A study on development for separation and reinforcement geotextiles with horizontal drain property

Hong-Kwan Kim & Eun-Mi Lee
FITI Testing & Research Institute, Korea

Min-Soo Ahn
Hankook Eng., Korea

ABSTRACT: According to the recent civil engineering construction work site which is a complex process, development of multi-functional geotextiles is required. In this study, the characteristics of five different modified cross-section fiber yarns for the selection of wicking yarns were analyzed and yarns that can achieve target properties were selected. Experimental prototype geotextiles suitable for horizontal wicking drain property and reinforcement was developed and its tensile strength, 2% secant modulus, vertical water permeability, AOS, friction characteristics by the direct shear method, and vertical/horizontal wicking test were analyzed. These tests are conducted to verify the performance of the geotextile with horizontal wick drain property, separation and reinforcement developed in this study.

Keywords: geotextiles, separations, horizontal, wicking yarns

1 INTRODUCTION

The main functions of geosynthetics are mainly separation, filtration, reinforcement and drainage. Recently, civil engineering construction is often made up of large-scale and complex processes, so that the function of geosynthetics requires complex multi-functionality. In particular, the contents required from the functional standpoint are as follows.

1) Demand for products with improved lateral drainage characteristics for drainage of soil water generated between the original soil layer and the embankment layer.

2) Possibility to create new markets through the development of functional characteristics capable of draining by natural osmotic pressure in the absence of horizontal gradients

From this point of view, the characteristics required for the product should be ensured for long-term dimensional stability, improvement of AOS and horizontal permeability. Research and introduction of fabric structure is required for capability of satisfying such performance. For this characteristics, weaving design and technical development of a special structure is needed with composed of composite yarns.

In this study, high strength yarn (polypropylene type, flat yarn, split yarn, other high strength yarn, etc.) and shaped yarn for giving wicking property are applied to manufacture high performance geotextiles with reinforcing and separating function. For the development of high functionality (improvement of friction interaction coefficient, improvement of permeability, improvement of tensile property), yarns of different cross sections were used for warp and weft.

In order to design the fabric structure in which the characteristics of the friction surface of the woven fabric are improved and the apparent void and the water passage are secured, mono filament yarns or flat yarns are used for warp yarns, and the wicking weft yarns are used not only for vertical permeability but also for the improved horizontal permeability and friction interaction coefficients.

In order to impart these functions, the basic properties of the geotextile with horizontal permeability woven using the woven structure design technology were verified through laboratory tests, and the vertical and horizontal absorption rate tests of the developed geotextiles were conducted to test the horizontal capacity in the soil layer, which is similar to the actual site conditions, an indoor test was designed and tested.

In this study, we performed to test for one general PP woven geotextiles and two woven geotextiles with different types of shaped yarn, and was conducted to confirm whether the horizontal permeability in the soil layer is exerted.

2 TESTS FOR PROPERTIES OF GEOTEXTILES

The basic properties such as tensile strength, permeability and apparent opening size were evaluated for the geotextiles developed in this study and the vertical absorption performance and horizontal absorption performance were evaluated to evaluate drainage performance in the horizontal direction.
The test samples were selected from the existing products and the developed products as shown in table 1.

Table 1. Test sample preparations

Sample	***Warp***	***Weft***
#1 Filament	PP FILAMENT	PP FILAMENT
#2 A-FSW-1-3	PP FILAMENT	Yarn1: PP FILAMENT Yarn2: PET(945d), PET(AC)
#3 A-FSW-1-6	PP FLAT	Yarn1: PP FILAMENT(Black, HJ) Yarn2: PET(900D), PET(AC:HS)

2.1 *Test results of properties*

The test results of geotextile samples are shown in Table 2. Tensile strengths were measured in the range of (89.3 ~ 98.8) kN/m as a result of selecting the product with similar values of tensile strength considering the above three products. However, the highest tensile modulus at 2% extension value was measured with # 3 using PP Flat yarn. Permittivity of developed geotextiles(0.29 ~ 0.36)s^{-1} were higher than the existing geotextile(0.13s^{-1}), which is considered to be related to the opening size of developed geotextiles. AOS of the existing geotextile was measured to be 0.255mm, which is smaller than that of the developed geotextiles(0.270mm, 0.294mm), which is considered to be related to the shape of yarn and weaving density of the geotextile. Vertical wicking speed results were significantly lower than those of wicking yarn because the existing geotextile is composed of normal yarn, which is a result of proving that the wicking phenomenon is significantly affected by the characteristics of the yarn. In addition, the wicking performance of the existing geotextile and the developed geotextiles was much different from the result of the horizontal wicking speed. The vertical and horizontal wicking speed test are shown in Figure 1.

Table 2. Test results of the properties

Properties		***Unit***	***#1***	***#2***	***#3***	***Test Methods***
Tensile strength		kN/m	98.8	89.3	93.8	ASTM D4595
Tensile modulus @2% extension		kN/m	607.8	610.4	799.8	ASTM D4595
Permittivity		s^{-1}	0.13	0.29	0.36	ASTM D4491
AOS		mm	0.255	0.270	0.294	ASTM D4751
Vertical wicking speed (127mm)		min	over 10	4.95	5.56	KS K 0815 6.27.1B modified
		mm/s	-	0.428	0.381	
Horizontal Wicking speed	1hr	mm	210	454	364	
	5hrs		256	944	847	
	15hrs		387	1505	1487	
	20hrs		425	1705	1657	

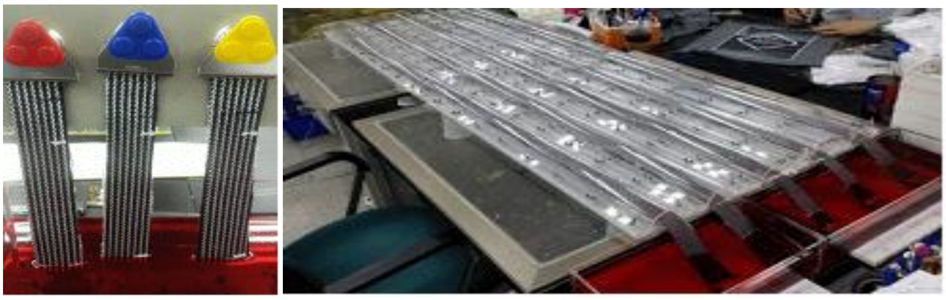


Figure 1. Vertical & Horizontal wicking speed test

3 LABORATORY SOIL BOX TESTS

3.1 *Preparation of laboratory test*

In the laboratory test, the performance of horizontal permeability function of geotextile for reinforcing the ground shear strength is verified. The existing geotextile and the developed geotextiles in this study were installed on the granite soil, and the horizontal drainage ability was verified by observing the change of water content according to the horizontal drainage ability.

The specific gravity of the granite soil used in the test was 2.68. According to the unified classification method (U.S.C.S), was classified as SP. Based on the characteristics of the laboratory test, the unit weight of 1.6ton/㎥ was applied. The applied soil specifications are shown in Table 3.

Table 3. Applied soil specifications

Gs	***Grain Size Distribution(%)***		***U.S.C.S***	***Applied weights (t/㎥)***
	NO.4	**NO.200**		
2.68	99.8	1.0	SP	1.6

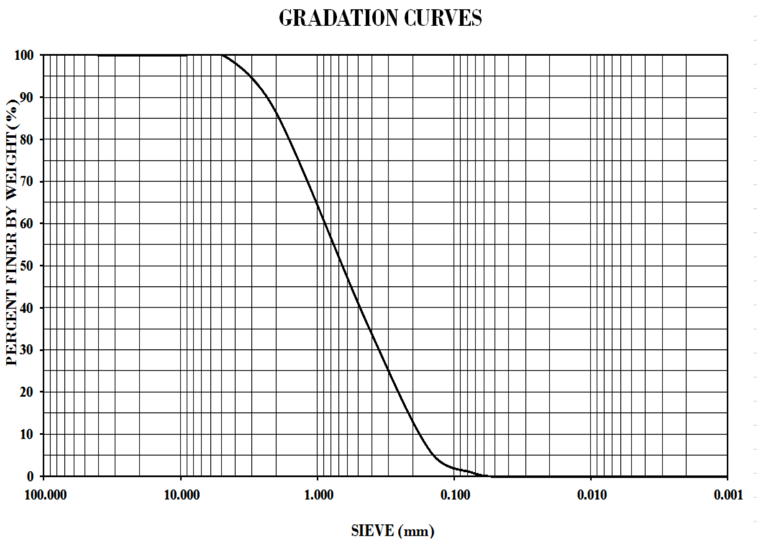


Figure 2. Analysis of soil samples for test

3.2 *Soil box design for laboratory test*

In order to keep the water level of the water tank constant, it is designed to supply water to the inside of the soil box using the siphon phenomenon. The Wicking effect was investigated by observing the rate of increase of the water content due to the interception of the pore water or the upward penetration of the pore water. The details of the design are as follows. The schematic diagram of laboratory test is illustrated in Figure 3 and the test preparation of soil box is shown in Figure 4.

- The unit weight applied for test was 1.6ton/㎥ which can compose the manpower was selected.

- In order to maintain the water level of the water tank constant, it is designed to supply water to the in side of the soil box using the siphon phenomenon
- Designed to allow upward penetration from the bottom to the top by installing piping so that water can be supplied from the bottom.
- In order to check the efficiency of geotextile due to upward penetration of water between CH11 and CH12, geotextile was installed so that it can be exposed to the outside of the trench.
- In order to observe the change of water content due to the upward penetration of water, the water ratio sensors CH13 and CH14 were installed at regular intervals above the sensor CH12. In addition, pore water pressure gauge and LVDT were installed for investigating the swelling amount of the soil due to pore water pressure and pore water.

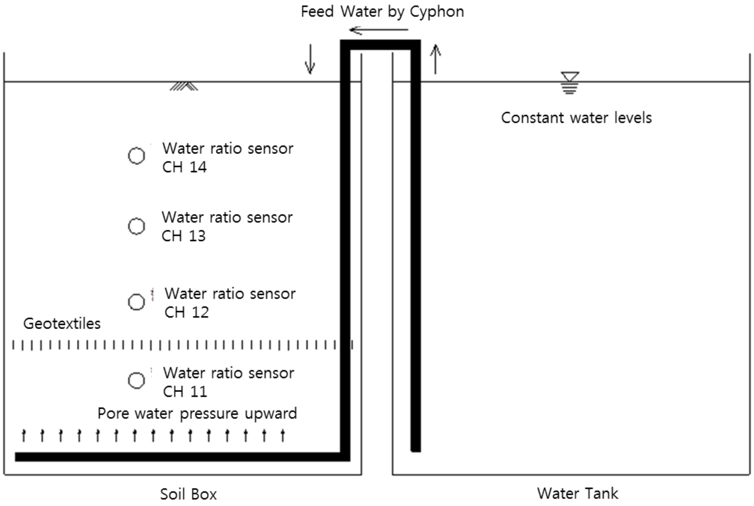


Figure 3. Schematic diagram of laboratory test

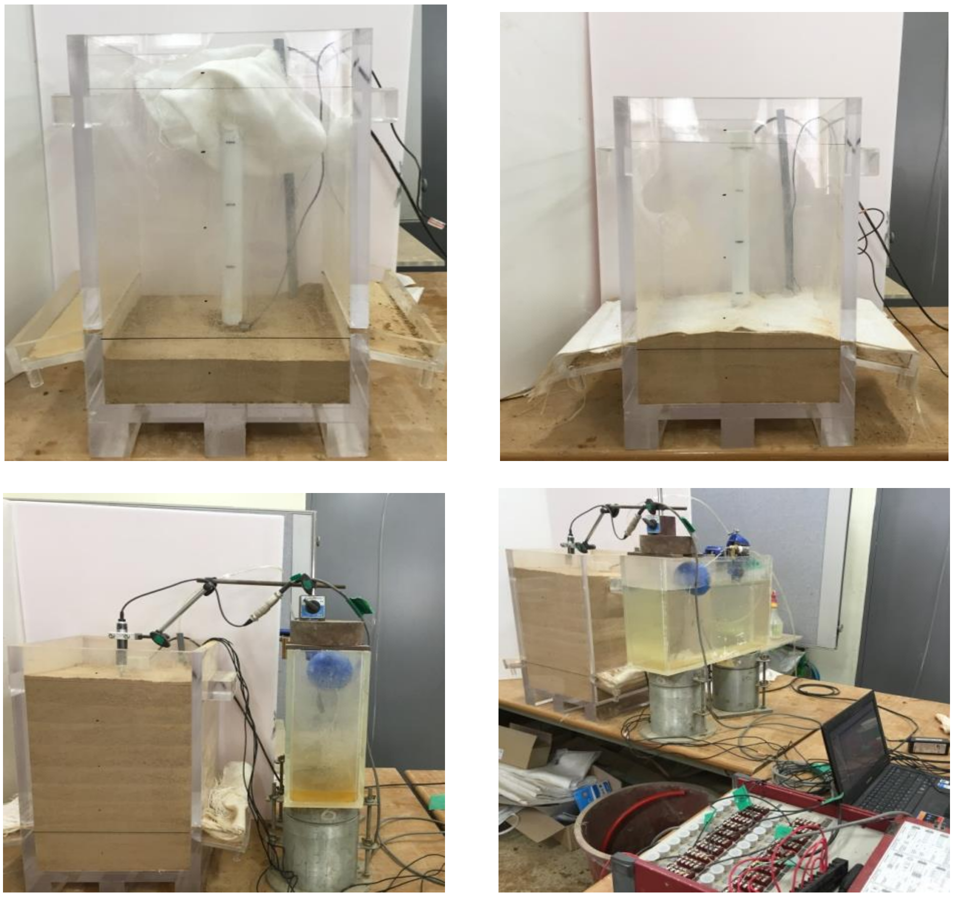


Figure 4. Test preparation of soil box

3.3 *Analysis of Laboratory test results*

CH 11 sensor was installed at the bottom of geotextile to measure the reliability of laboratory test. The rate of increase in water content per hour, and the convergence function ratio in the inflection part of the graph were similar so, confirming that the reliability of the indoor test was high, as shown in Figure 5 and Table 4.

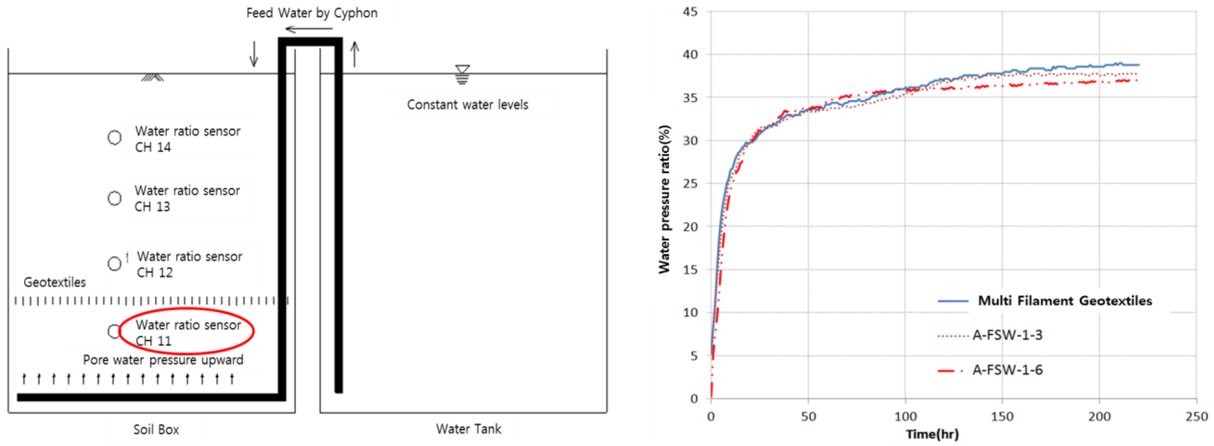


Figure 5. CH 11 location and water content curve

Table 4. The rate of increase in the water content of CH 11

Items	***Rate of water contents at initial***		***Inflection part of water contents***		***Convergence of water contents(%)***
	Time(hr)	***Rate of water contents(%)***	***Tme(hr)***	***Rate of water contents(%)***	
	Increasing speed		***Increasing speed***		
#1	0 ~ 10	5.2 ~ 26.6	12 ~ 24	27.6 ~ 32.8	38.6
	2.14		0.17		
#2	0 ~ 10	5.8 ~ 25.5	12 ~ 50	26.4 ~ 33.5	37.6
	1.97		0.19		
#3	0 ~ 10	4.98 ~ 24.38	13 ~ 69	26.4 ~ 35.2	36.8
	1.94		0.16		

In the CH 12 sensor, it was observed that the rate of increase of the water content after 50 hours was 0.18% for #1 and 0.14% for #3, as shown in Figure 6 and Table 5.

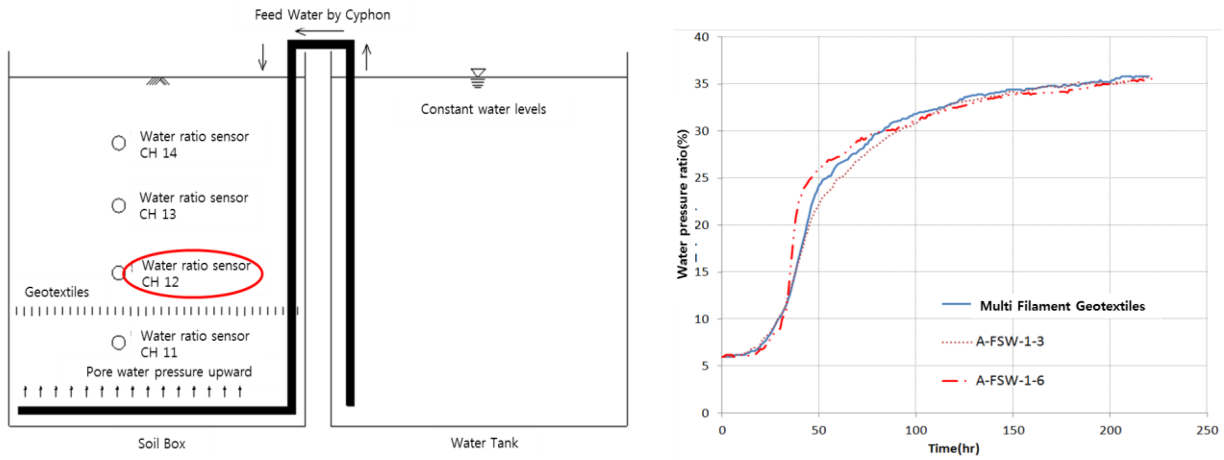
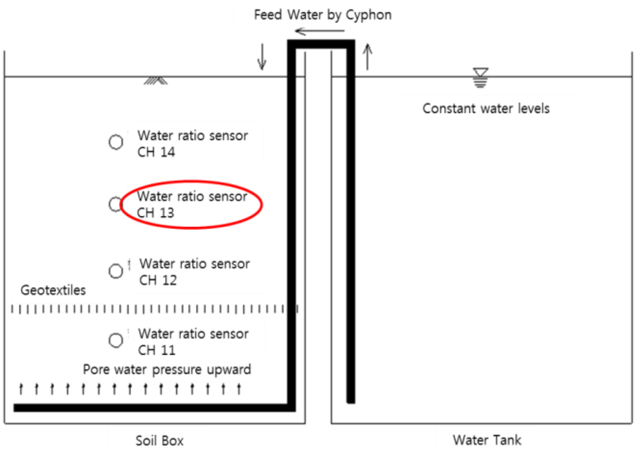


Figure 6. CH 12 location and water content curve

Table 5. The rate of increase in the water content of CH 12

Items	*Rate of water contents at initial*		*Inflection part of water contents*		Convergence of water contents(%)
	Time(hr)	Rate of water contents(%)	Tme(hr)	Rate of water contents(%)	
	Increasing speed		Increasing speed		
#1	33 ~ 50	11.4 ~ 24.2	50 ~ 87	24.2 ~ 30.8	35.8
	0.75		0.18		
#2	28 ~ 50	9.6 ~ 22.2	50 ~ 90	22.2 ~ 29.9	35.4
	0.57		0.19		
#3	33 ~ 40	10.8 ~ 22.92	47 ~ 78	25.3 ~ 29.8	35.2
	1.73		0.14		

In the CH 13 sensor, #1 showed a maximum water content ratio of 33.1% at 135 hours and a tendency that the water ratio decreased sharply to 29.5% in the case of #3 at the same time, as shown in Figure 7 and Table 6.



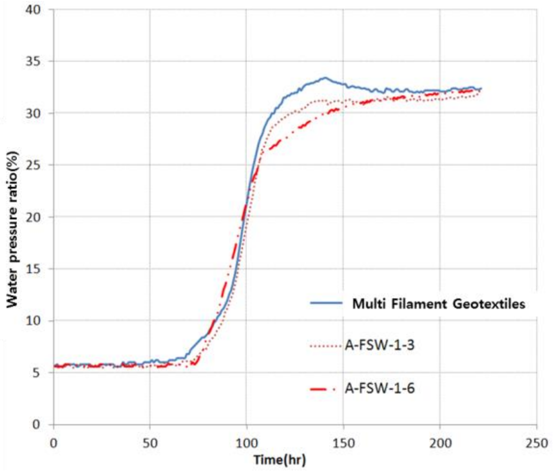


Figure 7. CH 13 location and water content curve

Table 6. The rate of increase in the water content of CH 13

Items	*Rate of water contents at initial*		*Inflection part of water contents*		Convergence of water contents(%)
	Time(hr)	Rate of water contents(%)	Tme(hr)	Rate of water contents(%)	
	Increasing speed		Increasing speed		
#1	90 ~ 108	12.6 ~ 28.6	110 ~ 140	29.4 ~ 33.4	32.1
	0.89		0.13		
#2	85 ~ 110	9.4 ~ 27.8	107 ~ 135	26.16 ~ 21.2	31.2
	0.74		0.18		
#3	74 ~ 107	6.3 ~ 26.16	107 ~ 140	26.16 ~ 30.1	31.9
	0.60		0.12		

Finally, in the case of CH14 water content converged after 187 hours, which was observed distinct difference to be 31.7% for #1 and 23.0% for #3, as shown in Figure 8 and Table 7.

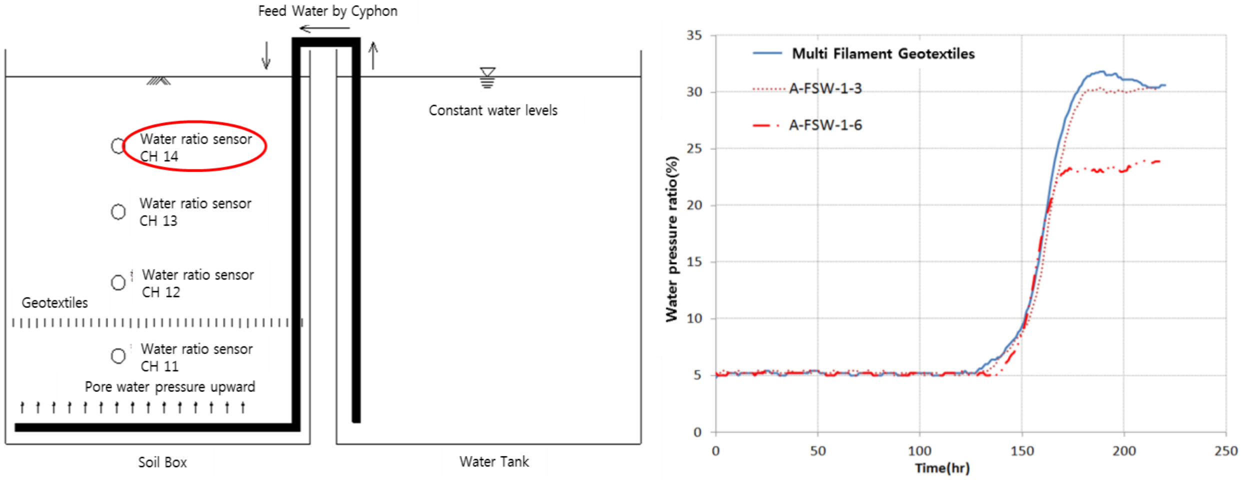


Figure 8. CH 14 location and water content curve

Table 7. The rate of increase in the water content of CH 14

Items	*Initial part of water contents*		*Convergence of water contents(%)*
	Time(hr)	*Water contents(%)*	
	Increasing speed		
#1	150 ~ 174	9.4 ~ 29.0	30.8
	0.82		
#2	149 ~ 175	8.6 ~ 28.2	30.3
	0.75		
#3	150 ~ 167	8.9 ~ 22.14	23.0
	0.78		

Based on the test results, it was confirmed that the wicking geotextile applying the shaped yarn was effective in reducing the pore water to upper part by shifting the pore water moving to the upper part in the soil layer in the horizontal direction, and the function of geotextile was proved the horizontal permeability.

According to the results of developed geotextiles, the pore water in the ground can be prevented from being transmitted to the upper part of the road, or the rainwater falling down on the road can be prevented from flowing into the road.

4 REVIEW OF RESULTS

4.1 *Analysis of yarn and physical properties results*

As a result of evaluating the three kinds of geotextiles, the geotextiles using shaped yarn were also excellent in the evaluation of physical properties, and the capillary effect by the shape of cross section was verified by the experimental results. The tensile strength and modulus of the yarn applied to the developed geotextile were higher than expected, and the vertical and horizontal wicking performance of the yarn and the prototype geotextile was excellent.

In the development of composite weaving technology for vertical and horizontal permeability functions, geotextile was developed optimum fineness through the fineness, density combination, and weaving technology applied for the development of tissue with vertical and horizontal permeability while maintaining separation reinforcing function.

The prototype woven geotextile analysis showed that tensile strength and modulus performance were excellent and that AOS, vertical permeability coefficient, and frictional shear number were higher than expected and vertical and horizontal wicking performance were also excellent than general geotextiles.

4.2 *Analysis of Soil box test results*

In case of sensor CH11 showed similar results for all three geotextile products, confirming high reliability for laboratory testing.

In the case of sensor CH13, the water ratios were higher in the order of # 1, # 2, # 3 of graph vertices, and the rate of increase in initial water content was also slowed down by changing the yarn condition of the geotextiles.

In the sensor CH14, convergence ratio of # 1, # 2, # 3 (30.8%, 30.3%, 23.0%) was observed in order of low water content, and the horizontal permeability was confirmed as wicking effect and weaving method were improved,

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