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The damage resistance of triple liner system against the local pressure on the uneven ground surface in the sea area landfill site

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1. Introduction

In the slope hydraulic barrier of the sea area landfill sites, the hydraulic barrier are designed and constructed used by the double geomembrane sheets and the buffer material or low permeability layer between them to keep the barrier function. Because the slope in the sea area landfill sites are normally composed the rubble mound break water and there are possibility of the uneven ground surface at the slope damage the geomembrane sheets. Therefore the size of uneven surface on the slope ground in sea area landfill sites has prescribed (the permissible range from the design ground level is less than ± 40cm)(WAVE 2000).

But it is so difficult to get safety against the damage of the geomembrane sheets because the damage of the geomembrane sheets are influenced by the construction condition as follows that,

1. It is difficult to get the high leveling accuracy of the base ground surface in the sea area.
2. The shape and the size of the rubble cusp are variously changed on uneven ground surface.

Therefore the study of the relation between the shape variation of the rubble cusp on the uneven

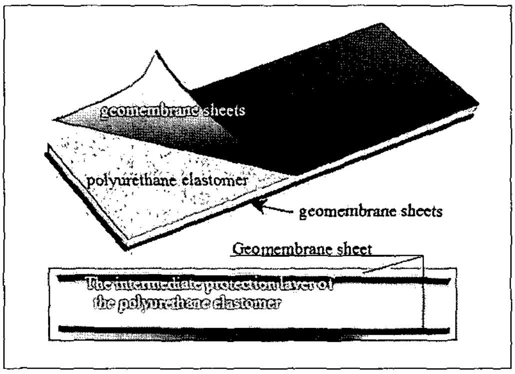

Figure 1. Three-layer structure of TLS

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ground surface and the damage of the geomembrane sheets has been carried out (Kano and others 2004). And the suitable specification about nonwoven geotextile to protect against the damage of the geomembrane sheets on the uneven ground surface has been studied (Akai and others 2003).

We have developed hydraulic barrier sheet is called triple liner system (it is referred to as TLS after this) as shown Figure 1.

TLS is used polyurethane elastomer as an intermediate material between double geomembrane sheets, and this polyurethane elastomer as nonlinear material has low conductivity (less than 10^{-13}-10^{-14}cm/s) and high flexibility (the maximum tension strain more than 650%). Therefore TLS has triple liner structure and this system has high hydraulic barrier function in itself only (Kamon and others 2002). And TLS have been already checked the basic performance about the barrier function and flexibility in the laboratory tests(Kamon and others 2002).

In this study we have carried out the loading tests to investigate the durability of TLS against the damage in the cause of the local pressure generated by the uneven ground surface and upper load in the sea area landfill site. So in the loading tests we have reproduced the uneven slope ground surface in the sea area landfill site used by the No.2 crush stone and the local pressure condition.

In this paper we have explained this loading test in detail and the results of these loading tests. And we have estimated the durability of TLS and compared the durability of TLS and of the hydraulic barrier structure used by the geomembrane sheets and the nonwoven geotextile.

2. The Loading Test and Test Cases

Figure 2 shows the view of the loading test apparatus and Figure 3 shows the outline of the loading tests apparatus. The loading test apparatus has been composed with (inner size: length 50cm × width

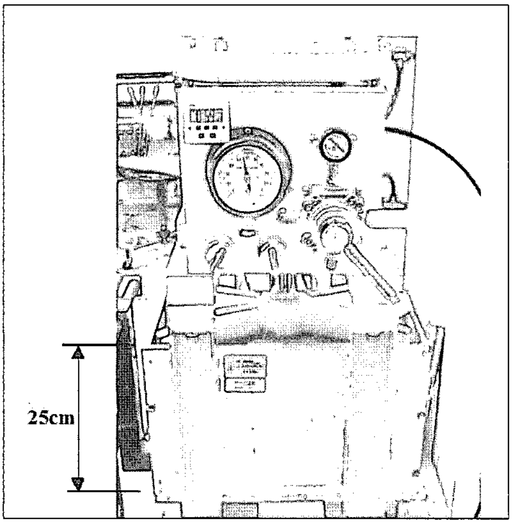

Figure 2. View of the loading test apparatus

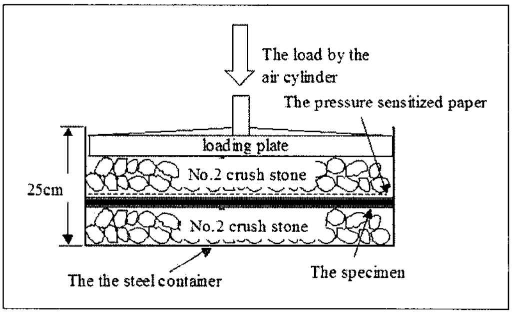

Figure 3. Outline of the loading test apparatus

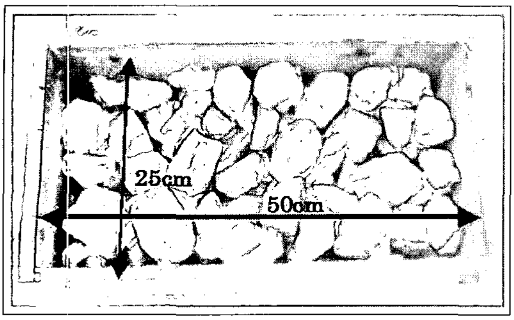

Figure 4. Model uneven ground layer used No.2 crush stones

Table 1. Indication of each test combination

GT45	nonwoven geot extile/the unit area weigt of 450g/㎡
Ps	PVC goemembrane sheet: thickness 3mm
Ls	LLDPE goemembrane sheet: thickness 1.5mm
PU1 · Ps	TLS PVC goemembrane sheet: thickness 3mm Polyurethane elastomer: thicness 10mm
PU2 · Ps	TLS PVC goemembrane sheet: thickness 3mm Polyurethane elastomer: thicness 20mm
PU1 · Ps	TLS LLDPE goemembrane sheet: thickness 1.5mm Polyurethane elastomer: thicness 10mm
PU2 · Ps	TLS LLDPE goemembrane sheet: thickness 1.5mm Polyurethane elastomer: thicness 20mm

The combination of the model hydraulic barrier
$PU_1 \cdot Ps$
$PU_2 \cdot Ps$
$PU_1 \cdot Ls$
$GT_{45} + PU_1 \cdot Ps + GT_{45}$
$GT_{45} + PU_2 \cdot Ps + GT_{45}$
$GT_{45} + PU_1 \cdot Ls + GT_{45}$
$GT_{45} + PU_2 \cdot Ls + GT_{45}$
$GT_{45} + Ps + GT_{45} + Ps + GT_{45}$
$GT_{45} + Ls + GT_{45} + Ls + GT_{45}$
GT_{45} + Ps? + GT_{45}
GT_{45} + Ls? + GT_{45}

25cm × depth 25cm), the air cylinder and guide frames. In the loading test, first the crushed stone are put into the container and leveled in about 9cm height. And next TLS or the other test specimen (the geomembrane and nonwoven geotextile) is spread on the model ground surface. And the crushed stone are put on the test specimen again and leveled in about 9cm height as shown Figure 4.

The loading has been loaded on the surface of the second crush stone layer. In these tests the crush stone was used No.2 crush stone (grain size: 40mm-60mm). The grain size of this crush stone is bigger than other crush stone in the field slope ground material and this crush stone are shaped the bigger uneven ground surface.

The unit weight of the crush stone layer was 1.35gf/cm³ in the target. But In these tests the average unit weight of the crush stone layer was 1.48gf/cm³.

On the other hand the loading tests were carried out with 294kPa load that was estimated at the point of depth 15m in the sea area landfill site. The loading time interval was set one hour, because the settlement of the crush stone layers has been almost zero in one hour.

In the loading tests the combinations of TLS, geomembrane and nonwoven geotextile have been carried out. In this study nonwoven geotextile was used in unit area weight of 450g/m², and the geomembrane sheets were used PVC and LLDPE sheet.

And we have investigated the durability of the hydraulic barrier structure used by this nonwoven geotextile, geomembrane sheets and TLS.

The pressure sensitized paper were spread on the specimen (it is referred to as model hydraulic barrier

Table 2. List of all test results

No	test combination	nonwoven geotextile	tests resule	
			max. local pressure (MPa)	damage level
A-1	$PU_1 \cdot Ps$	-	78.3	1
A-2	$PU_2 \cdot Ps$		62.6	1
A-3	$PU_1 \cdot Ls$		79.3	1
B-1	$GT_{45} + PU_1 \cdot Ps + GT_{45}$	the unit area weight 450g/m²	12.6	1
B-2	$GT_{45} + PU_2 \cdot Ps + GT_{45}$		18.1	1
B-3	$GT_{45} + PU_1 \cdot Ls + GT_{45}$		69.5	1
B-4	$GT_{45} + PU_2 \cdot Ls + GT_{45}$		59.8	1
C-1	$GT_{45} + Ps + GT_{45} + Ps + GT_{45}$		110.43	3
C-2	$GT_{45} + Ls + GT_{45} + Ls + GT_{45}$		80.6	2
C-3	GT_{45} + Ps? + GT_{45}		49.7	2
C-4	GT_{45} + Ls? + GT_{45}		143.7	3

after this), to investigate the local pressure and distribution of the local pressure on their surface.

Table 1 shows the indication of each test combination.

3. Test Results

Table 2 shows the extent of damage on the model hydraulic barrier surface after these tests and the maximum contact pressure on the each model surface during loading.

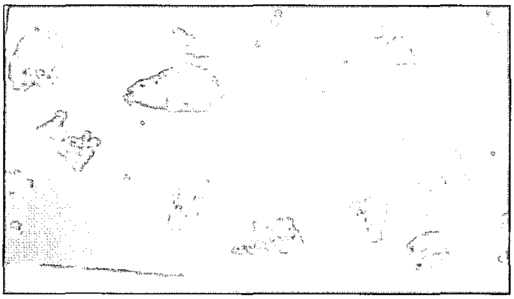

Figure 5. Condition of TLS surface after loading test

We have classified the damage condition of all model hydraulic barrier after the test as follows that,

1. Level 1: normal condition
2. Level 2: the condition that there is possibility of the damage on the model surface
3. Level 3: the condition that the model surface has been damaged.

Level 2 means the case that there are the trace or the hollow of pushing the crush stone edges into the nonwoven geotextile or into the geomembrane sheets surface and there is the possibility of the damage on the model surface.

Level 3 means the case that there are the damage or the penetrated hole on the model hydraulic barrier surface. The tests case of TLS only (A-1 to A-3) and combination case of TLS and nonwoven (B-1 to B-4) were all Level 1 as shown Table 1.

Figure 5 shows the condition of TLS surface after

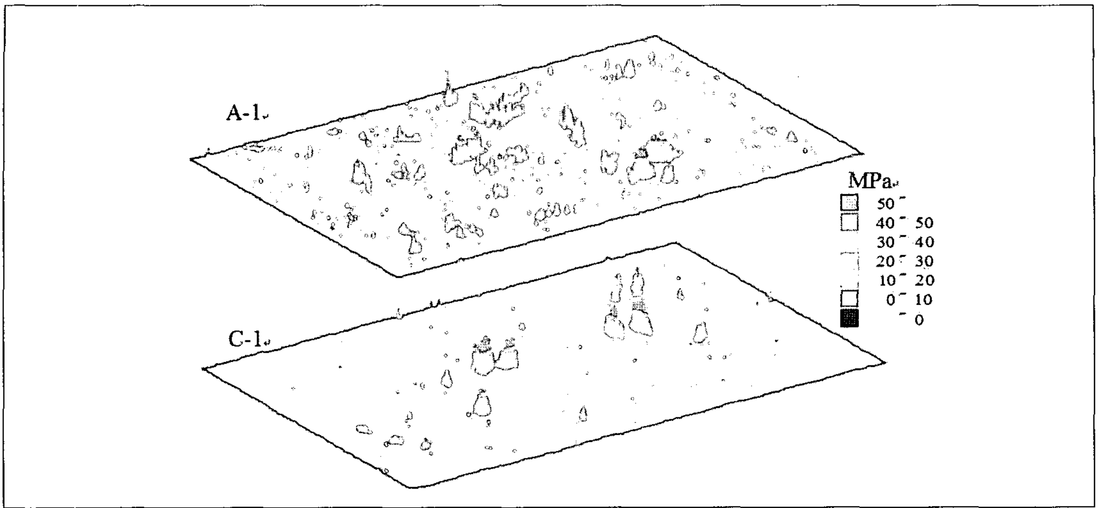

Figure 6. 3-D contour of the contact pressure on the model hydraulic barrier surface in A-1 and C-1

loading test in A-2. There was no damage of TLS surface though the marks of the several crush stones pushed have been put on the TLS surface.

On the other hand, in the combination cases of the geomembrane and nonwoven geotextile the damage level were level 2 or level 3. And it seemed that the durability of these combinations case are not higher than TLS only cases

Figure 6 shows the 3-D contour of the contact pressure on the model hydraulic barrier surface in A-1 (the TLS only case) and C-1 (the combination case of the geomembrane and nonwoven geotextile). And the damage level of A-1 was level 1 and C-1 was level 3 as shown Figure 6.

In the test C-1 it seemed that the contact pressure area were relatively smaller than A-1 and the contact pressure were higher than A-1 and it was assumed that the relation the contact pressure and contact pressure area will be caused the damage.

And then we have checked the contact pressure area and the maximum contact pressure in all test cases and investigated the relation between the maximum contact pressure and contact pressure area ratio (the model surface area versus contact pressure (more than 1MPa) area).

Figure 7 shows the relation between the maximum contact pressure and ratio of the contact pressure area

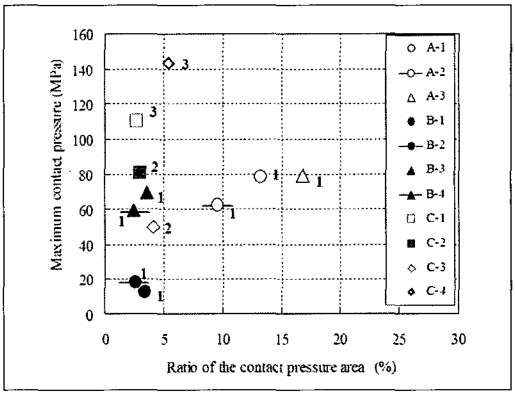

Figure 7. Relation between the maximum contact pressure and ratio of the contact pressure area

in all test cases. And the damage level of each test was indicated into Figure 7.

In the C-series loading tests (the combination of the geomembrane and nonwoven geotextile) the ratio of the contact pressure area were about 5%, the maximum contact pressure were more than 60MPa and the damage level were more than level 2.

On the other hand in the A-series tests (TLS only and B-series (TLS only cases and the combination of TLS and nonwoven geotextile) the ratio of the contact pressure area were about 5% and the maximum contact pressure were more than 60MPa, however the damage level were level 1.

And when the maximum contact pressure was about 80MPa, the ratio of the contact pressure area had been increased from 15 % to 20% and the damage level were level 1. In other words, it assumed that when the local pressure has increased by the cause that the uneven ground cusps have shoved into TLS surface, the polyurethane nonlinear elastomer (thickness: 10mm - 20mm) as the intermediate protecting layer has dispersed the local pressure. Therefore it seemed that there were no damage of TLS by this dispersion mechanism of TLS.

From these results of the loading tests, it seems that it is expected that the thickness 10mm intermediate protecting layer have the sufficient durability.

On the other hand in the combination case of the geomembrane sheet and nonwoven geotextile it seemed that the durability of the model hydraulic barrier have been influenced by the damage strength not the dispersion mechanism of them and that therefore the geomembrane sheets (PVC and LLDPE) have been damaged by the contact pressure more than their damage strength.

4. Conclusion

In this study we have carried out the loading tests to investigate the TLS damage durability against the local pressure on the base ground surface in the sea area landfill site. And we have recognized the conclusion as follows that,

1. It assumed that when the local pressure has increased by the cause that the uneven ground cusps have shoved into TLS surface, the polyurethane nonlinear elastomer (thickness: 10mm - 20mm) as the intermediate protecting layer has dispersed the local pressure
2. It seemed that there were no damage of TLS by the dispersion mechanism of TLS,
3. In the combination of the geomembrane and nonwoven geotextile it seemed that the durability of the model hydraulic barrier have been influenced by the damage strength not the dispersion mechanism of them
4. The geomembrane sheets (PVC and LLDPE) has been damaged by the contact pressure more than their damage strength.

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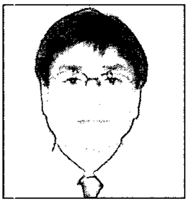

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