한국토목섬유학회논문집 제4권 1호 2005년 1월 pp. 37 ~ 46

Performance Assessment of PVA Geotextile/HDPE Geomembrane Composites

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Abstract

PVA geotextile/HDPE geomembrane composites were made to examine the waste landfill related properties. Tensile properties, tear and bursting strengths, AOS(apparent opening size) and permittivity of PVA geotextiles were evaluated, respectively. Ultraviolet stability and chemical resistance to the leachate was evaluated also. Friction property and creep deformation were tested at various loading condition. From this, it was seen that PVA geotextile/HDPE geomembrane composites have more excellent properties than the typically used polypropylene and polyester geotextiles in waste landfill. Finally, creep deformation behaviours of PVA geotextile/HDPE geomembrane composites were more stable than polypropylene and polyester geotextiles through the reduction factor analysis.

요 지

폐기물 매립지 관련 특성을 조사하기 위하여 PVA 지오텍스타일/HDPE 지오멤브레인 복합재료를 제조하였다. PVA 지오텍스타일의 인장특성, 인열 및 파열강도, 유효구멍크기와 투수성 등을 각각 측정하였다. 또한 침출수에 대한 화학저항성과 자외선 안정성도 측정하였으며, 하중조건에 따른 크리프 변형거동과 마찰특성도 측정하였다. 이들 결과로부터 PVA 지오텍스타일/HDPE 지오멤브레인 복합재료는 일반적으로 폐기물 매립지에 적용되는 폴리프로필렌이나 폴리에스테르 지오텍스타일에 비해 우수한 특성을 나타내었다. 끝으로, 감소인자 분석으로부터 PVA 지오텍스타일/HDPE 지오멤브레인 복합재료의 크리프 변형거동도 폴리프로필렌이나 폴리에스테르 지오텍스타일에 비해 안정함을 알 수 있었다.

Keywords : PVA Geotextile/HDPE geomembrane cmposites, Waste landfill, Tensile properties, Ultraviolet stability and chemical resistance, Creep deformation behaviours

1. Introduction

Geotextile related products are mainly used for reinforcement of ground and slope plane, reclamation, dam and tunnel construction, reinforcements for costal embankment and soil retaining wall, railway and road construction, and waste landfill construction etc. Among them, geotextiles(GT) are used for the purposes of protection/reinforcement, filtration, drainage, and separation. In particular, as GT are generally adopted for the above part of geomembrane(GM) as for waste landfills, it is very significant

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to consider the long-term performance of GT against sunlight and chemical condition until a landfill is complete. In addition, the exposed temperature generally rises to about 80℃ in summer season due to corruption of food garbage and a landfill becomes more exposed to ultraviolet and leachate solution as the period for reclamation has become longer. Therefore, it is needed to use GT proved invulnerable to such exposure in waste landfills. The needle punched nonwoven GT of staple fibers mainly used as flooring material in waste landfills contain polypropylene and polyester as main raw materials, maintaining stability against acid and alkali but tending to decompose when exposed to ultraviolet and sunlight. Meanwhile, polyester is superior to polypropylene in terms of dynamical performance but may cause degradation of tensile strength from hydrolysis occurring when exposed to acid or alkali in higher temperature. As for polypropylene nonwoven GT more efficient in terms of long-term performance, they have some problems in durability when exposed to alkali or ultraviolet in higher temperature. In addition, when such additives as carbon black and antioxidant are mixed with polypropylene to improve stability against ultraviolet, it may entail the problem of manufacturing cost more increasing and becoming more difficult to produce textiles than polyester. Besides this, polypropylene or polyester GT are installed upon the HDPE GM in the waste landfill and frictional property between these is the cause of long-term performance decrease of these geosyntheics. To take into this consideration, this study is to develop high performance GT composites with GM by using PVA GT to be capable of improving frictional property, chemical and ultraviolet stability etc. Composites of PVA GT and HDPE GM were made to examine the advanced properties of long-term performance to be related waste landfill application. Finally, the same properties of typically used polypropylene and polyester GT were examined and compared to PVA GT/HDPE GM composites.

2. Experimental

2.1 Manufacture of Geotextile Composites

Geotextile composites of PVA GT/HDPE GM, PVA GT of 600, 1,500, 2,000g/m^2 and HDPE GM (thickness; 1.5 mm) were made by thermal bonding. Table 1 shows the specifications of these composites and for comparison of their long-term performances polyester and polypropylene nonwoven GT similar each other in terms of thickness and weight.

Left side of Figure 1 shows the schematic diagram of geotextile composite and right side of this Figure shows the typically installed polypropylene or polyester GT upon HDPE GM, separately. Figure 2 shows the photographs of geotextile composites of 1000 g/m^2.

Figure 1. Schematic diagram of geotextile composite

Table 1. Specifications of Geotextile Composites and Nonwoven Geotextiles

Geosyntheics	Geotextile Composite					Polyester GT					Polypropylene GT				
Weight(g/m^2)	600	1000	1500	2000	2500	600	1000	1500	2000	2500	600	1000	1500	2000	2500
Fineness(d)	8 for PVA GT					10					12				
Manufacturing	Thermal Bonding					Needle Punching									

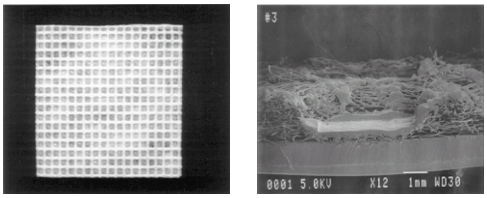

Figure 2. Photographs of geotextile composite

2.2 Evaluation of Waste Landfill Applied Properties

(1) Tensile, Tear and Bursting Strength

The tensile strength of geotextile composites was measured in accordance with grab test of ASTM D 5034 by using INSTRON 4302. Tear and bursting strengths were conducted in accordance with ASTM D 4533, 3786, respectively.

(2) AOS (apparent opening size)

Apparent opening size (AOS) of PVA, polypropylene and polyester GT was measured and evaluated in accordance with ASTM D 4751.

(3) Permittivity

Hydraulic conductivity evaluating vertical permeability of PVA, polypropylene and polyester GT was measured and evaluated in accordance with ASTM D 4491.

(4) Ultraviolet Stability

Ultraviolet stability of geotextile composites was evaluated by exposing them for a total of 500 hours with the repeats of 120-minute cycle consisting of 102-minute light curing and 18-minute water blast in accordance with ASTM D 4355, ASTM Committee G 26 using Xenon-arc.

(5) Chemical Resistance

As there is no general method to evaluate chemical resistance of geotextile composites, this experiment made use of a modified version of EPA 9090 Test Method as the method of evaluating chemical resistance of FML(flexible membrane liner) offered by the US Environmental Protection Agency(EPA). After immersing samples into solutions with 25, 50, and 80℃, we acquired samples up to 150 days at 30-day interval to find tensile strength holding rate in Machine Direction and evaluate chemical resistance. The test of tensile was conducted in accordance with ASTM D 5034, and buffer solutions(pH 3 and 12) and leachate(pH 8.4) acquired from waste landfills were used as immersion solutions.

(6) Frictional Property

Friction characteristic of geotextile composites was measured by using Compact Direct Shear Apparatus in accordance with ASTM D5321. The garnet paper with #36 grit having similar size to particle of domestic standard earth was attached to the surface of the upper parts movable shear box and we found friction coefficient after adding vertical stresses of 25, 50, 100psi(173, 345, 690 kPa) to evaluate their effects.

(7) Measurement of Rate of Creep Deformation for Long-term Performance Evaluation

The rate of creep deformation of geotextile composites was measured and evaluated in accordance with ASTM D 5262. Values equivalent to 20, 40, and 60% of the maximum tensile strength of geotextile composites were added to creep load and feasibility was given only when the rate of creep deformation is within 10%.

3. Results and Discussion

3.1 Mechanical Properties of Geotextile Composites

As shown in Table 2, polypropylene nonwoven GT are more remarkable than polyester GT in terms of tensile irrespective of weight.

Probably, that is why renewable polyester was used. In particular, geotextile composites showed the largest value.

Table 3 shows tear strength of geotextile composites. It is seen that tear strength of geotextile composites showed the similar tendency as tensile strength. Table 4 shows bursting strength of geotextile composites and it was seen that bursting strength of geotextile composites also showed the similar tendency as tensile and tear strengths. To overall this result, mechanical properties of geotextile composites are more excellent than polyester or polypropylene GT and they are expected to be used more widely for improvements of protection/reinforcement functions in the waste landfill.

3.2 AOS of GT

AOS values of GT are indicated in Table 5. But AOS values of PVA GT are relatively lower than other GT. From this, it is thought that textile unity effects of PVA GT due to needle punching became larger than polyester or polypropylene GT, proving their excellence in separation/protection functions.

Therefore, geotextile composite of PVA GT should have more excellent separation/protection functions than GT and GM separately installed waste landfill system.

Table 2. Tensile Properties of Geotextile Composites

Geosynthetics	Geotextile Composite					Polyester GT					Polypropylene GT				
Weight(g/m^2)	600	1000	1500	2000	2500	600	1000	1500	2000	2500	600	1000	1500	2000	2500
Tensile Strength(kg)	263	301	344	398	424	166	184	233	264	302	250	284	302	363	385
Tensile Elongation(%)	72	72	70	68	68	104	102	101	101	98	84	82	83	80	81

Table 3. Tear Strength of Geotextile Composites

Geosynthetics	Geotextile Composite					Polyester GT					Polypropylene GT				
Weight(g/m^2)	600	1000	1500	2000	2500	600	1000	1500	2000	2500	600	1000	1500	2000	2500
Tear Strength(kg)	52	65	72	103	134	38	43	52	81	91	45	56	63	98	123

Table 4. Bursting Strength of Geotextile Composites

Geosynthetics	Geotextile Composite					Polyester GT					Polypropylene GT				
Weight(g/m^2)	600	1000	1500	2000	2500	600	1000	1500	2000	2500	600	1000	1500	2000	2500
Bursting Strength(kg)	51	53	58	62	64	45	47	50	53	57	47	48	52	56	62

Table 5. Apparent Opening Size of Geotextiles

Nonwoven Geotextiles	PVA GT					Polyester GT					Polypropylene GT				
Weight(g/m^2)	600	1000	1500	2000	2500	600	1000	1500	2000	2500	600	1000	1500	2000	2500
AOS(mm)	0.21	0.21	0.20	0.19	0.19	0.23	0.24	0.23	0.24	0.24	0.25	0.24	0.24	0.23	0.23

3.3 Permittivity of GT

Table 6 shows vertical hydraulic conductivity, permittivity of GT. This value is dependent to AOS as flow path directly affecting permeability. Therefore, geotextile composite of PVA GT should have more excellent separation/protection functions than GT and GM separately installed waste landfill system.

3.4 Ultraviolet Stability of Geotextile Composites

Table 7 shows changes of physical properties of geotextile composites after 500hour exposure to ultraviolet. In this case, both tensile strength of polypropylene GT were dramatically reduced in particular about 30% to 60% on average. But as weight became greater, the extent of the reduction of tensile strength was accordingly less. It is seen that as GT are heavier the degree of ultraviolet becomes less, resulting in stability of tensile strength. On the other hand, polyester GT exceeded 80%, deemed more stable than polypropylene GT against ultraviolet, but geotextile composites have more-then-90 percent of tensile strength holding rate.

3.5 Chemical Resistance of Geotextile Composites

Table 8 shows the results of chemical resistance evaluations for geotextile composites in 25, 50, 80℃, pH 3, 12 and leachate, respectively. In pH 3 acid solutions with 25, 50, and 80℃, tensile strengths of geotextile composites were reduced by about 5 to 15% compared with before exposure, which indicates consequently stability. However, in pH 12 alkali solutions, tensile strengths of geotextile composites were almost constant in all temperature conditions but those of polypropylene GT decreased by about 15%. In the meantime, those of polyester GT were reduced by 20% at 25℃ and 60% at 50℃. In particular, at 80℃, the test itself was impossible because they were almost molten. Tensile strengths of geotextile composites against leachate were reduced by 10 to 20% in both polypropylene and polyester GT. And the reduction was more remarkable at 50℃ than 25℃. However, geotextile composites had little change and this means the demonstrating excellence of PVA GT in terms of chemical resistance.

3.6 Friction Property of Geotextile Composites

Table 9 shows friction coefficients of geotextile composites. The reason why geotextile composites

Table 6. Permittivity of Geotextiles

Nonwoven Geotextiles	PVA GT					Polyester GT					Polypropylene GT				
Weight(g/m²)	600	1000	1500	2000	2500	600	1000	1500	2000	2500	600	1000	1500	2000	2500
Permittivity(ℓ/min/m²)	0.21	0.21	0.20	0.19	0.19	0.23	0.24	0.23	0.24	0.24	0.25	0.24	0.24	0.23	0.23

Table 7. Ultraviolet Stability of Geotextile Composites Strength Retention

Geosynthetics	Geotextile Composites					Polyester GT					Polypropylene GT				
Weight(g/m²)	600	1000	1500	2000	2500	600	1000	1500	2000	2500	600	1000	1500	2000	2500
Strength Retention(%)	93	94	95	95	95	83	86	88	88	88	43	60	65	70	72

Table 8. Chemical Resistance of Geotextile Composites－Strength Retention

(a) pH 3, 25℃

Geosynthetics	Geotextile Composite					Polyester GT					Polypropylene GT				
Weight(g/m^2)	600	1000	1500	2000	2500	600	1000	1500	2000	2500	600	1000	1500	2000	2500
Strength Retention(%)	98	98	98	99	98	85	86	86	86	85	87	88	90	90	90

(b) pH 3, 50℃

Geosynthetics	Geotextile Composite					Polyester GT					Polypropylene GT				
Weight(g/m^2)	600	1000	1500	2000	2500	600	1000	1500	2000	2500	600	1000	1500	2000	2500
Strength Retention(%)	98	97	98	97	97	82	82	83	83	83	88	88	87	88	88

(c) pH 3, 80℃

Geosynthetics	Geotextile Composite					Polyester GT					Polypropylene GT				
Weight(g/m^2)	600	1000	1500	2000	2500	600	1000	1500	2000	2500	600	1000	1500	2000	2500
Strength Retention(%)	97	97	96	97	97	83	85	83	83	83	85	87	86	87	87

(d) pH 5, 25℃

Geosynthetics	Geotextile Composite					Polyester GT					Polypropylene GT				
Weight(g/m^2)	600	1000	1500	2000	2500	600	1000	1500	2000	2500	600	1000	1500	2000	2500
Strength Retention(%)	97	96	97	97	97	85	86	86	86	87	92	90	92	91	93

(e) pH 5, 50℃

Geosynthetics	Geotextile Composite					Polyester GT					Polypropylene GT				
Weight(g/m^2)	600	1000	1500	2000	2500	600	1000	1500	2000	2500	600	1000	1500	2000	2500
Strength Retention(%)	96	97	97	97	96	82	83	83	83	83	88	90	89	89	90

(f) pH 5, 80℃

Geosynthetics	Geotextile Composite					Polyester GT					Polypropylene GT				
Weight(g/m^2)	600	1000	1500	2000	2500	600	1000	1500	2000	2500	600	1000	1500	2000	2500
Strength Retention(%)	96	97	97	96	96	81	82	81	79	81	83	84	85	85	85

(g) pH 12, 25℃

Geosynthetics	Geotextile Composite					Polyester GT					Polypropylene GT				
Weight(g/m^2)	600	1000	1500	2000	2500	600	1000	1500	2000	2500	600	1000	1500	2000	2500
Strength Retention(%)	96	95	95	95	96	78	78	77	78	78	85	86	86	87	86

(h) pH 12, 50℃

Geosynthetics	Geotextile Composite					Polyester GT					Polypropylene GT				
Weight(g/m^2)	600	1000	1500	2000	2500	600	1000	1500	2000	2500	600	1000	1500	2000	2500
Strength retention(%)	96	97	96	95	95	75	77	75	75	75	84	84	84	85	84

(i) pH 12, 80℃

Geosynthetics	Geotextile Composite					Polyester GT					Polypropylene GT				
Weight(g/m^2)	600	1000	1500	2000	2500	600	1000	1500	2000	2500	600	1000	1500	2000	2500
Strength retention(%)	93	94	94	93	93	Impossible to evaluate					81	80	80	80	80

(j) leachate, 25℃

Geosynthetics	Geotextile Composite					Polyester GT					Polypropylene GT				
Weight(g/m^2)	600	1000	1500	2000	2500	600	1000	1500	2000	2500	600	1000	1500	2000	2500
Strength retention(%)	95	96	96	95	96	83	82	84	84	84	91	88	88	90	90

(k) leachate, 50℃

Geosynthetics	Geotextile Composite					Polyester GT					Polypropylene GT				
Weight(g/m^2)	600	1000	1500	2000	2500	600	1000	1500	2000	2500	600	1000	1500	2000	2500
Strength retention(%)	96	96	95	95	95	65	66	63	63	64	85	83	84	84	84

(l) leachate, 80℃

Geosynthetics	Geotextile Composite					Polyester GT					Polypropylene GT				
Weight(g/m^2)	600	1000	1500	2000	2500	600	1000	1500	2000	2500	600	1000	1500	2000	2500
Strength retention(%)	95	94	95	94	94	Impossible to evaluate					83	82	82	82	82

Table 9. Friction Coefficient of Geotextile Composites

Geosynthetics	Geotextile Composite					Polyester GT					Polypropylene GT				
Weight(g/m^2)	600	1000	1500	2000	2500	600	1000	1500	2000	2500	600	1000	1500	2000	2500
Friction Coefficient	0.20	0.20	0.21	0.21	0.21	0.15	0.16	0.16	0.16	0.16	0.17	0.17	0.18	0.18	0.18

have the largest friction coefficient is that PVA GT has the more compacted textile density than other GT. However, polyester and polypropylene GT have lower values of friction coefficients because their textile density is relatively small than PVA GT. Friction features of geotextile composites are apparently regarded as better than polyester and polypropylene GT but actual proof will be different in the event earth on the site is used in the experiment.

3.7 Long-Term Performance of Geotextile Composites

Generally, long-term performances of geosynthetics contain ranges of factor of safety(FS) by usage for the purpose of stabilizing construction. Factor of safety, or FS means an evaluation function indicating the proportion of engineering property to application property of geosynthetics such as geotextiles, geotextile composites etc.

$$FS = \text{application property value} / \text{engineering property value} \quad (1)$$

Application property value means a property value required at the time of installation, while engineering property value signifies a property value required in manufacturing process with taken into consideration the application property value. The reason why both values are not identical actually is that installation, chemical, biological, and creep damages are considered in using geosynthetic products. As a result of these damages, a consolidated FS is more than 1.

If general GT are used for reinforcement and protection, the rate of deformation exceeds 10%. Consequently, actual FS will become larger than the maximum 2.5 recommended by AASHTO M 288-96 as for geosynthetic products for reinforcement and protection. So it should not be disregard the fact that performances will be shrunk in long-term basis. The reduction factor for creep deformation follows this equation.

$$RF_{CR} = \frac{T_{ST}}{T_{LT}} \quad (2)$$

where, RF_{CR} = Creep reduction factor

T_{LT} = 10 year design life strength of the geogrid in sustained ASTM D 4595 or sustained GRI GG-1, or ASTM D 5262 testing at which curve becomes asymptotic to a constant strain line, of 10 percent or less

T_{ST} = Short term strength of the geogrid in ASTM D 4594, GRI GG-1 or GG-2 testing whichever is comparable to the long term creep test, i.e., wide width, single rib or through the junction test

The reduction factor by creep deformation is determined from the 10,000 hours curves as being the load at which the creep curve becomes asymptotic to a constant strain line, of 10 percent or less. This value of strength is then compared to the short-term strength of the geogrid in ASTM D 4594, GRI GG-1 and GG-2. Table 10 shows creep property of geotextile composites. In the event that 20 percent of the maximum tensile strength is added to polypropylene and polyester GT, creep deformation will be 10% or more, making reduction coefficient to creep deformation meaningless. On the other hand, as for geotextile composites, even if up to 40 percent of the maximum tensile strength is added to them, creep deformation will remain within 10% and thus creep FS have the value less than 2.5 recommended by AASHTO M 288-96 as maximum value of construction textile products for reinforcement and protection.

4. Conclusion

1. In order to develop application technology about PVA nonwoven geotextiles with 600, 800, 1,000, 2,000, and 2,500g/m^2 were manufactured, and to make a comparison of performance, polyester and polypropylene nonwoven geotextiles with same standard were used as samples. After measuring tensile, tear, and bursting strengths, AOS, permittivity, and ultraviolet and chemical resistance, we reviewed strength retention through comparison

Table 10. Reduction Coefficient Due To Creep Deformation of Geotextile Composites

Geosynthetics	Geotextile Composite					Polyester GT					Polypropylene GT				
Weight(g/㎡)	600	1000	1500	2000	2500	600	1000	1500	2000	2500	600	1000	1500	2000	2500
Creep Deformation at 20% of Maximum Tensile Strength(%)	9.4	9.3	9.3	9.3	9.3	13.4	12.7	12.8	12.8	12.8	12.7	11.5	11.2	11.3	11.3
Creep Deformation at 40% of Maximum Tensile Strength(%)	9.8	9.8	9.8	9.8	9.8	Meaningless									

with values of initial mechanical properties.

2. In terms of tensile properties, polypropylene nonwoven geotextiles were more remarkable than polyester nonwoven geotextiles, and in particular geotextile composites had the largest value. That is, tensile property of geotextile composites is understood to be the most excellent. In addition, tear and bursting strengths had same tendency as tensile strength.
3. AOS values of PVA nonwoven geotextiles were generally less than those of polyester and polypropylene nonwoven geotextiles. It is thought that textile unity effects due to needle punching became larger than polyester or polypropylene nonwoven geotextiles. Owing to reduction of diameter of AOS, their permittivities was decreased relatively compared with polyester and polypropylene nonwoven geotextiles.
4. As a result of ultraviolet resistance evaluation, it was confirmed that considerable reduction of tensile strength of polypropylene nonwoven geotextiles. Polyester nonwoven geotextiles seem to have been more stable against ultraviolet than polypropylene nonwoven geotextiles, but tensile strength holding rate of geotextile composites almost reached 90%.
5. In pH 3 acid solutions with 25, 50, and 80℃, tensile strengths of geotextiles were reduced by about 5 to 15% compared with before exposure. However, in pH 12 alkali solutions, tensile strengths of geotextile composites were almost constant in all temperature conditions. In the meantime, those of polyester nonwoven geotextiles were reduced by 20% at 25℃ and 60% at 50℃. In particular, at 80℃, the test itself was impossible because they were almost molten. Tensile strengths of geotextiles against leachate were reduced by 10 to 20% in both polypropylene and polyester nonwoven geotextiles. But we have little observed changes in geotextile composites.
6. In the case of using friction media having similar size to particle of domestic standard earth, friction coefficient of geotextile composites was relatively large compared with those of polyester and polypropylene nonwoven geotextiles.
7. In the event that 20 percent of the maximum tensile strength is added to polypropylene and polyester nonwoven ge-textiles, creep deformation becomes 10% or more, making it impossible to find reduction factors causing creep deformation. On the other hand, as for geotextile composites, even if up to 40 percent of the maximum tensile strength is added to them, creep deformation will remain within 10% and thus creep FS have the value less than 2.5, demonstrating that they are suitable for reinforcement works.

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