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A Study on Thermally Bonded Geotextile Separator and Properties of Waste Landfill Application of PVA Geotextile/HDPE Geomembrane Composites

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Abstract

This paper is concerned with geotextiles bonded chemically with geogrid to form a geocomposite. Geotextiles, thermally bonded and non-woven, play an important role as a separator. Also, this study investigates the resistance to the application environment of geotextile composites. Here, numerous tests have been performed and it was revealed from experimental results that thermally bonded geotextile in geosynthetic composites showed superior characteristics to that manufactured from needle punched non-woven method in terms of tensile strength, tensile strain and high separation performance. It was noted from experiments that the geotextile prepared for separation purpose and manufactured in a thermal bonding method showed relatively low permittivity so that it could be used as a smooth separator. In addition, PVA geotextile/HDPE geomembrane composites were designed and manufactured to investigate the waste landfill related properties. Numerous experiments have been performed and experimental results were summarized to evaluate practical applicability of PVA geotextile/HDPE geomembrane composites. Among the properties of proposed geomembrane composites, evaluation has been focused on the investigation of mechanical properties, AOS (apparent opening size), permittivity and ultraviolet stability.

Keywords

Geotextile, geocomposite, geomembrane, waste landfill application, thermal bonding

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1. Introduction

Geotextiles have been used as reliable, economic alternatives to the multiple layer granular filters or separators. Once they are manufactured as final products, they are often subjected to strict quality control procedures, such as the ISO 9001/9002. These geotextiles are simpler to use, quicker to install and can also replace several layers of a granular filter or separator by themselves. Nevertheless, the use of standard geotextile may have some limitations due to poor long-term performance and difficulties in installation. This is why a specific geoetxtile system has recently been developed for internal erosion control applications only [1, 2].

In the field of geotechnical structures, the demand for geocomposite, especially drainage geocomposite, has increased continuously. Since thermal bonded non-woven geotextile plays an important role as a separator in geocomposite, experimental analyses have been carried out to evaluate the various properties of geotextile. The thermal bonding type geotextile takes on a compressed form, and its thickness is thinner than the needle punching geotextile with the same weight. This is believed to be one of the reasons why the geotextiles manufactured in thermal bonding process have shown excellent performance as separator in many field applications. It is also interesting to note that the geotextiles made from the thermal bonding process have improved tensile features compared to those from other processes. This is the main reason why the geotextile produced in thermal bonding process is widely used as a popular geosynthetic.

Products related to geotextile have many applications for the purpose of reinforcements in construction sites. Among those applications, geotextiles (GTs) are used for the purposes of protection and/or reinforcement, filtration, drainage and even separation. Since GTs, in particular, are generally adopted as the covering material of geomembrane (GM) for waste landfills, it is very significant to consider the long-term performance of GT against sunlight and various chemical conditions imposed until a landfill is complete. In addition, the temperature exposure in the environment rises to about 80° in summer due to degradable organic wastes and a landfill becomes more seriously exposed to ultraviolet and leachate solution as the period for reclamation becomes longer. Therefore, there is a need to use GT which is proven invulnerable to such exposure in waste landfills [3–7].

The needle punched non-woven GT of staple fibers, which is mainly applied to flooring material in waste landfills, contains polypropylene and polyester as one of its raw materials and it helps to maintain stability against acid and alkali materials. However, it tends to decompose when exposed to ultraviolet radiation, i.e. sunlight. Meanwhile, polyester is superior to polypropylene in terms of dynamic performance, but may cause degradation of the tensile properties by hydrolysis occurring when it exposed to acid or alkali at relatively high temperature. Even though polypropylene non-woven GTs are more efficient generally in terms of long-term performance, they show some problems in durability when they are exposed to alkali or ultraviolet radiation at higher temperature. In addition, when additives such as carbon black and anti-oxidant are mixed with polypropylene to improve stability

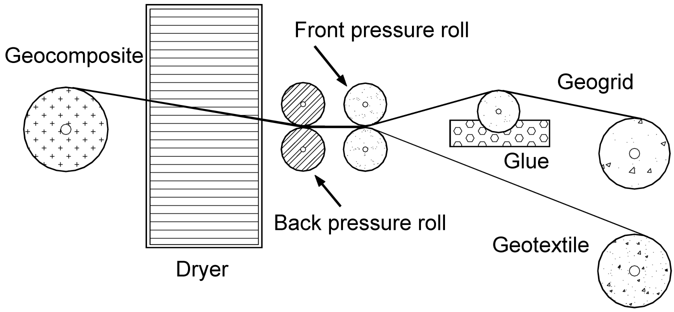

Figure 1. Standard manufacturing process for geocomposite.

against ultraviolet light, this may increase the manufacturing cost and thereby make it more difficult to produce textiles than polyester. Besides all of these, polypropylene or polyester GTs are used for installation over the HDPE GM in waste landfills and the frictional properties between these materials is known to be the cause of decrease in the long-term performance in the geosynthetics [8–10].

In this study, PVA geotextile/HDPE geomembrane composites were made to examine the waste landfill related properties such as tensile, tear and bursting strengths, AOS (apparent opening size), permittivity of PVA geotextiles and ultraviolet stability. Also, this study investigates thermal bonding type geotextile that was manufactured in two different types for the use of model material. Two kinds of specimen have been prepared for comparison and use the same raw material such as polypropylene. However, the dimensions of those specimens are different in terms of weight and thickness. The model material, namely, thermally bonded geotextile, has been tested for its appearance and fiber arrangements, which is one of the basic tests simply to verify its applicability as an engineering material. The wide-width tensile tests have also been conducted to investigate the relationship between the tensile properties and weight ratio. Tear and bursting strength have been measured in the trapezoidal tear test and ball-bursting test, respectively, to evaluate the resistance of the thermally bonded geotextiles to various environments in construction sites. The apparent opening size (AOS) and the permittivity of model geotextiles were also tested to evaluate the geotextile function in terms of drainage and water permittivity, respectively. Figure 1 shows the standard manufacturing process of geocomposites using geogrid and geotextile.

2. Experiments and Methods of Evaluation

Geotextile composites of PVA GT/HDPE GM, PVA GT of 600, 1000, 1500, 2000 g/m^2 and HDPE GM (thickness; 1.5 mm) have been produced in thermal bonding process. Table 1 shows the specifications of these composites; the specification was prepared for comparisons of their long-term performances between polyester and polypropylene non-woven GTs, which are similar to each other in terms of thickness and weight. Figure 2 shows the schematic diagram of geotex-

Table 1.
Specifications of geotextile composite and non-woven 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. Schematic diagram of geotextile composite (left) and its installation upon HDPE GM (right).

tile composite (left) and the typical installation of polypropylene or polyester GT upon HDPE GM (right), respectively. Note that polyester and polypropylene GT are manufactured in needle punching process.

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. Apparent opening size (AOS) of PVA, polypropylene and polyester GT was measured and evaluated in accordance with ASTM D 4751. Hydraulic conductivity tests evaluating vertical permeability of PVA, polypropylene and polyester GT were performed in accordance with ASTM D 4491. Evaluation for ultraviolet stability of geotextile composites was conducted by exposing them repeatedly for a total of 500 h with 120-min cycle time consisting of 102-min light curing and 18-min water blast in accordance with ASTM D 4355, ASTM Committee G 26 using Xenon-arc [11–14].

3. Features of Test Specimen

The two kinds (NW 1 and NW 2) of thermal bonding type geotextile were manufactured and used as a separator for the investigation in this paper. One hundred percent polypropylene was adopted as a raw material for manufacturing geotextiles. The specifications of raw materials and geotextiles produced are summarized in Table 2. Prepared geotextiles for the present investigation have two different product dimensions: one with 0.39 mm in thickness and 136 g/m in weight and the other with 0.53 mm in thickness and 220 g/m in weight, respectively. The appearance and fiber arrangements of the geotextile have been examined through a microscope to make fundamental evaluation on the geotextile produced in thermal bonding process and they are shown in Fig. 3. It is easily seen in the figures that the mono fiber made of NW 2 is found to be denser than the other, i.e. NW 1. It is also known from the figures that the specimen NW 2 is more complicatedly

Table 2.
Features of geotextile specimen

Feature		NW 1	NW 2
Raw material (polymer)	Specific gravity Melting point Diameter of mono fiber Manufacturing method	100% PP (polypropylene) 0.91 g/cm^3 165°C 40–50 μm Thermal bonding	
Geotextile	Weight (g/m)	136	220
	Thickness (mm)	0.39	0.53

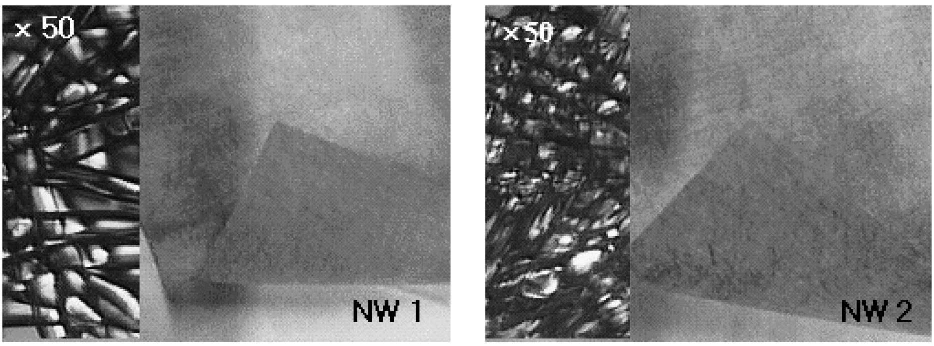

Figure 3. Appearance and fiber arrangement of geotextile.

arranged than that of NW 1. Through this microscopic evaluation, the separation and filtration effects of NW 2 are expected to be more effective than that of NW 1.

4. Mechanical Properties of Geotextile

The wide-width strip tensile strength test was conducted under the ASTM D 4594 test method [11]. In this wide-width strip tensile strength test of geotextile, the experiment has been carried out by placing the sample material between flat grips attached securely to the tensile experimental equipment. The results of tensile strength test are shown in Fig. 4. It is known from the test results that the modulus of the specimen NW 2 is greater by about two times than that of NW 1. It is interesting to note that the tensile strength of the specimen NW 2 is 1.8 times greater than that of the specimen NW 1 even though the weight of the specimen NW 2 is only 1.6 times heavier than that of the specimen NW 1. Both NW 1 and NW 2 specimens showed the tensile strain, i.e. elongation property, over 60%. From these results, it can be concluded that the separation property in field application could

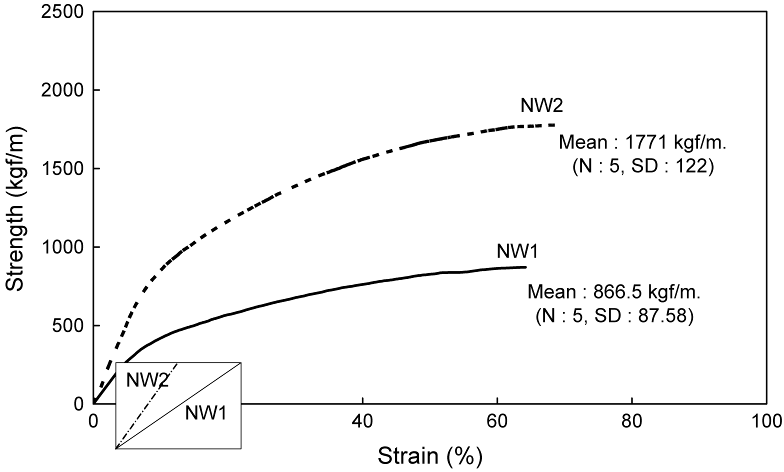

Figure 4. Strength–strain curve of geotextile specimen.

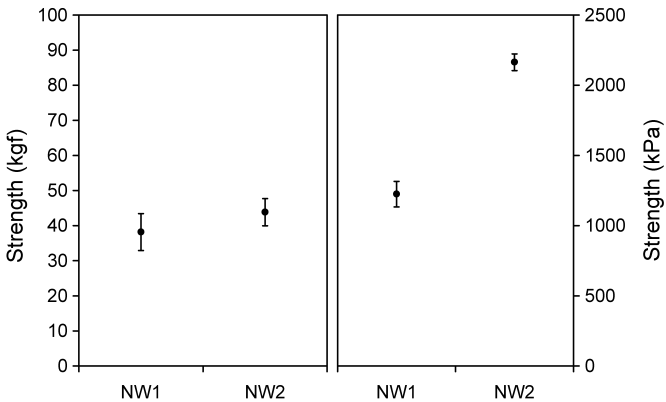

Figure 5. Tear (left) and bursting (right) strength.

be adequately fulfilled in consideration along with the geogrid's elongation property.

Figure 5 shows tear and bursting strength of geotextile specimens, respectively. Tearing of geotextiles takes place for many reasons, such as from equipments and/or environments in construction sites. These tests provide a very important method for assessing the resistance properties to such a harsh environment. The tear strength test has been performed according to the ASTM D 4533 test method [12]. In this study, the trapezoidal tear test was chosen and conducted under the condition of various samples at different phases. The bursting strength test is the one to assess the resistance property to bursting of a geotextile, and the bursting strength was properly evaluated according to the ASTM D 3787 ball-bursting test.

The results of tear strength test are related directly to the physical damage of material during construction. On the other hand, the results of bursting strength test are closely related to the damage sustained under the circumstances of particular situations after the construction in which the geotextile is serving. It is readily seen from the figure that there is no large difference between the specimens NW 1 and NW 2 in terms of tear strength. Thus, it can be easily concluded from the experimental results that the changes in weight and thickness would not have great or decisive influence on the tear strength of geotextile. As for bursting strength, it can be seen from the figure that the bursting strength of the specimen NW 2 is about twice as large as that of the specimen NW 1, which is different in trend from that in the tear strength. Both NW 1 and NW 2 geotextiles are expected to have very outstanding bursting strength in terms of geotextile thickness. The geotextile proposed in this paper has an advantage of light weight in service and its application to the construction sites would therefore be more feasible in terms of economy.

5. AOS and Permittivity of Geotextile

One of the major functions of geotextile is drainage and the apparent opening size (AOS) of geotextile was rated by the code that was published in ASTM D 4571 [13], and the water permittivity of the geotextile was evaluated under the procedure in ASTM D 4491 [14]. From these experimental results, AOS values and permittivity of geotextile are summarized in Table 3. For water permeability evaluation of geotextile, the non-woven fabric's apparent opening sizes (AOS) with regard to the specimens both NW 1 and NW 2 were measured. The AOS was measured at the time when 95% of the quantity of beads is passing through the sieve, and the measured results are also summarized in Table 3. It is seen from the experiments that the AOS diminishes as the cohesion of the filament becomes stronger, that is, as weight increases. It was revealed from the experiments that the specimen NW 1 increases about 3 times more than NW 2 does in terms of AOS. However, the water permittivity coefficient was found to decrease as weight increased. In case of the thermal bonding geotextile adopted in this study, both the tensile strength and bursting strength increase more or less proportionally as the specimen weight increases. However, it is also predicted from the experimental results that both AOS and water permittivity coefficient diminish as the weight increases.

Table 3.
AOS and water permittivity of geotextile

Water permittivity	NW 1	NW 2
AOS, O_{95} (μm)	205	78
Permittivity coefficient (cm/s)	5.4×10^{-2}	2.6×10^{-2}
Permittivity rate (s^{-1})	1.20	0.45

6. Results and Discussion

Figure 6 shows that polypropylene non-woven GTs are more remarkable than polyester GTs in terms of tensile properties, irrespective of weight. Probably, this is why renewable polyester is employed in real applications. It is particularly interesting to note that geotextile composites exhibit the greatest tensile strength. Figure 7 shows tear strength of geotextile composites. It is seen from the figure that tear strength of geotextile composites have the similar tendency as tensile strength.

Figure 8 shows the relationship between weight of geosynthetics and bursting strength of geotextile composites. It is readily seen from the figure that bursting strength of geotextile composites shows very similar tendency to that of tensile and tear strengths. As a result, it could be concluded from the figure that geotextile com-

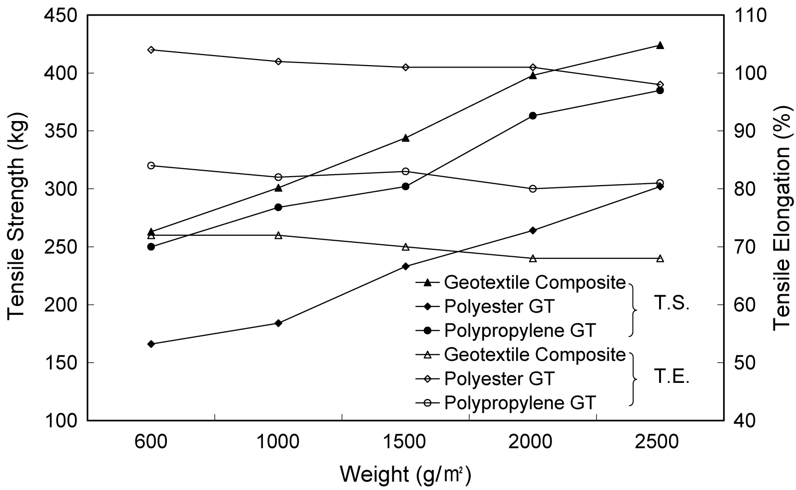

Figure 6. Tensile properties of geotextile composites.

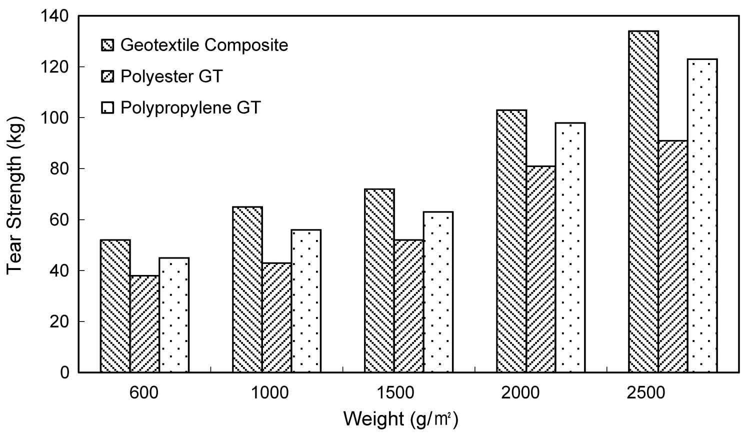

Figure 7. Tear strength of geotextile composites.

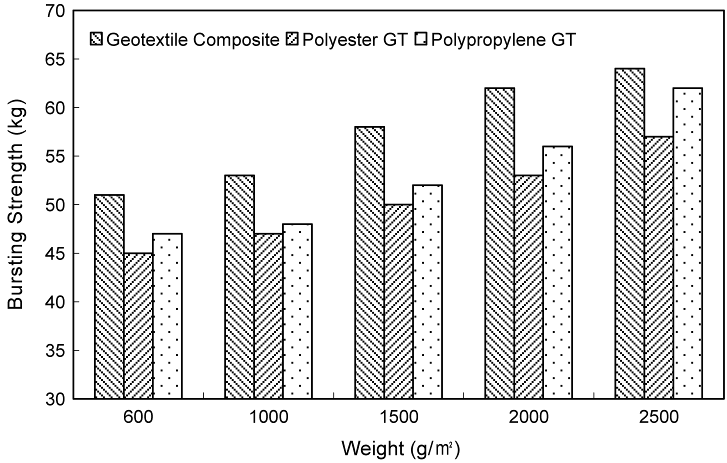

Figure 8. Bursting strength of geotextile composites.

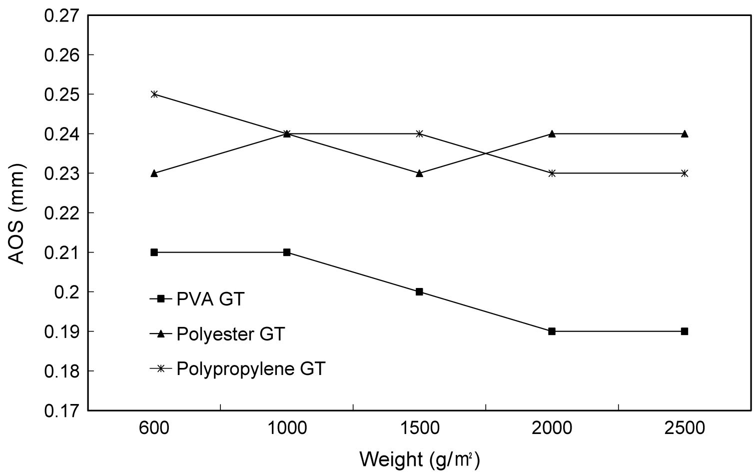

Figure 9. AOS of geotextile composites.

posites exhibit more efficient mechanical properties than polyester or polypropylene GT and they could be used widely for improvements of protection/reinforcement functions in the waste landfill. AOS values of GT are shown in Fig. 9. In the figure, it is readily seen that AOS values of PVA GT are relatively lower than that of other GTs. It could be assumed from this that textile unity effects of PVA GT due to needle punching became stronger than polyester or polypropylene GT and this proves their excellent characteristics in terms of separation and/or protection functions. Therefore, geotextile composite of PVA GT could have more efficient separation and/or protection functions than GT and GM when they are separately installed in a waste landfill system.

Figure 10 shows the vertical hydraulic conductivity, i.e. permittivity of GT. This value is dependent on AOS as flow path directly affects permeability. Therefore, the geotextile composite of PVA GT also should have more excellent separation/protection functions than GT and GM when they are separately installed in a waste landfill system. Figure 11 shows changes of physical properties of geotextile composites after 500 h exposure to ultraviolet radiation. As shown in the figure, both tensile strengths of polypropylene GT were dramatically reduced, specifically by about 30% to 60% on average. However, the reduction in tensile strength decreases with increasing weight. It is also seen from the figure that the degree of resistance to ultraviolet light decreases with increasing weight and it results in sta-

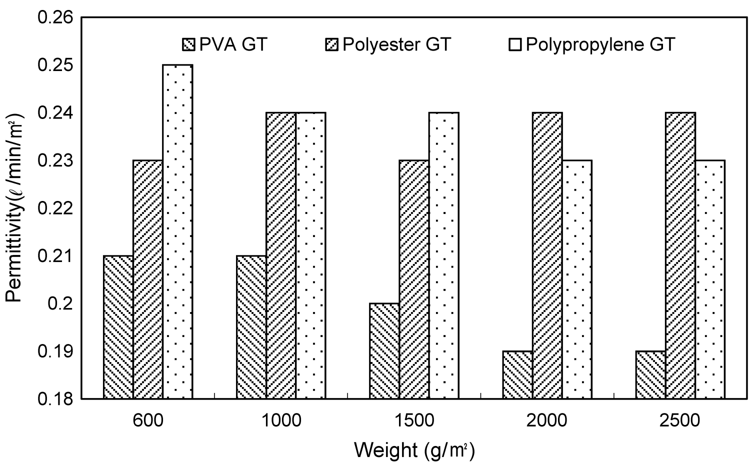

Figure 10. Permittivity of geotextile composites.

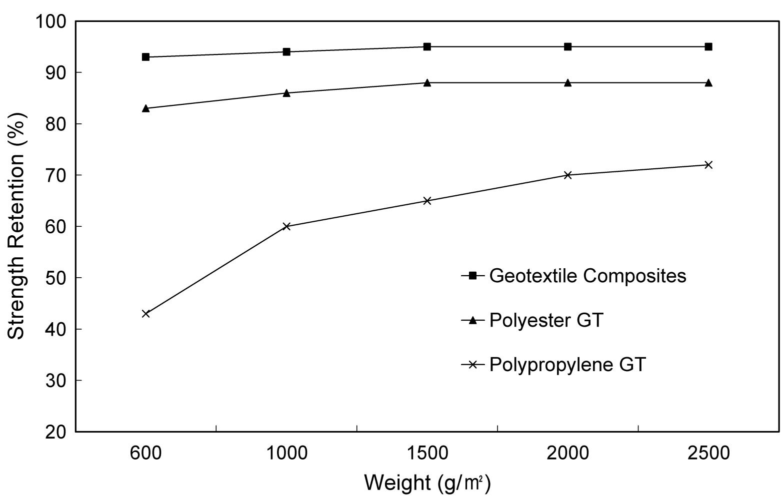

Figure 11. Ultraviolet stability–strength retention.

bility of tensile strength. On the other hand, polyester GT exceeded 80%, and is therefore deemed more stable than polypropylene GT against ultraviolet, but geotextile composites have more than 90% of tensile strength holding rate.

7. Summary

A thermal bonding type geotextile was introduced and manufactured in two different types for the investigation of properties as a separator. It has been concluded from the experimental results that the weight of the specimen does not have significant effect on the elongation property of the geotextile. It was also seen from the microscopic view that the mono fiber of the specimen NW 2 is denser and more or less complicatedly arranged than that of the specimen NW 1, and thus the specimen NW 2 could be better for the applications as a use of separator or filtration. Both NW 1 and NW 2 specimens are evaluated to have outstanding characteristics in terms of bursting and tear strengths even though their thickness is not large. It was also revealed from the experiments that the water permeability of the geotextile with a thermal bonding was relatively lower so that the separation function is expected to be carried out smoothly.

For tensile properties, polypropylene non-woven GT is more remarkable than polyester non-woven GT, and in particular geotextile composites had the largest value. Tear and bursting strengths show similar tendency to that of tensile strength. AOS values of PVA non-woven geotextiles are generally less than those of polyester and polypropylene non-woven geotextiles. Textile unity effect due to needle punching is assumed to be significant in PVA GT. Permittivity of PVA GT decreases more significantly with decreasing diameter of AOS than that of polyester and polypropylene non-woven GT. The polypropylene non-woven GT results in considerable reduction of tensile strength.

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