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Drainage effect of geosynthetics in high and very wet embankment

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ABSTRACT: Construction a high embankment using high water content clay, a belt drainage material is used as a drainage system in the embankment. And placing geosynthetics obtains a good result due to the accelerated consolidation effect of the drainage material. Based on the field observation results so far, horizontal displacements both during and after the construction period were found to be significantly small compared to the vertical displacements, and the effect on confining the displacement of the embankment (reinforcing effect) was considered to exist. Then a plate-type strain meter was set on the belt drainage material placed in the embankment, the stress generated in the drainage material was measured, and the reinforcing effect was confirmed. In addition, displacement measurement at the surface of the embankment by the inver wire extensometer , and field displacement measurement in the embankment by the inclinometer, and the settlement plate, were carried out. This paper reports on the discussion on the drainage effect and the reinforcing effect of the belt drainage material placed in a staggered arrangement in the embankment, from the measurement results.

1 INTRODUCTION

When constructing a high embankment using high water content clay, countermeasure shall be taken in order to stabilize the embankment. One of the countermeasure is to placing geosynthetics having drainage mechanism in the embankment. As this method has an advantage of utilizing low quality materials generated at site for embankment, it can be said as a effective method field observation and environmental points of view.

In actual construction, two belt drainage materials having different properties in permeability and stiffness were placed in an about 20 meter higb embankment, and field observation of the embankment was carried out.

Here describes the drainage effect and the reinforcing effect of the belt drainage material placed in a staggered arrangement in the embankment.

2 OVERVIEW OF MEASUREMENT

2.1 *Configuration of the embankment*

Configuration of the embankment is 20 m high, 1:2.0 slope inclination, as shown in Figure1. The drainage material was placed at every 5 m height, and at every 2 m horizontal interval, in a staggered arrangement. Drainage material A of high stiffness was mainly placed at the section No.1, and drainage material B of low stiffness was mainly placed at the section No.2.

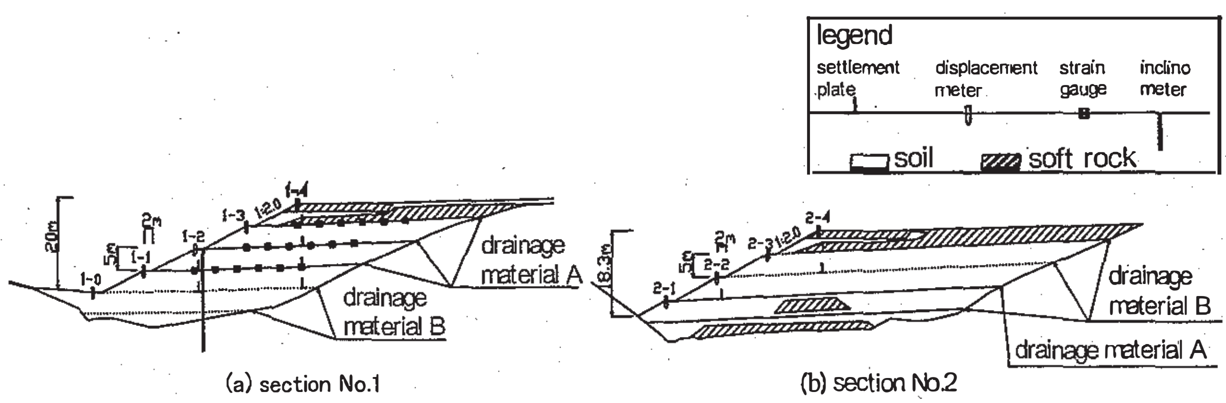


Figure 1. Configuration of embankment.

Table 1. Measurement scheme.

	Settlement	Displacement at surface	Displacement in ground	Strain of drainage material
Measurement method	Settlement plate	Electro optical	Inclinometer	Strain gauge
Section No.1	o	o	o	o
Section No.2	o	o		

2.2 *Measurement*

The measurement carried out at each section is shown in Table 1.

Interval of the measurement was once per day, and it started immediately after the setting. After the completion of the construction, the measurement was continued at properly extended intervals.

2.3 *Measurement apparatus*

As the drainage material is a composite material, it is not feasible to attach a strain gauge directly. Therefore, a polyethylene sheet on which the strain gauge was attached, was sandwiched with aluminum plates, and this device was fixed to the drainage material with bolts, and measurement was carried out (as see in Figure 2, Figure 3).

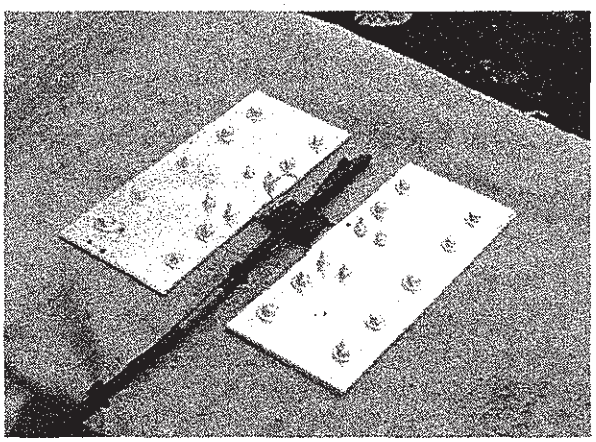


Figure 2. Outlook of strain measurement.

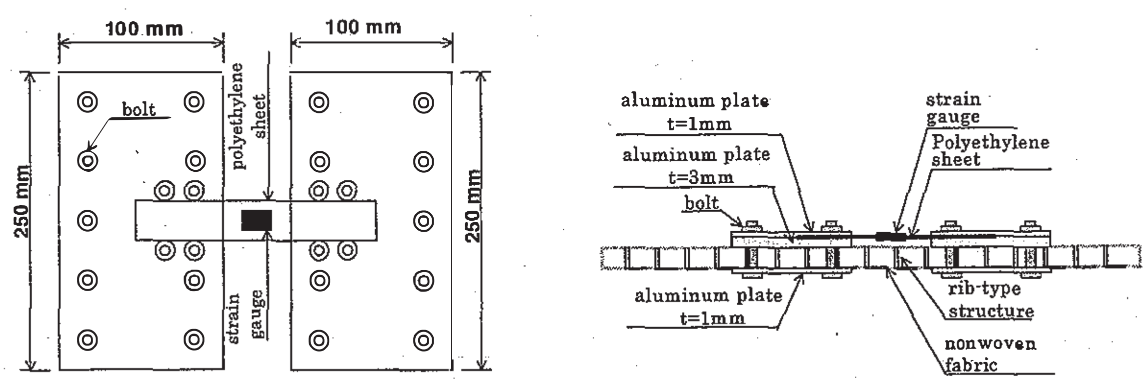


Figure 3. Detail of strain measurement.

3. MATERIAL PROPERTIES

3.1 *Embankment material*

Embankment materials were soil material aggressively weathered, or become clayly from tuffy breccia and andesite, and soft rock material. The natural water content of the material was high such as from about 50 % to 70 %, and the decrease in strength due to re-mixing was significant. Properties of the embankment material are shown in Table 2.

Table 2. Properties of embankment material.

Name of sample		Soil	Soft rock
Density of soil particle ρ_s (g/cm^3)		2.630~2.691	2.677~2.695
Natural water content Wn (%)		53.7~68.1	8.3~26.4
Particle Size	Gravel 2~75mm (%)	35.1~65.6	70.1~18.6
	Sand 75μm~2mm (%)	24.5~26.3	7.5~18.6
	Fine particles smaller than 75μm (%)	9.9~39.2	2.9~4.0
Liquid limit W_L(%)		75.0~99.3	—
Plastic limit Wp(%)		48.3~62.9	—
Plasticity index Ip(%)		26.7~46.0	—
Maximum dry density ρ_{dmax} (g/cm^3)		0.908~1.068	1.461~1.840
Optimum water content Wopt (%)		44.0~58.0	15.2~24.5

3.2 *Horizontal Belt drainage material*

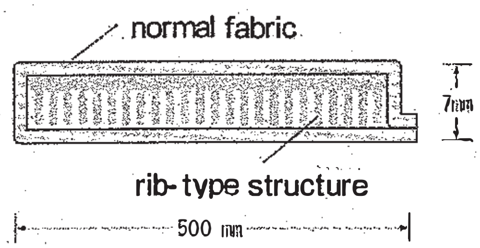
3.2.1 *Drainage material A*

As shown in Figure 4.(a), it is a plate-like drainage material consisting of HDPE rib-type structure wrapped with PP spun bonded nonwoven fabric. Its width is 50 cm, and its thickness is 0.7 cm. As shown in Figure 5, its tensile strength is 16.0 kN/m.

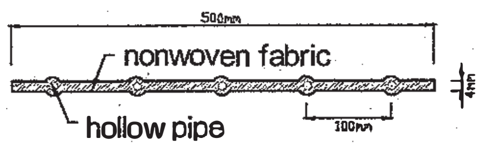
3.2.2 *Drainage material B*

As shown in Figure 4(b), it is a plate-like drainage material made of polyester nonwoven fabric in which polyester hollow tubes are embedded at 10 cm interval in a width direction. It is 50 cm wide and 0.4 cm thick, and has its tensile strength of 13 kN/m. Strain is larger than that of the drainage material A. It has low strength, and low stiffness material properties.

Table 3 shows properties of each drainage material.



(a) Drainage material A



(b) Drainage material B

Figure 4. Detail of drainage material.

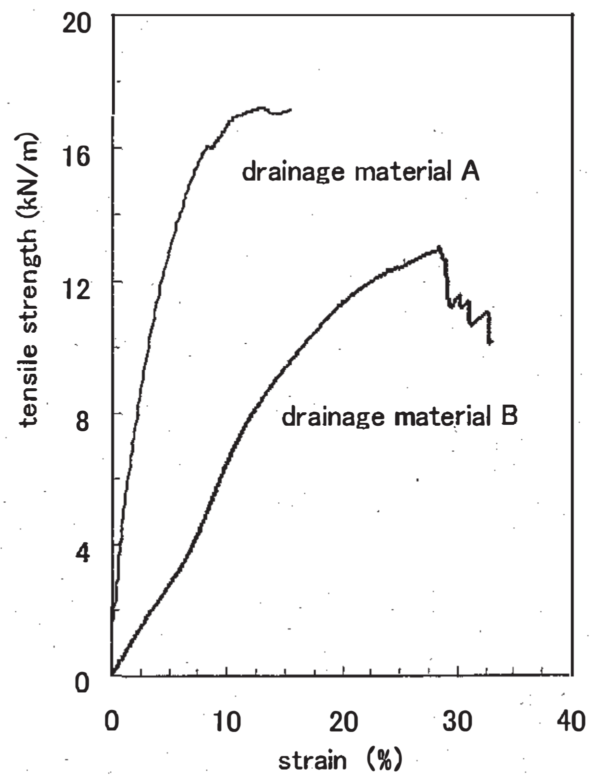


Figure 5. Tensile test result.

Table 3. Properties of drainage material.

Item		Drainage material A	Drainage material B	Remarks
Tensile strength (kN/m)		16.0	13.0	①
Strain (%)		12.5	27.0	
Section area	Width (cm)	50.0	50.0	
	Height (cm)	0.7	0.4	
	Section area (cm^2)	35.0	20.0	
Core material section area (cm^2)		17.45	—	
Inner permeability coefficient (cm/sec)		—	0.25	②
Flow rate (cm^3/sec)		150	0.16	

① Strain rate 5 %/min

② Flow rate test

Earth cover: 20kN/m^2

Hydraulic gradient: 4%

4 MEASUREMENT RESULTS

4.1 *Measurement results*

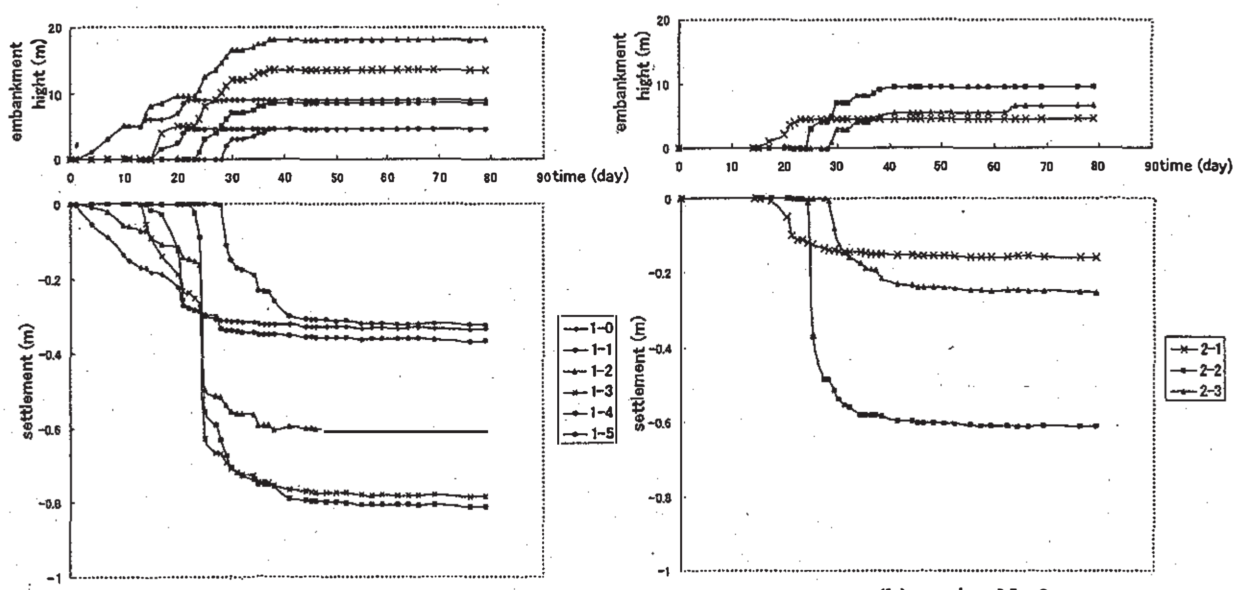
Figure 6 (a) and (b) show results of the settlement measurement at the section No.1 and No.2, respectively. At the section No.1, settlement of 61.4 cm was observed for the embankment height of 20 m, which was a consolidation settlement about 3 % of the embankment height. Consolidation was almost completed in about 40 days at either section, which was within the whole construction period of the embankment. Therefore, it was confirmed that a sufficient consolidation effect was obtained at either section.

The magnitude and speed of settlement at both sections were about the same.

4.2 *Displacement measurement at surface*

From the results of the displacement measurement at the surfaces by the sensors set on each shoulder of the embankment, the maximum horizontal displacement was about 2.5 cm at the section No.1, and about 4.0 cm at the section No.2, both to the slope side, which were very small displacement compared to the embankment height. Only the horizontal movement at the 3 rd shoulder took place toward the opposite of the slope side, and the similar behaviors were observed at every section.

However, judging from the displacement vector shown in Figure 7, vertical displacement dominates more than the horizontal displacement at the section No.1, whereas at the section No.2, horizontal displacement dominates. Thus, as though the similar



(a) section No.1

(b) section No.2

Figure 6. Results of settlement measurement.

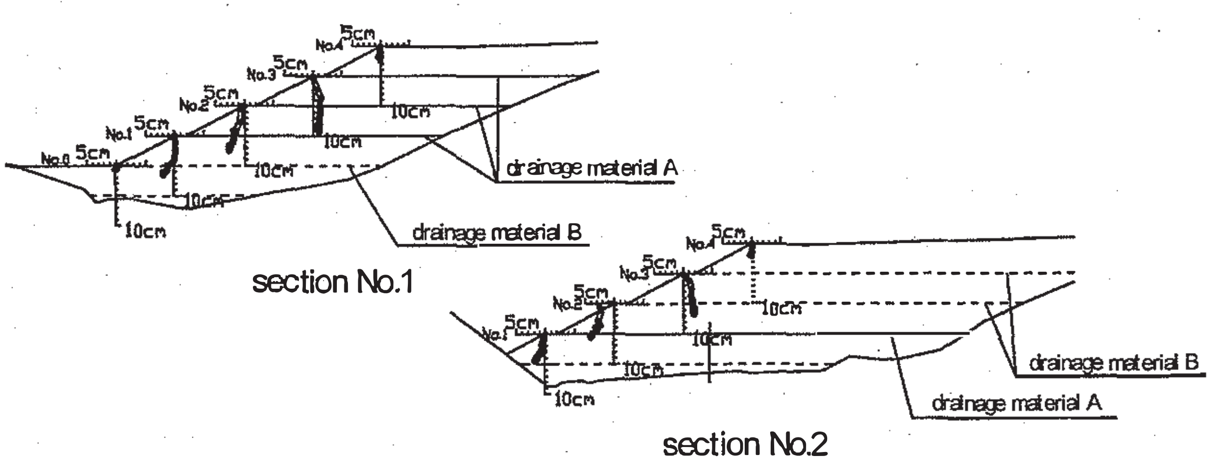


Figure 7. Displacement vector at ground surface.

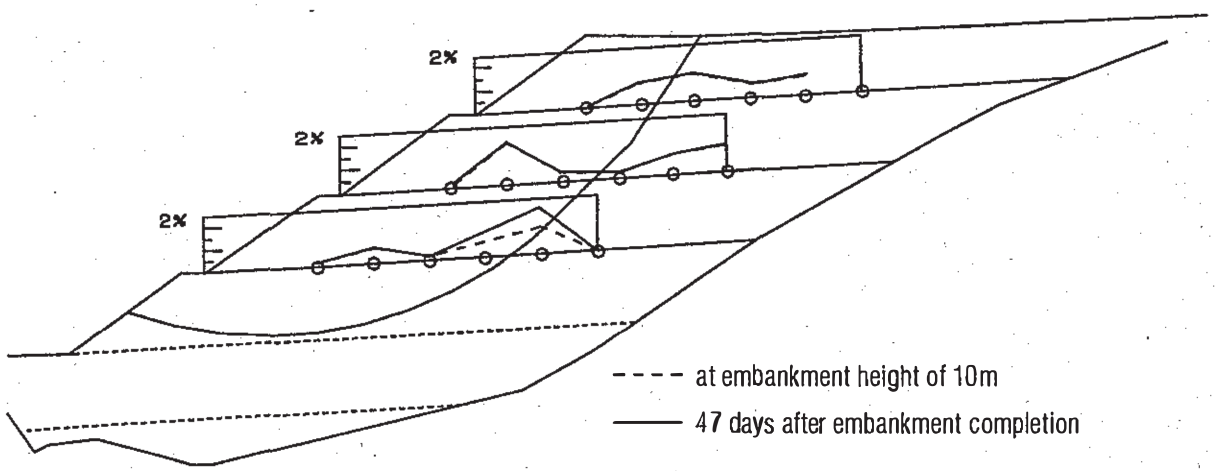


Figure 8. Result of displacement measurement in ground (section No.1).

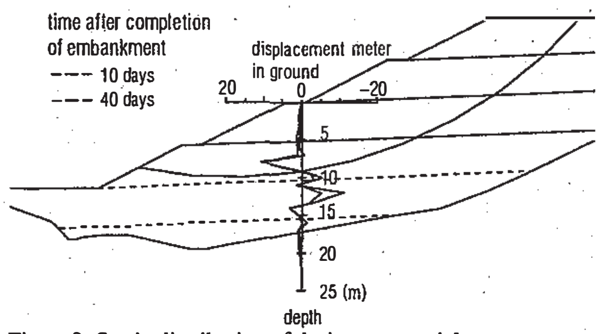


Figure 9. Strain distribution of drainage material.

deformation patterns are shown at those two sections, the section No.2 is considered to exhibits the more dangerous behavior. Though the difference is minimal, the absolute horizontal displacement at the section No.1 is smaller than that at the section No.2. If this can be attributed to the difference in the stiffness and the strength of the drainage material at each section, the drainage material is considered to resist against the tensile stress, and to confine the deformation.

4.3 *Measurement of displacement in the ground*

Figure 8 shows the distribution of the displacement in the ground measured at the section No.1. In this figure, taking the ground displacement at the completion of the embankment (embankment height of 20 m) as the initial value, the differential displacement at 10 days, and 40 days after the completion are exhibited. As shown in the figure, divided by the potential circular sliding line, the upper part displaced toward the slope front side, and the lower part displaced toward the opposite side. It is thus confirmed to become almost the same result as the circular case.

4.4 *Strain measurement of drainage material*

Figure 9 shows the strain distributions at the embankment height of 10 m, and at 47 days after the completion of the embankment. The circular line shown in the figure is the one gives the minimum safety factor.

The strain in the drainage material tends to exhibit its maximum either immediately after, or at several days after the completion of the embankment, and to decrease as time passes after that.

For the strain distributions in the first and third layers, the maximum strain takes place at the circular failure line. For that in the second layer, an increase in strain is shown at the fixed part in the outer side of the circular line. Its strain is about 2 %. Estimated from the results of the tensile test, this holds tensile stress of about 6 kN/m.

Therefore, from the design method of the reinforced embankment, this contribute little to the stability of the embankment. However, as the horizontal displacement is very small, the drainage material is considered to be effective in confining the displacement.

5 CONCLUSIONS

In this study, drainage materials having different drainage capacity and stiffness were used and compared. As a result, for all drainage materials, the settlement was almost completed within the construction period of the embankment, and sufficient consolidation effect was obtained.

At the section where the drainage material of high stiffness was placed, the horizontal displacement was found smaller, and deformation was more confined than the drainage material of lower stiffness.

The stress level generated in the drainage material was about 6 kN/m, and the drainage material is considered to work as a reinforcing material, and to be effective in being integrated with the embankment From this study, it was verified that the drainage material could act as reinforcing material, other than its original drainage purpose.

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