Assessment of long-term design strength of geotextile composites by durability test

H. Y. Jeon
Department of Textile Engineering, Chonnam National University, Kwangju, Korea

Keywords: Creep, Durability, Geogrids, Geotextiles, Performance evaluation

ABSTRACT: 700~2,000g/m^2 polypropylene needle punched nonwovens and 4~15 ton/m woven mats of polyester and polypropylene split yarns were used to manufacture [nonwoven/woven /nonwoven] structured composites by needle punching method to strengthen the reinforcement effects. Accelerated creep tests were performed in accordance with ASTM D5262-92 at different levels of temperature. And partial factors of safety for transmissivity, chemical degradation, biological degradation, joints and installation damage etc.. were determined by experimental data of durability tests. The allowable strength of geotextile composites were calculated from the ultimate tensile strength and these partial factors of safety. And the design strength of geotextile composites from these allowable strength values by GRI Standard Test Method GG 4(b) were determined. In addtion to this, 4~15 ton/m geogrids to compare the reinforcement performance with these geotextile composites were used and the test conditions of geogrids were as same as the case of geotextile composites. Finally, the design strength and partial factors of safety between geotextile composites and geogrids were compared and predicted the long-term behaviors of geotextile composites from these results.

1 INTRODUCTION

Woven geotextiles have the reinforcement/protection functions due to high tensile strengths in nature and they are frequently used as reinforcements in civil and geotechnical fields, slopes, segmental retaining walls and so on. In general, woven geotextiles are made of high tenacity polyester or polypropylene split yarns and low elongation woven geotextiles are used as reinforcing materials in construction fields. The most important factor to affect on the allowable strength of woven geotextiles for reinforcement is the creep behavior and to interpret the long-term design strength this the accelerated creep tests were performed with different temperature. In this study, polyester woven geotextiles to be bonded with nonwovens were manufactured as a kind of composite fabrics for reinforcement and the allowable strength of these were obtained by the results of creep tests. The long-term design strength as performance evaluation were calculated in consideration with factors of safety for design and construction and the long-term behaviors of geogrids were compared to those of woven geotextiles to examine the reinforcement function.

2 THEORETICAL BACKGROUND

2.1 *Theory of creep deformation*

‘Time-temperature superposition principle’ is applied to predict the long-term creep behaviors of geosynthetics and the relationship among strain-time-temperature in creep deformation could be explained by following equation:

$$\mathrm{E}(\mathrm{T}_0, t) = E(T, \frac{t}{a_t}) \tag{1}$$

where E = the creep modulus; T_0 and T = reference and test temperature, respectively; α_T = the shift factor; t = the test period.

Shift factor, α_T, is the parameter to be related to the overlapping movements of each creep deformation curve to write the master curve for long-term creep deformation with the different temperature and represented as:

$$Log\ a_T = \frac{-C_1 (T - T_0)}{(C_2 + T - T_0)} \tag{2}$$

where C_1 and C_2 = constants to be related to the geosynthetics respectively.

If the creep test were taken in lower temperature than T_g of polymer materials which compose the geosynthetics, these constants could be written by :

$$C_1^g = \frac{C_1 C_2}{\left(C_2 + T_g - T_0\right)} \tag{3}$$

$$C^g{}_2 = C_2 + T_g - T_0 \tag{4}$$

Therefore, equation (2) is:

$$Log\ a_T = \frac{-C^g{}_1\left(T - T_0\right)}{\left(C^g{}_2 + T - T_0\right)} \tag{5}$$

The master curve of creep deformation with different temperature could be obtained by application α_T to overlapping operation by ‘time-temperature superposition principle’ for each creep curve. By extrapolating the master curve to the creep strain axis, the allowable creep strain could be predicted for long-term scale. The slope of this regressive equation means the creep deformation rate during geosynthetic’s service period.

2.2 *Long-term design strength*

Design strength of geosynthetics is calculated by equation (6) in consideration with the factor of safety for design and construction as follows:

$$T_{design} = \frac{T_{allow}}{FS_{uc}} \tag{6}$$

where T_{design} and T_{allow} = the allowable and design strength of geosynthetic; FS_{uc} = the factor of safety for design and construction. Finally, long-term design strength for reinforcement of geosynthetics could be written by:

$$T_{allow} = T_{ultimate} [\frac{1}{FS}] \tag{7}$$

where $T_{ultimate}$ = the ultimate strength of geosynthetics; FS = total factor of safety for design and construction

3 EXPERIMENTAL

3.1 *Preparation of samples*

700~2000g/m^2 polypropylene needle punched nonwovens and 5~20 ton/m(;design strength) woven mats of 2700 denier polyester split yarns were used to manufacture the woven geotextiles as a kind of composite fabrics. For nonwovens, the high packing density web was used to strengthen the structural effects by fiber entanglements and to decrease the elongation against the applied stress. The split yarns of warp and weft for woven geotextiles were manufactured specially to have the high performance and tenacity. Woven geotextiles is located in the middle and the [Non-woven/woven mat/nonwoven] structured composite fabrics were produced by needle punching and thermal bonding methods to obtain the reinforcement/protection effects. Geogrids were used to compare the reinforcing effects and Table 1 shows the specifications of these geosynthetics.

Table 1. Specifications of geosynthetics

Specifications Geosynthetics	Design Strength, T_D (ton/m)	Composition
GTC-1	5	NW/WM/NW
GTC-2	8	〃
GTC-3	18	〃
GG-1	5	Coated by PVC
GG-2	10	〃
GG-3	20	〃

3.2 *Estimation of mechanical properties*

3.2.1 *Mechanical properties*

Tensile properties were examined in accordance with ASTM D 4595-86 and the ultimate strength values and those at 10% strain were applied to calculate the partial factors of safety.

3.2.2 *Creep deformations*

Creep tests were performed in accordance with ASTM D5269-92 and different levels of temperatures(20~60°C) were used to perform this accelerated test.

4 RESULTS AND DISCUSSION

4.1 *Tensile properties*

The reinforcing geosynthetics should have excellent tensile and the fabric type geogrids are widely used in the field of soil retaining wall due to these reinforcing effects. In this study, woven geotextiles were made to develop the reinforcing effects and confirm the alternative possibility instead of geogrids. Table 2 shows the wide-width tensile properties of geosynthetics. It is shown that there is no significant difference of tensile properties both machine and cross direction for woven geotextiles and this is due to the uniform evenness of woven geotextiles both directions. But for geogrids, tensile properties of cross direction are smaller than those of machine direction and this is due to the structural speciality of geogrids e.g., aperture structure, tenacity of warp and weft, junction method, viscosity and bonding strength of coating materials etc.. From this, it is known that woven geotextiles are more excellent reinforcing materials than geogrids without regard to directions.

Table 2. Wide-width tensile properties of geosynthetics

Tensile Properties / Geosynthetics	Machine Direction	
	Strength (ton/m)	Strain (%)
GTC –1	4.7	12.1
GTC –2	8.1	12.6
GTC -3	18.2	12.3
GG-1	5.2	11.4
GG-2	10.6	13.6
GG-3	22.6	12.8

4.2 *Creep behaviors*

The master curves were obtained by the creep tests to be taken in the temperature range as 20~60°C and equation (1)~(6). Figure 2~7 show the master curves of long-term creep deformations of geosynthetics. From these results of creep deformations, it is shown that the slopes of regression curves for woven geotextiles were a little smaller than those for geogrids at the same design strength level. it is seen that the applied stress could be distributed with fiber and yarn orientation direction for woven geotextiles but concentrated on the warp direction for geogrids. It means that this is a kind of evidence that woven geotextiles would be an alternative reinforcing material instead of geogrid. While it is known that the larger the design strength of woven geotextiles and geogrids, the lower the stability on the creep deformation. GTC-1, -2, -3 and GG-1, -2, -3 show the same creep behaviors without regard to the applied loads but the initial creep strains of these are different and this is due to the composition of geosynthetics as considered as the case of tensile properties. From this consideration, it is concluded that GTC would be a reinforcing geosynthetics.

4.3 *Factors of safety for creep deformation*

The factor of safety for creep deformations of geosynthetics could be the following equation:

$$F_{cr} = \frac{T_{ultimate}}{T_{10\%}} \qquad (8)$$

where $T_{10\%}$ is 10 year design life strength of geosynthetics in sustained ASTM D 5262.

The factors of safety for creep deformation are as following:

GTC-1, -2, -3 ; 1.84, 1.81, 1.80

GG-1, -2, -3 ; 1.87, 1.84, 1.82

4.4 *Long-term design strength*

The long-term design strength of GTCs and GGs could be calculated by:

$$T_{LTD} = T_D/FS_{LTD} \qquad (9)$$

and the total factor of safety, FS, is :

$$FS_{LTD} = FS_{ID} \times FS_{CR} \times FS_{CD} \times FS_{BD} \times FS_{JCT} \quad (10)$$

where, FS_{ID} is the factor of safety for installation damage, FS_{CR} is the factor of safety for creep deformation, FS_{CD} is the factor of safety for chemical degradation, FS_{BD} is the factor of safety for biological degradation, FS_{JCT} is the factor of safety for joint, respectively. Table 3 shows the long-term design strength of Geosynthetics and it is known that GTCs and GGs are the same tendency as the reinforcing Geosynthetics.

Table 3. Long-term design strength T_{LTD} of geosynthetics

Strength Geosynthetics	FS_{LTD}	T_D	T_{LTD} (=T_D/FS_{LTD}) (ton/m)
GTC-1	2.55	5	1.96
GTC-2	2.35	8	3.4
GTC-3	2.24	18	8.04
GG-1	2.25	5	2.22
GG-2	2.23	10	4.48
GG-3	2.23	20	8.97

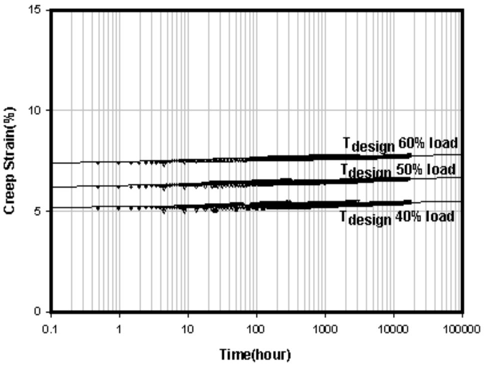


Figure 2. The long-term creep deformation of GTC-1

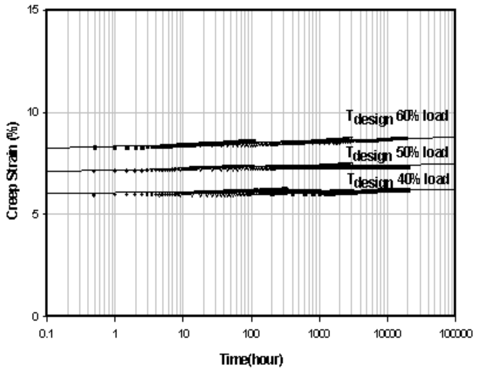
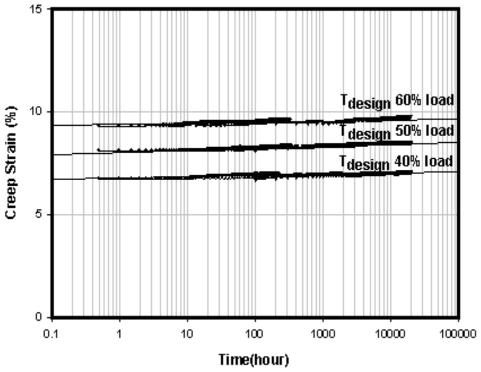


Figure 3. The long-term creep deformation of GTC-2



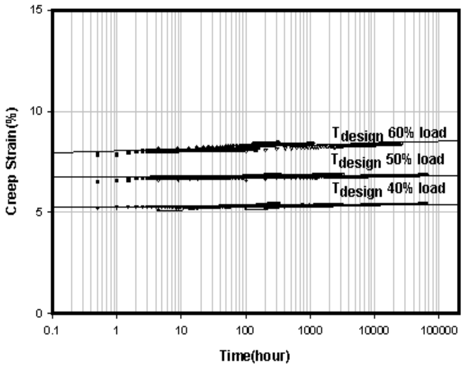


Figure 4. The long-term creep deformation of GTC-3

Figure 5. The long-term creep deformation of GG-1

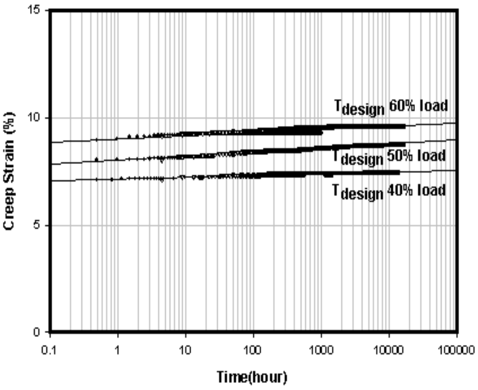


Figure 6. The long-term creep deformation of GG-2

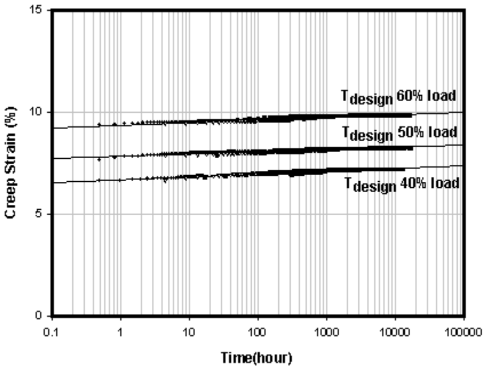


Figure 7. The long-term creep deformation of GG-3

From the above results, it was confirmed that woven geotextiles could have the sufficient performance as an alternative geosynthetics instead of geogrids and the further study will be continue to confirm the possibility of woven geotextiles as the excellent reinforcing material.

REFERENCES

ASTM, 1995. ASTM Standard on Geosynthetics. ASTM:Philadelphia, PA., USA.
GRI, 1999. GRI Test Methods & Standards, Drexel Univ: Philadelphia, PA, USA.
Holtz., R.D., 1997. Geosynthetic Engineering. Richmond:BiTech Pub. Ltd., USA.
Koerner, R.M, 1999. Designing with Geosynthetics, 4th Ed., New Jersey:Prentice Hall, USA.