	HDPE (white color of surface)	12.6	Not installed
Shizuoka	Municipal solid waste landfill site	EPDM	16	Not installed → installed
Fukuoka	Municipal solid waste landfill site (1)	TPO	5～11	Not installed → installed
	Municipal solid waste landfill site (2)	EPDM	18	Not installed → installed

TPO: Thermo Plastic Olefin, PVC: Polyvinyl Chloride, EPDM: Ethylene Propylene Diene Monomer, HDPE: High Density Polyethylene

Hokkaido, Iwate Prefecture, Shizuoka Prefecture, and Fukuoka Prefecture, as shown in Fig. 1, were selected to be investigated. In addition, an aged geomembrane—although it was not used in the MSW landfills—that was available from a test pond (an irrigation pond) at the National Institute for Rural Engineering (NIRE) in Tsukuba, Ibaraki Prefecture, was also investigated. Samples were also obtained from a simulated landfill in Kyoto Prefecture. The details about investigated geomenbranes are described in Table 1.

2.2 *Geomembrane Sampling*

In this study, tensile tests were conducted on the samples taken from the geomembranes. Sampling was conducted by accurately marking (Fig. 2) and cutting off (Fig. 3) a 50-centimeter square by using a cutter. Holes resulting from the sampling were repaired by gluing or fusing in consideration of materials of geomembranes and degradation state.

A total of 66 geomembrane samples were taken from eight sites (six municipal solid waste landfills, one test pond, and one simulated landfill).

3. CHANGES IN PROPERTIES OF GEOMEMBRANES ACCORDING TO THEIR MATERIALS

Table 2 shows the following parameters concerning the geomembranes: sites from which the samples were taken, constituent materials, whether protection mats were installed or not, age, rate of change in thickness, and the retention ratio of extension at break and the retention ratio of

Fig.2 Marking of geomembranes

Fig.3 Sampling of geomembranes

tensile strength obtained from tensile tests. Three replicas of each geomembrane sample were used in the tensile tests.

(1) Changes in properties of samples comprising

Table 2 Characteristic changes of geomembrane samples

Geomenbrane materials	Prefecture	Facilities	Protection geomat	Elapsed time (yaer)	Sample number	Average rate of characteristic change(%), standard deviation in parenthesis				
						Thickness	Extension percentage		Tensile strength	
							Machine direction	Cross-machine direction	Machine direction	Cross-machine direction
TPO	Ibaragi	Farm pond at National Institute for Rural Engineering	Not installed	18～24	14	0.75 (11.0)	−37.1 (43.9)	−80.8 (18.5)	−26.5 (21.3)	−23.2 (5.1)
	Fukuoka	Municipal solid waste landfill site (1)	Not installed → installed	5～11	10	1.5 (3.2)	−8.1 (6.6)	−5.0 (4.6)	−7.8 (10.1)	−10.6 (6.5)
PVC	Hokkaido	Municipal solid waste landfill site	Not installed	11	6	−7.6 (6.4)	−21.6 (5.9)	−16.2 (5.5)	1.7 (6.0)	−8.6 (10.2)
	Ibaragi	Irrigation pond at National Institute for Rural Engineering	Not installed	18～27	7	−33.6 (12.9)	−83.9 (12.2)	−86.4 (13.6)	66.2 (35.1)	56.0 (33.1)
EPDM	Iwate	Municipal solid waste landfill site (2)	Not installed	25	1	−11.7	−63.3	−59.4	2.4	−1.8
	Ibaragi	Farm pond at National Institute for Rural Engineering	Not installed	18	11	−12.2 (2.9)	52.7 (8.8)	−53.0 (10.1)	−6.3 (7.4)	−12.4 (6.0)
	Shizuoka	Municipal solid waste landfill site	Not installed → installed	16	5	−8.8 (3.0)	−42.8 (8.1)	−39.2 (7.8)	−19.1 (5.5)	−11.5 (4.4)
	Fukuoka	Municipal solid waste landfill site (2)	Not installed → installed	18	4	−5.8 (4.2)	−48.8 (4.8)	−46.2 (6.3)	−13.9 (4.7)	−19.0 (8.1)
HDPE	Iwate	Municipal solid waste landfill site (1)	Installed	8	5	7.3 (3.7)	−4.5 (8.4)	2.6 (2.4)	−24.7 (12.0)	−16.3 (4.7)
	Kyoto	Landfill simulator	Not installed (white color of surface)	12.6	3	15.3 (3.4)	−5.2 (2.3)	−6.5 (5.8)	−8.3 (2.4)	−10.9 (7.7)
All averages				15.6	66	−5.8 (13.9)	−35.8 (30.8)	−38.3 (31.3)	−5.2 (29.9)	−7.2 (27.5)
All averages of absolute values				15.6	66	11.0 (10.3)	37.5 (28.8)	39.3 (30.0)	20.3 (22.6)	20.2 (19.9)

TPO

There were two kinds of TPO samples—18- to 24-year-old samples that were not shielded with protection mats (obtained from NIRE in Ibaraki Prefecture) and 5- to 11-year-old samples that were initially not shielded but later shielded with protection mats (obtained from the municipal solid waste landfill (1) in Fukuoka Prefecture). There were little changes (+0.75% and +1.5%) in the rate of change in thickness in the former samples.

In the Ibaragi samples, the changes in the rate of extension were –37.1% along the machine direction and –80.8% along the cross-machine direction; the rate of extension in the cross-machine direction, in particular, decreased markedly. The rates of change in retention ratio of tensile strength were –26.5% in the machine direction and –23.2% in the cross-machine direction. On the other hand, the rates of change in thickness in the latter (Fukuoka) samples were +2.0% in the machine direction and +1.0% in the cross-machine direction; the rates of extension were –8.1% in the machine direction and –5.0% in the cross-machine direction; further, the retention ratio of tensile strength was –7.8% in the machine direction and –10.6% in the cross-machine direction.

It was observed that the rate of extension and retention ratio of tensile strength of the Ibaraki samples were lower than those of the Fukuoka samples. This is because the Ibaraki samples were up to 13 years older than the Fukuoka samples, and, in addition, advances in the design of TPO geomembranes could have resulted in the improvement in their durability. And also the installation of protection mats could have influenced on the durability in the Fukuoka samples.

(2) Changes in properties of PVC samples

There were two kinds of PVC samples—11-year-old samples that were obtained from the municipal solid waste landfill in Hokkaido and 18- to 27-year-old samples that were obtained from NIRE in Ibaraki Prefecture. None of the samples of either kind were shielded with protection mats. The rates of change in thickness in the PVC samples obtained from Hokkaido were –7.6%; the rates of extension were –21.6% in the machine direction and –16.2% in the cross-machine direction; the retention ratio of tensile strength was +1.7% in the machine direction and –8.6% in the cross-machine direction. There was a considerable change in the retention ratio of extension at break when compared to the retention ratio of tensile strength.

On the other hand, the rate of change in thickness in the Ibaraki samples was –33.6%; this is the largest change among all the geomembrane samples. While the rates of extension decreased remarkably (–83.9% in the machine direction and –86.4% in the cross-machine direction), the retention ratio of tensile strength increased (+66.2% in the machine direction and +56.0% in the cross-machine direction). This indicates that the PVC sheets hardened with degradation.

(3) Changes in properties of EPDM samples

There were three kinds of EPDM samples—25-year-old samples that were not shielded with protection mats (obtained from the municipal solid waste landfill (2) in Iwate Prefecture), 18-year-old samples that were not shielded with protection mats (obtained from NIRE in Ibaraki Prefecture), and 16- and 18-year-old samples that were initially not shielded but were later shielded with protection mats (obtained from the municipal solid waste landfills in Shizuoka Prefecture and Fukuoka Prefecture, respectively). Owing to the considerable amount of data collected, details have been omitted in this paper for simplification. The rates of change in thickness ranged between –5.8% (Fukuoka Prefecture) and –12.2% (Ibaragi Prefecture); these samples were second to the PVC samples with regard to their change in thickness. While the rate of extension decreased (ranging between –42.8% (Shizuoka Prefecture) and –63.3% (Iwate Prefecture)), the retention ratio of tensile strength ranged between –19.1% (Shizuoka Prefecture) and +2.4% (Iwate Prefecture); it was observed that the change in the rate of extension was more remarkable than the change in the retention ratio of tensile strength.

(4) Changes in properties of HDPE samples

There were two kinds of HDPE samples—8-year-old samples that were shielded with protection mats (obtained from the municipal solid waste landfill (1)) and 12.6-year-old samples with white surfaces that were not shielded with protection mats (obtained from the experimentally simulated landfill in Kyoto Prefecture). There was an increase in the thickness of both samples (+7.3% and +15.3%). However, the rates of extension hardly changed: there was a maximum change of –6.5% in the cross-machine direction (Kyoto Prefecture). On the other hand, the changes in retention ratio of tensile strength were relatively large: –24.7% in the machine direction and –16.3% in the cross-machine direction in the Iwate samples and –8.3% in the machine direction and –10.9% in the cross-machine direction in the Kyoto samples.

4. CONCLUSION:

Evaluation of durability of geomembranes

The largest change in thickness was –33.6% in PVC samples from Ibaragi and the second change was +15.3% in HDPE samples from Kyoto.

The rates of extension changed –83.9% in the machine direction and –86.4% in the cross-machine direction and the retention ratio of tensile strength varied between +66.2% in the machine direction and +56.0% in the cross-machine direction in PVC samples from Ibaragi. These were largest changes in the rates of extension and tensile strength. This is because the Ibaragi samples were oldest among all samples.

The influence of the installation of protection mats was more obvious in TPO samples. The changes of the retention ratio of extension and tensile strength were much less in the case of the protection mats installation. The influence of protection mats was not clear in other geomenbrane materials.