A qualitative improvement of river dykes with breathable and waterproof fabrics

Takayuki MASUO

Taiyokogyo.Corp.(SUN)

Toshifumi MUKUNOKI / Kazuki HINO
Kumamoto Univ.

Masatoshi ISHIDA / Kenji HARA
Taiyokogyo.Corp.(SUN)

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ABSTRACT:
In general, waterproof geomembranes are installed underneath dyke slope to prevent from water immersion into the river dykes. However, the behavior of water migration in the river dykes should be in three dimensions so somehow water can permeate into the river dykes. Meanwhile, the river dyke installing geomembranes has the issue that air and water under geomembranes would not be removed out from the river dykes quickly. This is indicates that river dykes keep high saturation degree even though the heavy rain stops. In order to to create the mechanism of drainage from dyke inside, authors propose that active intake of air into dyke is effective. Nowadays, there is a new geosynthetic materials called Breathable and waterproof fabrics (refered as BWF herein). The developed sheets are not impermeable sheets such as geomembrane but have low permeability with air conductivity..
The objective of this study is to understand the water migration in the soil installing BWF and to propose the new design concept to construct river dykes. In order to observe the water migration in the soil, an experimental apparatus using X-ray Computed Tomography (CT) scanner was newly developed to visually observe the states of air intake through various waterproof breathable fabrics ,usual non-woven Geotextiles and waterproof Geomembranes.. , Based on these test results, relationship between drainage and air intake through the fabric will be discussed in the paper.. Their properties of breathability are different from fabrics to fabrics depending on their production methods.

1 INTRODUCTION

An abnormal weather, such as a sea water rise, has been reported everywhere on the earth due to the global warming. IPCC reported on its 4th report that we are living in an environment which can be easily turn into high precipitation and high expectation of concentrated heavy rain. Intense precipitation rate days of more than 200mm/day have been increasing over long time period as shown in Fig. 1.

Average year precipitation rate in Japan is about 2000mm and it shows typical temperate zone climate that year around rain is observed. However, the number of washout of river dyke which cause severe damage on civic lives has been increased because of increase of precipitation and increase of concentrated heavy rain.

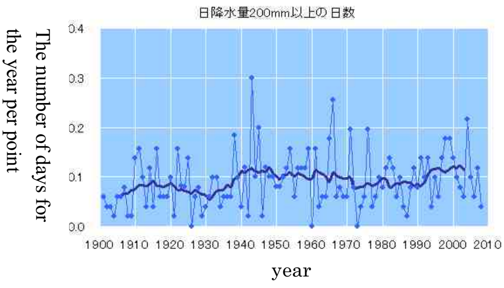


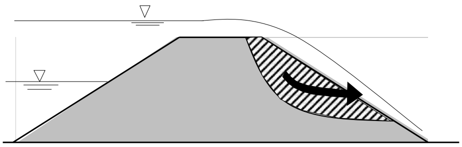
Fig.1 Long-term changes about the number of days over 200mm daily rainfall at 51pionts in Japan

Photo-1 Appearance a failure of dyke[2)]

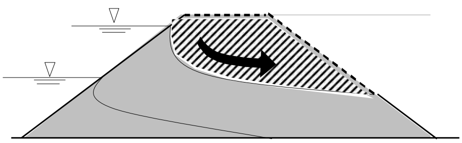
Photo-1 shows an example of flooding due to swelling of a river. The interior of the dyke was immersed due to the swelling and it made the saturation level of soil inside the dyke increased. This increased saturation level was the cause of the decreasing of shear strength of the soil to make the dyke body weak and this was the cause of the failure of the dyke.

Generally, a failure of dyke is classified into following 2 categories;

1) Overflow failure: Overflowed river water causes a landside slope failure which leads to a dyke break, and
2) Permeable failure: immersed water into dyke causes a decrease of shear strength of soil inside leads to a dyke break.



(1)Overflow failure



(2) Permeable failure

Fig.2. Generally categories, a failure of dyke

To increase its function, a dyke has to have;

1) High resistance ability to erosion:the slope structure should be strong enough not to slide when overflow happens,
2) High waterproof ability: the slope should be well protected from immersing the water into the dyke, and
3) Fast discharge ability (breathability): the dyke should be discharge the water inside as fast as possible.

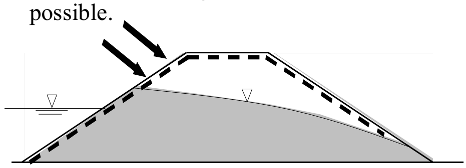


Fig.3. Anticipated efficacy from breathability of BWF

Conventionally, a combination of waterproof geomembranes and concrete blocks has been placed on the slope to prevent the permeation of river water and/or rain water into the dyke. With this conventional method, it is expected to prevent the swelling water not to immerse into the dyke. However it is irrational to expect the water inside discharge fast after the water level decrease with this method.

The report proposes an improvement for river dykes using breathable and waterproof fabrics, referred as BWF hereafter. The BWFs are to be placed on a dyke slope and are expected to interchange water and air positively so that the water inside the dyke is discharged faster. A qualitative improvement of dyke is expected because shear strength decreasing of soil could be suppressed by with this faster discharge.

2. BREATHABILTY OF BREATHABLE AND WATERPROOF FABRICS.

2-1 CT Scanning Test

2-1-1 Purpose

When BWFs are to be used for an improvement of dykes, their breathability is a very important factor to consider. To examine their breathability, an industrial X-ray computed tomography scanner (CT-Scanner) was used to visualize the water displacement inside sand specimens in which the air was introduced through a BWF.

2-1-2. Test

Saturated sand layers were placed in a simple cylindrical earth tank. The pressurized air was introduced into the sand layers through the BWF. Here, exchange of air with water by introducing pressurized air into the sand is expected.

To observe the exchange, the sand layers were CT scanned in 10mm distance. The density differences can be visualized by taking the CT-Scan images of before and after introducing the pressurized air. The conditions for CT-scanning were X-ray tube voltage of 300kV, slicing depth of 0.3mm, and pixel count of 2048 x 2048. Refer to the reference #3) for the detail of this X-ray CT-Scanner at Kumamoto University.

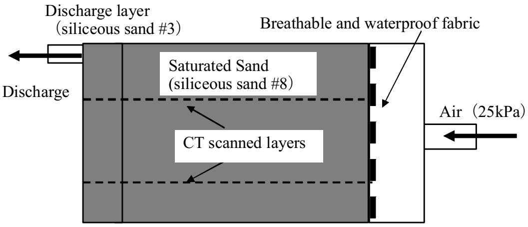


Fig.4. The test apparatus

The test apparatus is shown in Fig.4.

The diameter of the earth tank is about 10cm and its height is 13cm. Saturated SOUMA siliceous sand #8 was packed in the earth tank. Also SOUMA siliceous sand #3 was placed as a discharge layer to get faster water discharge from the tank. Table-1 shows the characteristics of BWF for the test.

Table-1 The characteristic of BWF

Item	Specification	Test Method
Material	Polyolefin Nonwoven Fabric	
Weight	$330g/m^2$	JIS L 1908
Thickness	0.8mm or more	JIS L 1908
Tensile Strength	800N/5cm or more	JIS L 1908
Permeability	1.1×10^{-9}cm/sec or less	compliance with JIS A 1218
Water Vapor Transmission Rate	$2500g/m^2 \cdot 24h$	JIS Z 0208

2-1-3. Results and Discussion

Fig. 5 and Fig.6 show the CT-scan images of before and after introducing the pressurized air, respectively. CT-scan images are shown in 256 gray-scale to visualize the density distribution of the specimens. The white part represents high density area and the black part represents low density area in the images. The discharged area is visualized as black color after the introducing pressurized air, which causes the density difference. Also, the area where the color was white initially and turned into black afterwards shows the water gets into the area. Fig.5 Average density of SOUMA siliceous sand #3 was $2.65t/m^3$ and SOUMA siliceous sand #8 was 1.5t/m3. Since the focus of CT-scanner was set to $2.65/m^3$, SOUMA siliceous sand #3 was visualized as white color area and SOUMA siliceous sand #8 was visualized as more grayish color area. Fig-6.(a). shows that the white area increased its area of SOUMA siliceous sand #3 at boundary area of two sand layers. Also it is obviously shown in Fig-6.(b) there is a discharged area. Therefore, a loose sand area was created due to exchange of initially saturated water and air. This result indicated the possibility that air was introduced through the BWF because of its breathability.

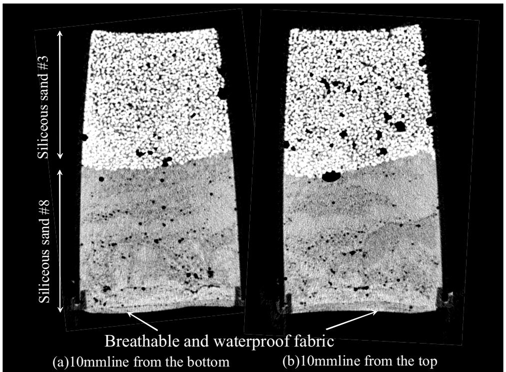


Fig.5 CT-scan images
(Inside of Test Picse before introducing the pressurized air)

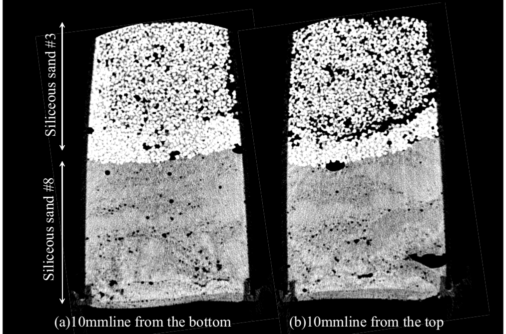


Fig.6 CT-scan images
(Inside of Test Picse after introducing the pressurized air)

2-2. Comparison of BWFs

2-2-1 Purpose

BWFs are classified into 2 categories from their manufacturing process as follows;

1) Non-woven fabric, and

2) Porous film and Non-woven fabric

Because the breathability characteristics shown by each manufacturing company differs from each other, it is very important to examine their breathability in a common unified testing method for comparison. Here, test was conducted for two different BWFs with simplified testing method to compare their breathability.

2-2-2 Test

The test apparatus is shown in Fig.7. Inner diameter of the cylindrical jar is 100mm. After the jar was filled with water, the BWF specimen was placed to seal the top opening of jar. The top surface of specimen was open to the air. For the placement of the specimen, sealing material was used so that the air comes into the jar from inside diameter of the jar only. By releasing the pinch underneath of the jar, discharge will occur if the specimen shows breathability.

The timing was measured while the water was discharged for 20cm.

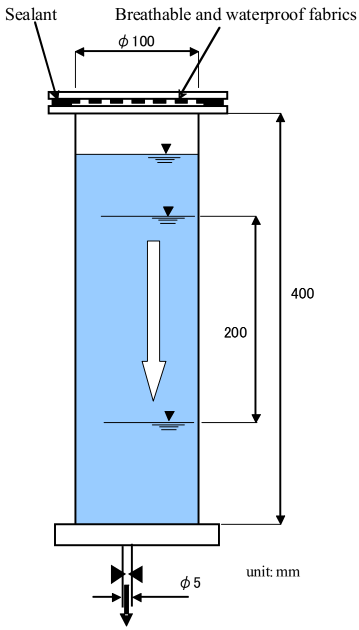


Fig.7. The test apparatus

The test was performed for 4 different types of BWFs. Also, a non-woven geotextile which is used for general erosion control was tested. And also timing was measured for without any fabric for comparison. A test with rubber sheet was made to confirm the air tightness of the apparatus.

2-2-3. Results and Discussion

2-2-3-1. breathability

The test results are shown in Table-2. The test show the water discharge while taking the air inside of the jar through BWFs. Also, the discharge rates were different from each BWFs. There is a certain BWF which shows good breathability that the discharge rate is almost same as that of without fabric and that of non-woven geotextile.

Table-2 Test Result of Breathability of BWFs

№	Test Specimen	Specification	Structural Fabric of BWF	Time(sec)			
				n=1	n=2	n=3	Ave.
1	Blank			48.53	48.59	48.03	**48.38**
2	Type.A	Breathable and waterproof fabrics	Fiber layers material	49.50	50.29	50.65	**50.15**
3	Type.B			53.69	53.89	53.96	**53.85**
4	Type.C		Fiber and porous film composite layers material	108.53	100.29	98.01	**102.28**
5	Type.D			67.92	62.45	57.64	**62.67**
6	Type.E	Nonwoven Fabric	—	52.31	52.29	52.23	**52.28**

3. CONCLUSION

To examine the breathability of breathable and waterproof fabrics (BWF), fundamental tests were performed. Comparing the visualized test images of before and after introducing the air to the earth tank, the test showed that the air was taking into the soil through the BWF. Also, it was confirmed that the difference of manufacturing procedure of BWFs results in different discharge rate through a simplified common testing method.

We will study a time growth inside the soil by taking the air and/or growth of air passage way through X-ray CT-scanning images. Also, we will further study the movement of air and water through BWFs by comparing of an opening size of BWFs and their number, physical properties of waterproof, and interaction between soil and BWFs.

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