AN EXPERIMENTAL INVESTIGATION ON THE EVALUATION OF SEEPAGE CONTROL WORK FOR SOLID WASTE LANDFILL SITES III

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ABSTRACT

In Japan, the society has been loosing confidence on the reliability of seepage control works performed at final disposal sites, especially on the construction works for ground water pollution control using geomembranes.

Considering the situation, we have been engaged in various studies since 1994, in order to establish a method for evaluating seepage control works, which is based on a new concept. The studies include research related to the damages on geomembranes, fundamental tests on geomembranes subject to a constant stress, fabrication of test apparatus which can apply combined stress on geomembranes. Based on the results of the previous studies, the authors have devised a test apparatus capable of applying representative combined stresses (e.g. penetration stress, multi-axial tensile stress and tearing stress), which could occur in an actual waste landfill, to geomembranes, and have conducted tests using this apparatus in order to verify the phenomena observed in the above mentioned fundamental tests. This report describes several findings on test methods for evaluating seepage control works, which were obtained from the verification tests.

INTRODUCTION

In Japan, the society has been loosing confidence on the reliability of seepage control works performed at final disposal sites, especially on the construction works for ground water pollution control using geomembranes.

Considering the situation, the Study Group of the Board of Landfill Techniques and Systems has been engaged in technical development projects, which study from various perspectives the ways to enhance the safety of seepage control works using geomembranes for final disposal sites. Another objective of these studies was to regain the society's confidence and esteem for seepage control works. The authors attempted to establish test methods to evaluate seepage control works using geomembranes, and has developed a new testing apparatus described below.(Study Group of The Board of Landfill Techniques and Systems, 1995 and 1996 and 1998 and Ebihara et al, 1999)

This paper describes the results obtained at the tests leading to fracture of seepage control works under various conditions, using the test methods we have developed.

PARTICULARS OF THE STUDY

The following summarizes our objectives for the study, its basic flow, and current status, referring to

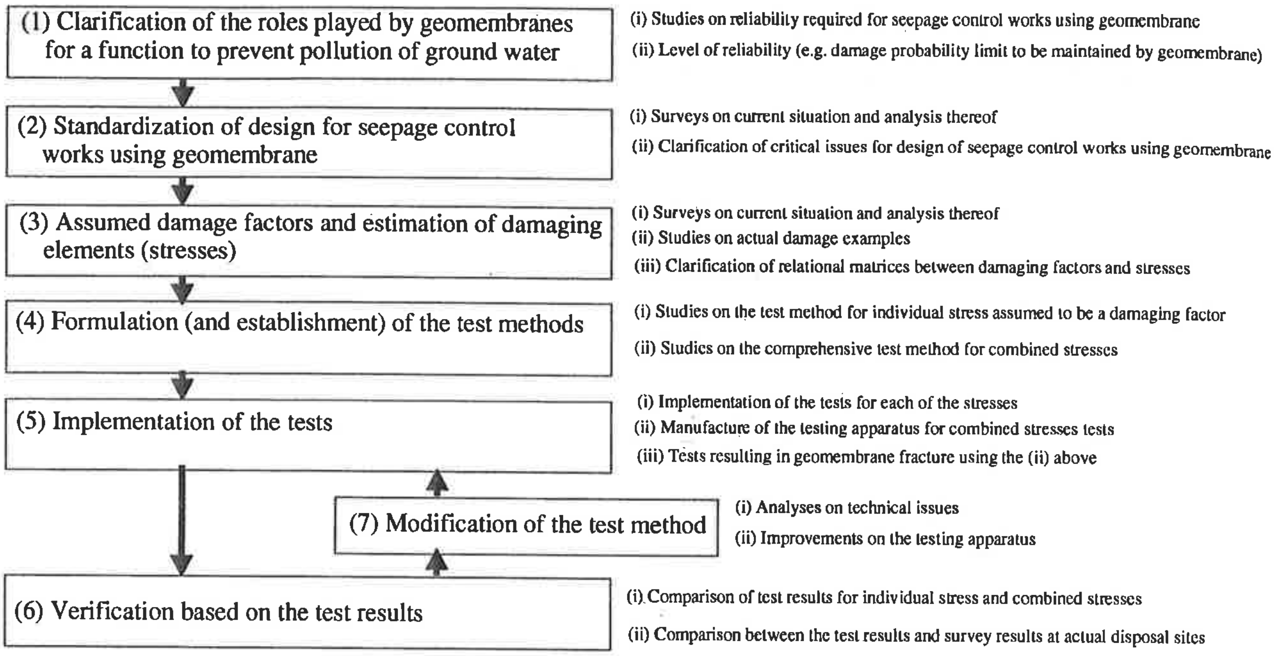

FIGURE 1 BASIC FLOW OF THE STUDY

Figure 1.

- At an initial stage of the study, items (3), (4) and (5)(i) shown in Figure 1 were completed.
- Tasks remain to be performed for items (5)through (7), in order to clarify proper testing apparatus and methods.
  We consider it is also important to carry out item (6) (ii).
- Items (1) and (2) comprise prerequisites of the study, of which the outcomes are yet to be finalized. We believe it is necessary to provide feedback, and to reconsider these items based on results of other studies.
  From the results of the study so far, it is known that the stresses resulting in damage of geomembranes, or in other words the main stresses acting on the seepage control works using geomembranes, are:
  (i) tensile forces (uniaxial, biaxial and multi-axial);
  (ii) tearing force; and
  (iii) penetrating force.

It was assumed that these forces are likely to be exerted in various combinations, rather than as a solely working damaging element.3)
Deteriorations due to "ultraviolet rays," "ozone," "temperature changes," "freezing" and "moisture," or those caused by weathering, chemical reactions, and damages at connections, were not considered for the study. It is because these deteriorations could only derive from the material characteristics of geomembrane, and therefore countermeasures should be formulated in terms of membrane specifications and construction methods.
Thus, test methods assuming combinations of the above three types of stresses to be exerted on seepage control works were studied, by which a destructive test method using six types of stab terminals, a universal testing machine, and some other equipment, has been derived.3)

OUTLINE OF THE TESTS FOR VERIFICATION

Testing apparatus

Figure 2 shows the testing apparatus developed and used for the study. The apparatus mainly consists of a constant temperature water tank to maintain geomembranes at moisture and temperature conditions similar to those found at actual sites, molds and flanges to fix a membrane and to lay a base layer, a universal testing machine, and stab terminals to be pressed onto geomembranes for testing.
Stab terminals were prepared to enable testing of the three types of forces that are known from the results of previous studies to damage geomembranes, through interactions with flanges used for fixing them. (See Figure 3.)

Test method

The tests were performed by the following processes:
(i)a stab terminal to be used was fixed onto the universal testing machine;

(ii) flanges attached with the specimen were set at a prescribed position in the constant temperature water tank on the universal testing machine;
(iii) the universal testing machine was adjusted so that the tip of the stab terminal is immediately in front of (directly above) the specimen;
(iv) velocity of the universal testing machine was set to the prescribed level;
(v) the universal testing machine was actuated to start the test;
(vi) the specimen was monitored through the window of the constant temperature water tank and observation holes of the flanges, to capture and record onto a test sheet the moment when the stab terminal pierces through the specimen;
(vii) the test was continued until the specimen fractured completely, at which time the universal testing machine was stopped; however, the tests were suspended before fracture of the specimen when the test load almost reached the maximum load of the universal testing machine, or when the tip of a stab terminal neared the flange bottom, since continuation of the test under these circumstances may result in a damage to the testing apparatus; and
(viii) the universal testing machine was restored to the original state, to repeat the same procedure for another set of flanges and specimen after setting them in the constant temperature water tank on the universal testing machine.
The test conditions for the study are summarized in Table 1 below.
Although the temperature of geomembranes placed in a disposal site is usually around 28° C (under a protective layer 50cm thick)(Oshikata,1996)tests were also performed at higher temperatures up to 60° C to enable analyses in a future of data pertaining to the effect of stabbing velocities.(Suzuki et al, 1995)

TEST RESULTS

The results of the above mentioned tests are shown below:

Effect of different stabbing velocities (Figure 4)

Example test conditions: [Protective mat] Used、[Water temperature] 60。 C、[Stab terminal] No. 3、[Base layer] Laid

・ Geomembranes A, C, and D showed higher resistance against rupture at higher velocities. The effect of stabbing velocity is more obvious for geomembrane D.
・ Geomembrane B showed almost no effect of stabbing velocities.

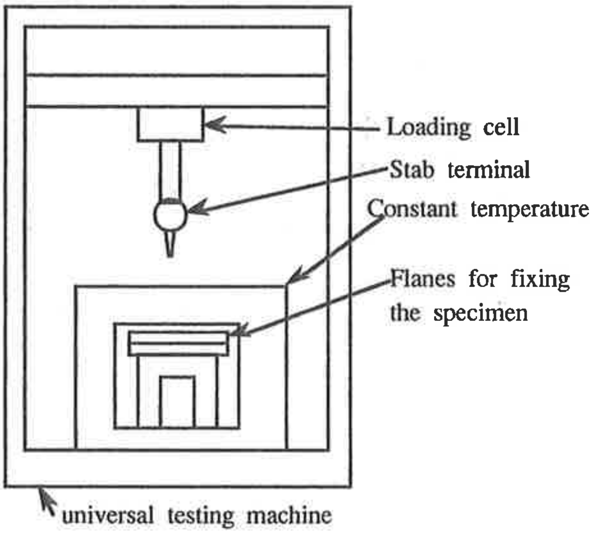

FIGURE 2 COMPOSITION OF THE TESTING APPARATUS

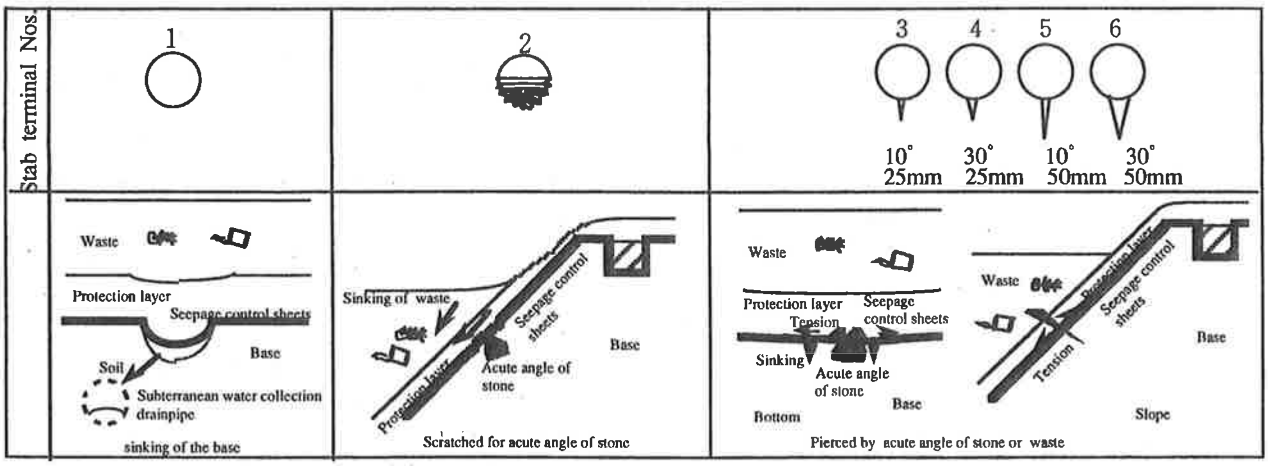

FIGURE 3 TYPE, SHAPE AND NO. OF TERMINAL

TABLE 1 TEST CONDITIONS

Items		Notes
Velocity	5 mm/min 50mm/min	
Temperature	Normal room temperature 6 0 ℃	
Protective mat	Used Not used	Geotextile with long fibers 500g／m²
Base layer	Laid Not laid	No. 6 silica sand 110 mm thick on a stylofoam layer 150 mm thick
Number of samples	3	
Types of geomembrane	TPU、TPO、HDPE、As-D	

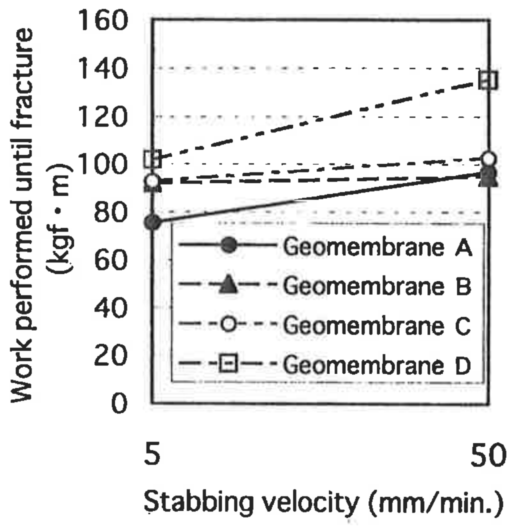

FIGURE 4 WORK PERFORMED UNTIL FRACTURE FOR DIFFERENT STABBING VELOCITIES

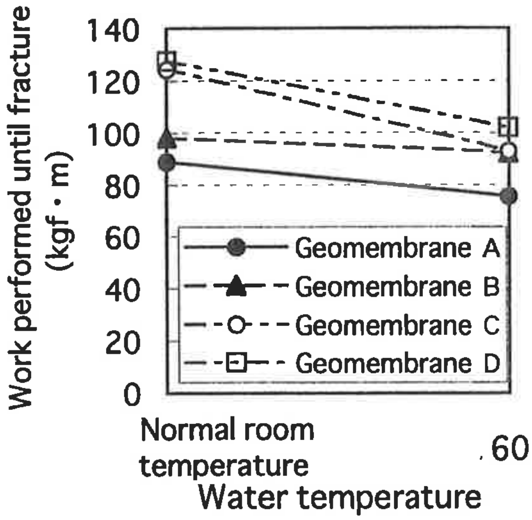

FIGURE 6 WORK PERFORMED UNTIL FRACTURE FOR DIFFERENT WATER TEMPERATURES

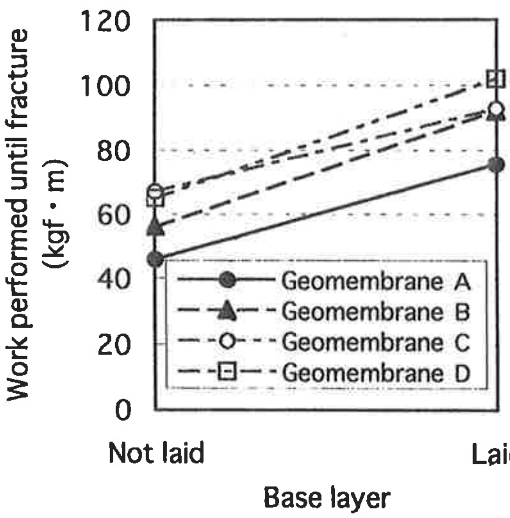

FIGURE 5 WORK PERFORMED UNTIL FRACTURE FOR CASES WITH AND WITHOUT A BASE LAYER

Effect of base layers (Figure 5)

Example test conditions: [Protective mat] Used、[Stabbing velocity] 5 mm/min.、 [Water temperature] 60。 C、 [Stab terminal] No. 3

・ All the membranes showed higher resistance against rupture when a base layer was laid.

Effect of contacting water temperatures(Figure 6)

Example test conditions:[Protective mat] Used、[Stabbing velocity] 5mm/min.、 [Stab terminal] No. 3、 [Base layer] Laid

・ Geomembranes A, C, and D showed lower resistance against rupture at higher water temperatures.

・ Geomembrane B showed no effect of water temperatures.

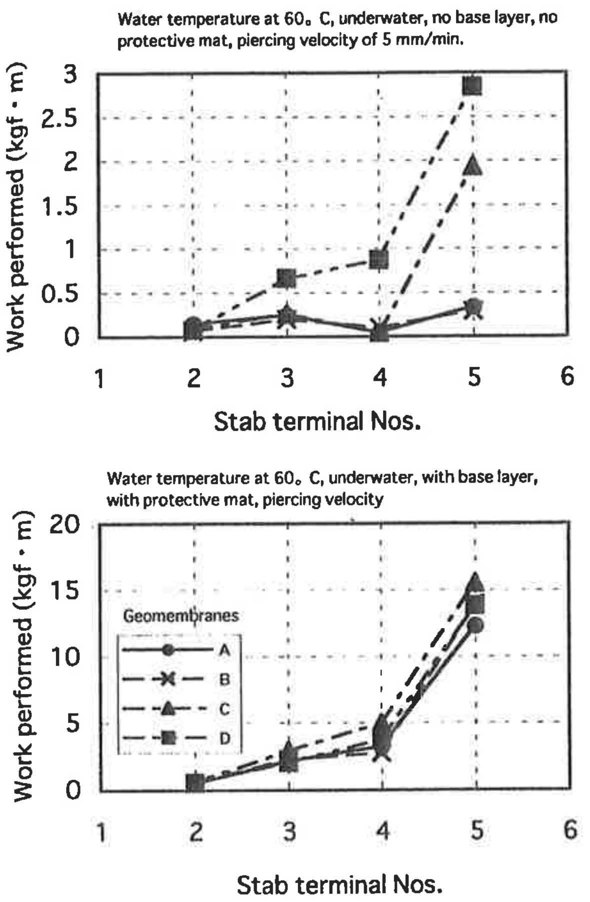

FIGURE 7 RESISTIVITY AGAINST STAB

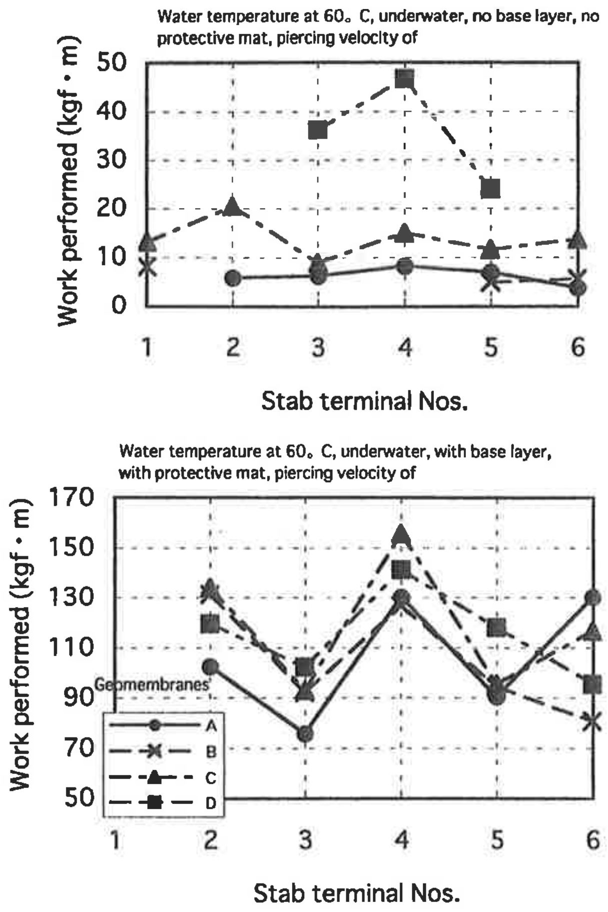

FIGURE 8 FRACTURE STRENGTH PROPERTIES

Effect of stab terminals on resistivity against stabbing and fracture strength (Figures 7 and 8)

A. Resistivity against stabbing
Example test conditions:[Protective mat] Not used、[Stabbing velocity] 5 mm/min.、[Water temperature] 60。 C、[Base layer] Not laid

・Resistivity against stabbing was lower for the cases with shorter terminals.

・Resistivity against stabbing was lower for the cases with sharper terminals.

Example test conditions:[Protective mat] Used、[Stabbing velocity] 5 mm/min.、[Water temperature] 60。 C、[Base layer] Laid

・Resistivity against stabbing was lower for the cases with shorter terminals.

・Resistivity against stabbing was lower for the cases with sharper terminals.

・For all geomembranes, resistivity against stabbing was higher under the test conditions where "protective mat was used and base layer was laid," compared to the cases where "protective mat was not used and base layer was not laid."

B. Fracture strength
Example test conditions:[Protective mat] Not used、[Stabbing velocity] 5 mm/min.、[Water temperature] 60。 C、[Base layer] Not laid

・Fracture strength differed considerably among geomembranes.

・Geomembrane D showed different fracture strengths for different stab terminals.

Example test conditions:[Protective mat] Used、[Stabbing velocity] 5 mm/min.、[Water temperature] 60。 C、[Base layer] Laid

・Similar properties were observed for fracture strengths of all geomembranes.

・Effect of the protective mat was more significant for the cases with sharper terminals.

・Test results under the conditions where "protective mat was used and base layer was laid" showed smaller differences among geomembranes for the fracture strength compared to those under the conditions where "protective mat was not used and base layer was not laid."

DISCUSSION

Figure 9 shows an example of the correlation between the results of the previously conducted fundamental tests, where a constant stress was applied on geomembranes, and the results of the tests conducted this time. The fundamental tests were conducted by the SM method6), which was developed by the Railway Technical Research Institute as a testing method for evaluating resistivity against stabbing, while the tests at this time were conducted using stab terminals Nos. 2 to 5 (correlation coefficient could not be calculated from the test using terminal No.2, since only two measurements were obtained by this test) at an ambient temperature of 20_C and at a stabbing velocity of 5 mm/min, but without using base layer. As shown in this figure, a relatively good correlation was obtained, with the correlation coefficients ranging from 0.965 to 0.996.

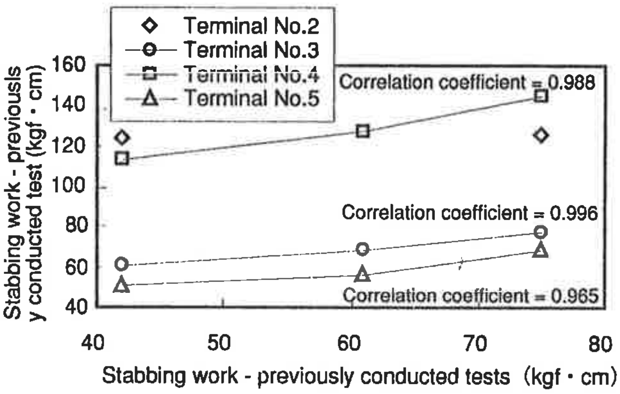

FIGURE 9 CORRELATION BETWEEN THE RESULTS OF PREVIOUSLY CONDUCTED SM STUBBING TESTS AND THE RESULTS OF STUBBING TESTS CONDUCTED THIS TIME (WITHOUT BASE LAYER)

Although the correlation shown in this figure may not be so reliable, since it is based on only three measurements for each case, it is considered that this figure provides a reference criterion.

In order to confirm this result, the correlation coefficients between the results of previously conducted fundamental tests, where a constant stress was applied on geomemberas, and the results of tests conducted this time were calculated: the results are given in Table 2. The cases with a correlation coefficient of more than 95% are surrounded with thick solid lines. As shown in this table, the results for non-base layer tests using terminals Nos. 3 to 5 had good correlations with the results of SM type and JIS type stabbing tests, but prominent inverse correlations with the results of cone tests. This indicates that although geomembranes show a good performance when tested by the methods used this time, the performance deteriorates when tested by the cone method. Among the results of multi axial tensile tests, the results of type A biaxial tests showed a good correlation with the results of non-base layer tests using terminal No.1 and the results of non-base layer tests using terminal No.3. The results of tests, where geomembranes were subject to deformation, also showed a good correlation with the results of non-base layer tests using terminal No.3. However, the results of protrusion stabbing tests, CBR stabbing tests, type B biaxial tests, and crack tests did not exhibit a prominent correlation with the results of tests conducted this time.

In summary, it was found that the results by the four methods, i.e., protrusion stabbing test, CBR

TABLE 2 CORRELATION COEFFICIENT BETWEEN THE RESULTS OF PREVIOUSLY CONDUCTED (constant stress) and the results of tests conducted this time

		Terminal	Previously conducted tests using constant stress: SM stabbing test	Protrusion stabbing test	JIS stabbing test	CBR stabbing test	Type A biaxial test	Type B biaxial test	Cone tests	Crack test	Deformation test
Tests conducted this time	Without base layer	①					1.00				
		③	1.00	-0.09	1.00	0.34	0.73	0.36	-0.96	-0.30	0.88
		④	0.99	-0.03	1.00	0.29	0.69	0.42	-0.98	-0.24	0.85
		⑤	0.97	0.09	0.99	0.18	0.60	0.52	-0.99	-0.13	0.79
	With base layer	③	0.94	-0.50	0.91	0.71	0.95	-0.06	-0.76	-0.67	1.00
		④	0.92	0.21	0.95	0.05	0.49	0.62	-1.00	-0.01	0.70
		⑤	0.88	0.31	0.92	-0.06	0.40	0.70	-0.99	0.10	0.62

Conditions for tests conducted this time: temperarture = 20° C, wet condition,stabbing velocity = 5 mm/min., with non-woven fabric (test conditions for terminal No.1: temperature = 60° C, without non-woven fabric)

Values surrounded with thick lines are correlation coefficients of more than 95%.

stabbing test, biaxial B test, and crack test, all of which were conducted in the previous study, do not have a correlation with the results of tests conducted this time. This means that these test methods are difficult to use as an alternative for the test method used this time. On the other hand, it was revealed that five tests methods, i.e., stabbing SM test, JIS stabbing test, type A biaxial test, cone test, and deformation test, could be used as an alternative, since the results obtained by these methods showed a good correlation with the results by the test method used this time.The following are the simplified names for constant stress testing methods2):

o SM Stabbing test: SM type penetration resistance test method proposed by the Railway Technical Research Institute

o Protrusion stabbing test: protrusion penetration resistance test method

o JIS stabbing test: JIS L 1096 B test method

o CBR stabbing test: CBR penetration resistance test method

o Type A biaxial test: Water pressure puncture test method using a mold with a diameter of 250 mm

o Type B biaxial test: test method where the membrane is compressed by pressures applied on the upper surface of gravel layer

o Cone test: cone drop test

o Crack test: crack propagation test

o Deformation test: stab resistance test under uniaxial slip deformation condition

CONCLUSION

As mentioned above, the results of the tests conducted this time showed relatively high correlation with those of previously conducted tests, i.e. tests where a constant stress is applied on geomemberanes and five other tests. This indicates that stresses, which are considered to cause damages on seepage control works using geomembranes, can be evaluated by the test method developed this time, which uses only one testing apparatus.

In the future study, the authors will analyze and investigate the relationship among the factors of tests where three types of stresses are simultaneously applied on geomembranes, and conduct i) analyses on technical issues and ii) improvements on the testing apparatus (shown in (7) of Figure 7), to establish a more practical testing method for water proofing works.

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