Landmarks in Earth Reinforcement, Ochiai et al. (eds),
© 2001 Swets & Zeitlinger, ISBN 90 2651 863 3

Reinforcing function of a liner system by geotextile and geogrid

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ABSTRACT: When the base of landfill subsides, deformation occurs in the geomembrane which is used as a component of liner. Usually, non-woven textile is being used to protect a geomembrane from mechanical damage. This non-woven geotextile seems to function as reinforcing the geomembrane when it deform. A geogrid if it was used together with the non-woven textile may emphasize this reinforcing. That influence was examined here. For example a geogrid is used together in HDPE. Assuming the amount of maximum distortion with only geomembrane is 100, it is amount with not only but geogrid becomes 53. A geogrid is thought to show effect by not only the frictional decrease of the geomembrane but also rigidity increasing.

1 INTRODUCTION

A geomembrane is being used as a main component of a liner system in waste landfill. This functions to prevent the polluted water (leachate) from flowing into underground. When local subsidence may happen at the bottom of waste landfill, deformation of the liner occurs. Then strain creates within the geomembrane. As for the deformation and/or the strain of geomembrane caused by subsidence of the base, some evaluation-methods have been proposed. Usually, a geomembrane is placed on the base ground together with the non-woven textiles to prevent it from mechanical damage.

The authors thought that use of the geogrid as well as geotextile may emphasize the function of protecting and reinforceing the geomembrane. In this paper, they conducted the trapped door tests of modeled liner which was composed of geomembrane made from HDPE (High Density PolyEthylene) or FPA (Flexible Polypropylene Alloy) under- and overlying the geotextile, and of geomembrane underlying geotextile and overlying geogrid.

2 THE OUTLINE OF THE EXPERIMENT

2.1 *Device and used material*

The outline of the device is shown in Figure 1. This device is composed of steel container having a length of 250cm, a width of 90cm and a depth of 70cm. The bottom board of the container is divided into three parts. The center part of the board with a length of 30cm can settle by the jack and the motor. This simulate the local subside of the base ground

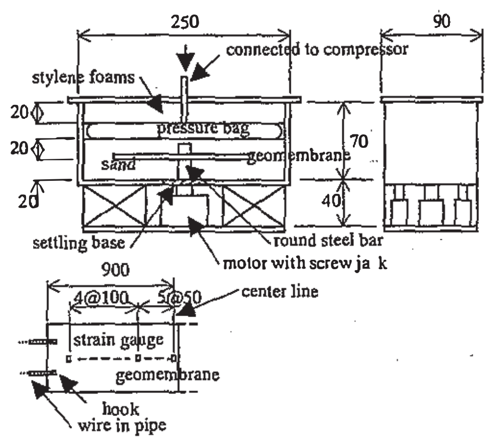

Figure 1. Outline of device.

overlying the liner system including geomembrane.

The sand layers with a thickness of 20cm were underlaid and overlaid the liner system. The dimension of the liner system is a length of 180cm and a width of 80cm. An air-bag made of rubber was installed on the upper layer of the sand. This air-bag can apply the sand layer the pressure up to 255kPa by the air compression machine. The steel-cap was fixed to the container by the bolts.

Two kinds of geomembrane were used. One is HDPE (High Density PolyEthlene) with a thickness of 1.5 mm, and the other is FPA (Flexible Polypropylene Alloy) with a thickness of 1.5mm. Forty-two strain gauges in total were pasted on the both surface of geomembrane. These points are center of geomembrane, each 5cm far (10 points), and each 10cm far (10 points) toward the outside. Therefore, axial strain and bending strain can be estimated at 21 points of geomembrane.

The sand used for the experiment is made from crushed stone. This sand was sieved for the grain size to distribute between 840μ and 74μm. It's internal friction angle that was determined by tri-axial compression test is about 48°.

The used geotextile as protection layer is a stapled non-woven geotextile with a thickness of 10 mm reinforced by short fiber.

Geogrid is also used in the experiments. This geogrid made from polypropylene was enlarged biaxially to form big net.

The physical and mechanical properties of these materials are listed in Table 1.

Table 1. Properties of geosynthetics.

Geomembrane	HDPE	FPA
Density (g/cm^3)	0.95	0.9
Tension strength (20°C) (MN/m^2)	33.5	22.7
Breaking elongation (20°C) (%)	860	720
Liner expansion coefficient ($\times 10^{-4}$°C)	1.65	1.2
Elastic modulus (20°C) (MN/m^2)	484	81.9

Geogrid	longitudinal	transverse
Reference strength (kN/m)	10.0	20.0
Creep strength (kN/m)	3.0	6.0
Quality of the material	Polypropylene	

Non-woven geotextile	
Thickness (mm)	10
Density (g/cm^3)	0.12
Tension strength (20°C) (MN/m^2)	1.27
Breaking elongation (20°C) (%)	154
Permeability coefficient (cm/sec)	2.65x10^{-2}

2.2 *Testing cases and procedure*

Table 2 showed the testing cases. The tests where no protective layer was used were case1 and case5 for HDPE and FPA, respectively. The tests where geo textiles were placed both on and under the geomembrane were case2 and case6 for HDPE and FPA. The tests where geogrid was placed on the geomembrane were case3 and case7 for HDPE and FPA. The tests where geogrid was placed on the geomembrane and geotextile was placed under the geomembrane were Case.4 and Case.8 for HDPE and FPA.

Table 2. List of the experiment.

Case	Geomembrane	Geotextile	Geogrid	Pressur (kPa)	Temperature (°C)
1	HDPE	Without	Without	49	15.4
2	HDPE	With	Without	49	19.7
3	HDPE	Without	With	49	−8.4
4	HDPE	With	With	49	27.1
5	FPA	Without	Without	49	2
6	FPA	With	Without	49	27
7	FPA	Without	With	49	−7.1
8	FPA	With	With	49	5.2

First, the sand was poured into the container for its thickness to be 20cm. Then its surface was smoothed. When the geotextile was used as bottom protective layer, it was placed on the sand. Then geomembrane was spread on the geotextile. In case the geotextile was not placed, the geomembrane was spread directly on the lower sand. Then, after geotextile or geogrid was placed on the geomembrane, upper sand layer with a thickness of 20cm was compacted. In case no geotextile or no geogrid was placed on the geomembrane, upper sand layer was directly compacted on the geomembrane.

The wire that was used to measure vertical displacement of geomembrane was glued to the center on its bottom surface. This wire was connected to displacement transducer outside of the container through the settling board. Forty-two strain gauges were lead to the data logger outside of the container through its side-wall. The pressure of 49kPa was applied on the upper sand layer through the air bag.

Center part of base board, then, was lowered by electrical motor screw at a rate of 1mm/min. The amounts of strains and vertical deformation were measured and recorded each 0.5mm of base settlement. It lasted until the amount of lowing of board reached to 65mm.

3 RESULT AND DISCUSSIONS

3.1 *Vertical displacement and elongation of the geomembrane*

Firstly, axial strains at 21points were estimated as an average value of strains measured on top and bottom surfaces of geomembrane at given settlement of central base board. Then the axial strains were integrated along the axial of geomembrane to result in its elongation. Figure 2 shows changes of the amount of vertical displacement (*d*), elongation ($2\Delta L$) of geomembrane, and the ratio of $(2\Delta L)/(d)$ versus settlement of base board.

In case of HDPE, the vertical displacements of geomembrane are somewhat smaller than the settlement of base and the trends are almost similar whether there are protective layer or not. In case of FPA, which is more flexible than HDPE, it can be recognized that vertical displacement of geomembrane is almost equal to the settlement of base when no protective layer was placed. However, when some protective layer as geotextile or geogrid was placed on or/and under the geomembrane, vertical displacement beyond about 30mm of base settlement is somewhat smaller than that in case of without any protective. In both cases, among three types of placement of protective layer, geotextiles on and un-

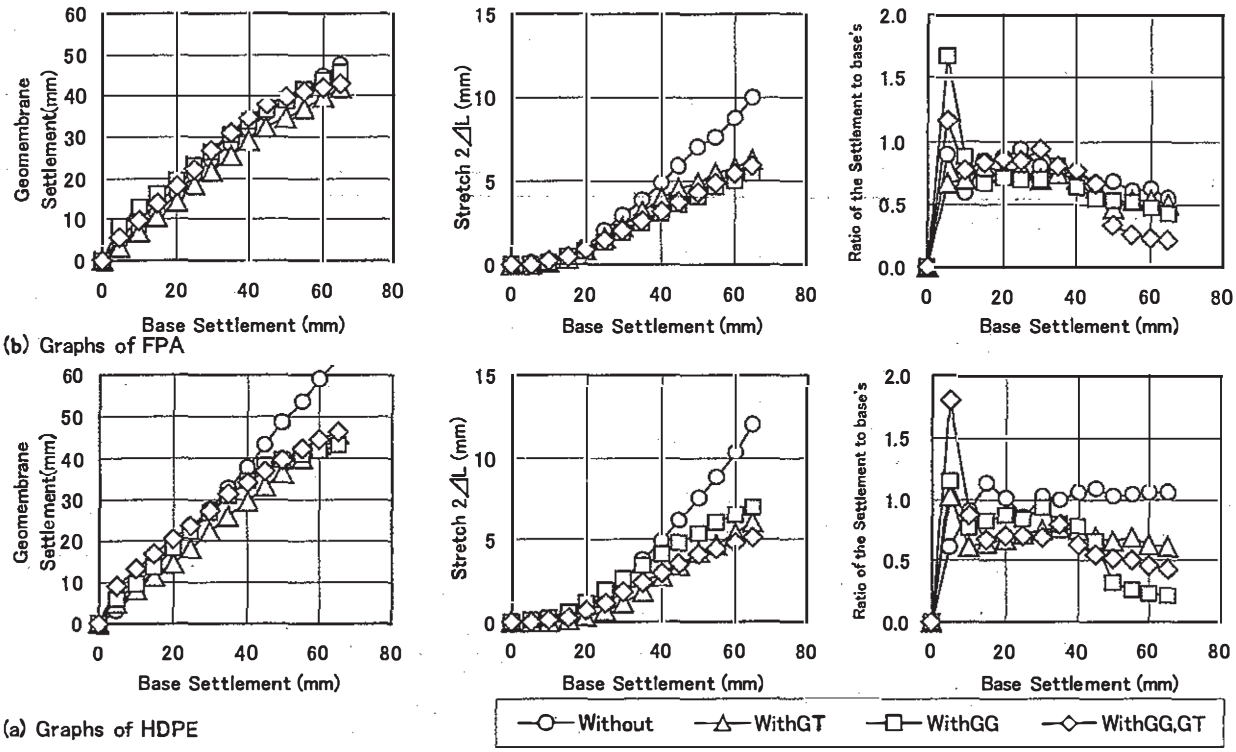

Figure 2. The amount sinking of Base and Geomembrane.

der the geomembrane seems to give a bit smaller vertical displacement.

As for the elongation, it was largest for both case of HDPE and FPA when no protective layer was placed. It can be found that the elongation is the smallest when geotextile was placed under geomembrane and geogrid was on the geomembrane. An amount of the latter is about 50% of the former in case of HDPE and about 40% in case of FPA.

Therefore, placing the geotextile and/or geogrid on and under the geomembrane functions to reduce the vertical displacement of geomembrane when the base subsides partially and then results in a reduction of elongation. This is due to the increase of rigidity of liner system including geomembrane.

3.2 *Distribution of the axial strain of geomembrane*

Figure 3 shows the distribution of axial strain of geomembrane when the elongation is 5mm, where the axial strain was estimated as a mean of an amount of strain gauges pasted on top and bottom surfaces. The cases where no protective layer was used show the largest value of strain at center point both for HDPA and FPA. The cases where geotextile was placed under the geomembrane and geogrid placed on show the smallest value. However, the axial strain creating at the point far from the center, for example 50cm far, the former cases seem to show the smallest. As the reason for this difference, it is thought theoretically that the case without any pro-

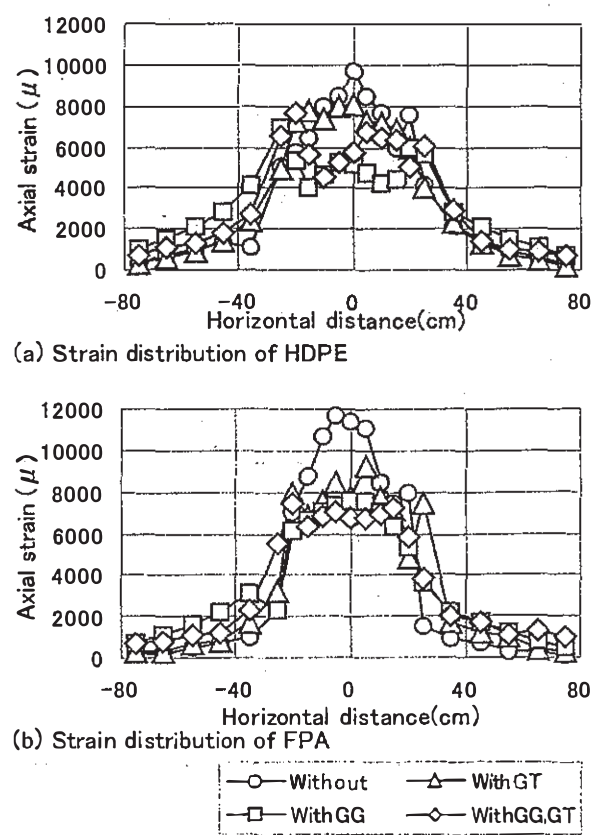

Figure 3. Distribution of axial strain at elongation of 5mm.

tective layer has lower rigidity and high froctional coefficient between geomembrane and adjacent material.

It is also seen that the range of strain distribution of HDPE is somewhat larger than that of FPA. This is due to the fact the rigidity of HDPE is much higher than FPA.

To see the effect of placing the protective material on axial strain distribution, an amount of strain at given point with protective layer was divided by an amount corresponding point incase of without any protective layer. Figure 4 shows the distribution of the ratio (%). The ratio is less than 100 within the central 40cm and more than 100 beyond it. This trend is somewhat considerable in case of FPA, having lower rigidity. As for the type of materials of protective layer, placing the geotextiles both on and under the HDPE geomembrane gives the most marked redistribution of the axial strain, for example, 53% at the central point. Placing geogrid on and geotextile under the FPA geomembrane give also remarkable effect of strain redistribution, as 59% at central point. Placing the geotextile only under the geomembrane seems to do a little effect of redistribution, as 83% and 70% for HDPE and FPA respectively.

Using the geogrid on the geomembrane, it is though that rigidity of the liner system, of course, may increase. But the frictional coefficient on the surface may not change because the sand can contact with the surface of geomembrane through open area of geogrid. As the result, the effect of redistribution of strain is as similar as the case with placing the geotextiles on both sides.

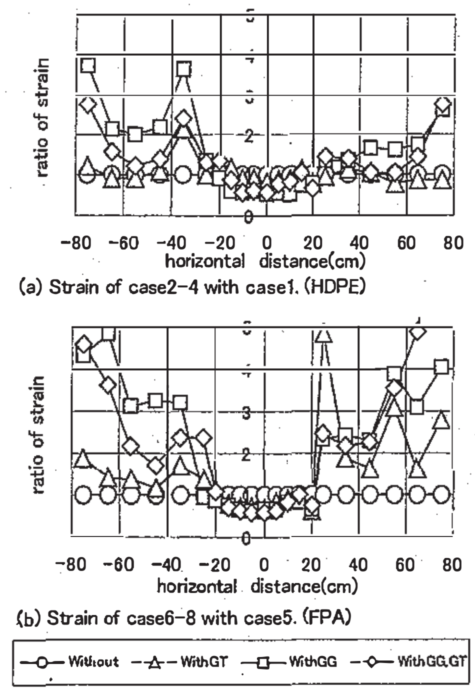

Figure 4. Distribution of strain ratio.

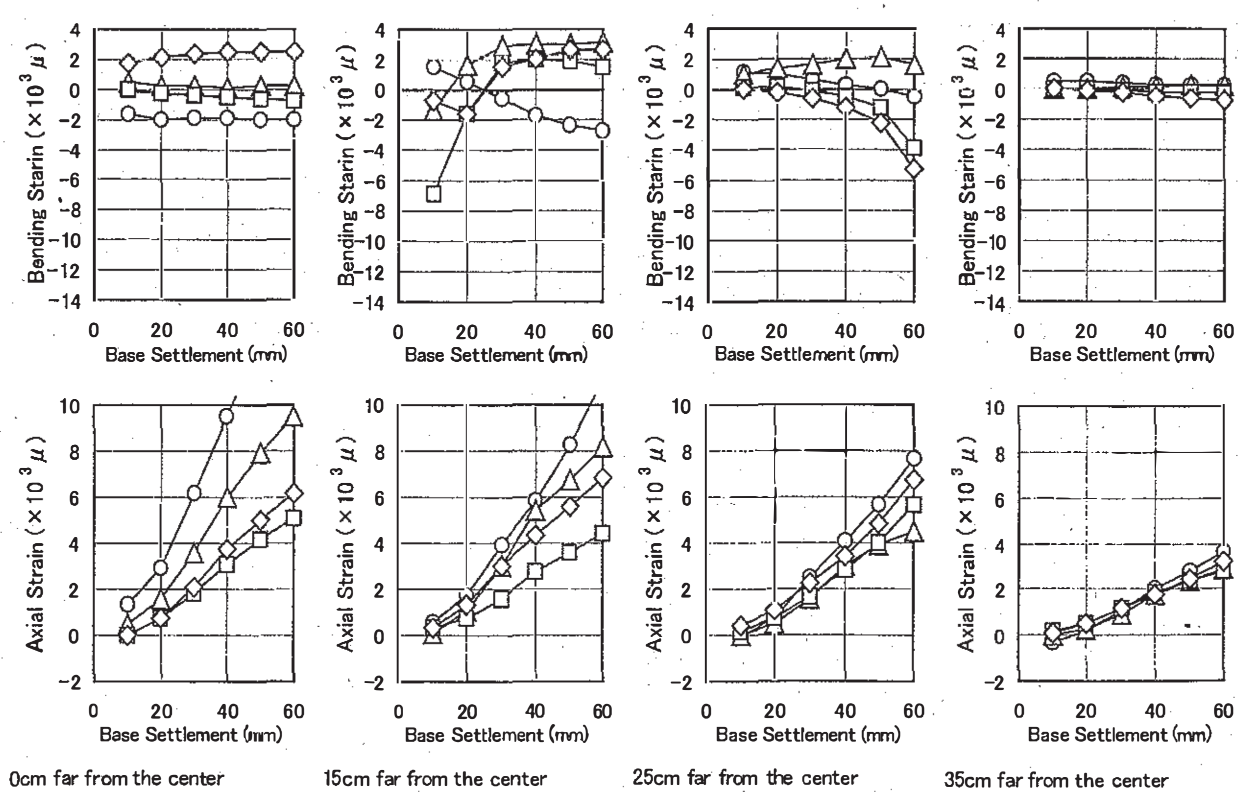

Figure 5. Axial- and bending strain versus base settlement. (HDPE)

3.3 *Distribution of the bending strain of the geomembrane*

Figure 5 shows the change of axial- and bending-strain at the points 0, 15, 25 and 35cm far from the central point for HDPE geomembrane with settlement of the base board. At the central point, axial strain in case of without any protection layer gives the highest values. The axial strain decreases in order of the case of with geotextile under HDPE, the case of with geotextiles on both sides, and the case of with geogrid on and geotextile under HDPE. At the point of 25cm far, the case of with geotextiles on both side gives the smallest strain.

As to the bending strain, positive value means that the geomembrane deforms concavely. When the geomembrane was spread without any protective layer, the bending strain beyond 30mm of base settlement at points of 15cm indicates negative one, this means it deforms convexly, though other cases indicates positive one. These behavior come from the difference of their rigidity.

Figure 6 shows the distortion of FPA for each position of 0,15,25 and 35cm from the center. Bending strain is stable in the position of 15cm at the time of a sinking 30mm of case7 which a geogrid was used for. The value of the bending strain is reduced at the stage. They fall down slowly as for which case as well after the value of the bending strain increased from the negative value and became maximum distortion value.

The bending strain of case6 in which a non-woven textile was used for is big, and it is moving to the negative side in the position of 25cm. It shows a tendency of being the same even in the position of 35cm. As friction is small, it is because the influence of sinking appears in the wide range. And, these mean it deforms convexly, though other cases indicates positive one.

Axial strain shows the increase which is comparatively simple. The value of the axial strain of case5 is big and the influence of the non-woven textile and the geogrid is big in the central point around the center.

4 CONCLUSION

The authors conducted trapped door tests of geomembrane sandwiched by sand-layer. Material of protective layer that was installed between geomembrane and sand was changed such as geotextiles on and under the geomembrane, geogrid under the geomembrane, and geotextile under and geogrid on the geomembrane. Two types of geomembrane, HDPE and FPA, were used. Main results obtained from the experiments are follows.

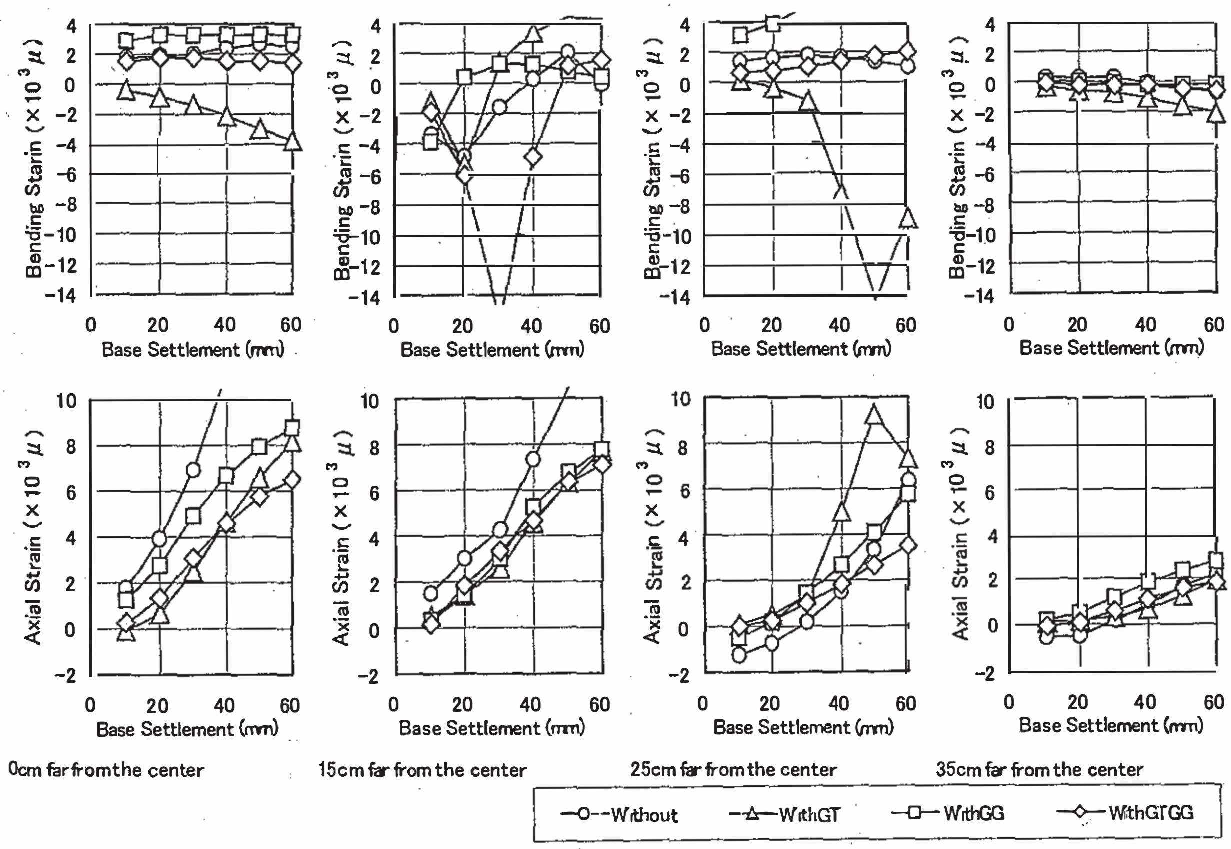

Figure 6. Axial - and bending strain versus base settlement. (FPA)

(1) When a non-woven textile and a geogrid are used, the amount of sinking of the geomembrane and stretch can be restrained. As for the early stages of sinking, the effect by the non-woven textile is bigger than the effect of the geogrid. However, sinking in the one which a geogrid was used for when sinking grew more than 40mm.

(2) Bending strain is big, and proceeds at the negative side with the progress of sinking when the distortion of HDPE is seen in the position of 25cm from the center. It shows a tendency of being the same even in the position of 35cm. On the other hand the absolute value of the bending strain which a non-woven textile and a geogrid were used for is bigger than the case in which they are not used. If a non-woven textile and a geogrid are used, the influenced range of sinking grows big. The size of the influence range is geogrid + non-woven textile, geogrid, non-woven textile and use-less in the order.

(3) The distortion of FPA falls down in the position of 15cm after the value of the bending strain increased from the negative value as for which case as well and became maximum distortion value. The bending strain of case6 in which a non-woven textile was used for is big, and it is moving to the negative side in the position of 25cm. It shows a tendency of being the same even in the position of 35cm. As friction is small, it is considered that these phenomena are because the influence of sinking appears in the wide range.

(4) Axial strain shows the comparatively simple increase. The value of the shaft distortion of case5 is big, and the influence of the non-woven textile and the geogrid is greatly shown in the position of 15cm around the center.

(5) When the distribution of the distortion is researched, distortion in the center decreases, and both geomembranes are on the increase in the circumference part. Assuming the amount of distortion of case1 is 100% in HDPE, the amounts of each distortion of case2, case3 and case4 become 83%, 53% and 59%. Supposing the distortion of case5 regarding FPA is 100, the amounts of each distortion become 68% (case6), 66% (case7) and 59% (case8). On the other hand the size of the distortion far from the center grew conversely large. FPA of effect on a decrease of the maximum distortion by the non-woven textile and the geogrid was bigger. Particularly, the effect of the geogrid was shown with FPA remarkably. As for this, rigidity is enhanced by the geogrid regarding FPA more than HDPE.

It can reduce the friction to install non-woven textile or geogrid at landfill sites, which can also increase their rigidity. Therefore the result stated above is important regarding the safety of the liners at the landfill sites.

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