ANALYSIS OF CREEP BEHAVIORS OF GEOSYNTHETIC REINFORCEMENTS BY NEWLY DESIGNED TEST METHOD

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ABSTRACT: 8 ton/m warp-knitted type geogrid was used to examine the creep behaviors by 3 different creep tests e.g., accelerated creep test, SIM creep test and newly designed creep test etc.. Also, installation damage test was performed to estimate the effects of installation damage of geogrid on the creep deformation. These creep deformation tests were done within 3 temperature ranges. This combined reduction factors of installation damage and creep deformation through the newly designed creep test compared to those of accelerated creep test, SIM creep test. Finally, long-term design strengths of geogrid were interpreted from the factor of safety by reduction factors of installation damage and creep deformation.

1 INTRODUCTION

Geogrids have aperture structures with typically 10~100mm between longitudinal and transverse ribs, respectively.

There are many types of geogrids widely used in the field of geotechnical engineering. One of them is the textile type geogrid and this is made with the high tenacity filament polyester using a conventional weaving and/or knitting process.

Commonly, the fabric type geogrids are coated with polymer resins such as PVC (polyvinylchloride), bitumen, PP (polypropylene), and rubber, which contain a light stabilizer and antioxidant. Since the geogrids possess high tensile strengths in nature, they are frequently used as reinforcements in unpaved/paved road construction, slopes of waste landfill liner system, embankments and slopes, segmental retaining walls, and so on.

Using geogrids for reinforcement, the allowable strength of the geogrid must be calculated based on the results of creep tests. In this study, three different creep tests were performed on the 8 ton/m warp-knitted type geogrid which is typically used in Korea.

The newly designed creep test apparatus was used to consider the effects of the above combined situations. Also, it is possible for this apparatus to estimate the combination reduction factor by installation damage and creep deformation within all the temperature ranges.

This combined reduction factors through the newly designed creep apparatus were compared to those of typical reduction factor by creep deformation.

By using this new creep test method, it is very reasonable to determine the creep behaviors to be considered the combined geogrid installation conditions. Besides this, test period will be shortened because 3 combined tests are possible simultaneously by this creep apparatus.

2 THEORETICAL BACKGROUND

2.1 *Time-temperature superposition principle*

In general, 10,000 hours is used to predict the long-term strain of geogrid in extension creep tests.

Therefore, it is a general practice that the test results from accelerated conditions are extrapolated up to one order of time by using the principle of time-temperature superposition.

The relationship between time and temperature can be explained with the shift factor at accelerated temperatures.

Through this relationship the strain exist time can be shift with time by a shift factor at the elevate temperature.

Eq. 1 shows such a relationship, and the shift factor can be obtained by using the WLF equation (Eq. 2) suggested by Williams, Landel, and Ferry.

$$E(T_O, t) = E(T, \frac{t}{a_T}) \tag{1}$$

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

In the WLF equation the C_1 and C_2 vary with material and reference temperature.

If a glass transition temperature (T_g) is used for extrapolation, the C_1 and C_2 take the value of 17.4 and 51.6, respectively.

2.2 *Long-term design strength*

From GRI Standard Test Method GG4[b], the allowable strength of geosynthetic reinforcements could be written in the following equation to be taken into consideration of the ultimate strength, total factors of safety for application of geosynthetic reinforcements.

$$T_{\text{allowable}} = T_{\text{ultimate}}[\frac{1}{FS}] \tag{3}$$

where, $T_{ultimate}$ = ultimate strength of geosynthetic reinforcements, $T_{allowable}$ = allowable strength of geosynthetic reinforcements, FS = total factor of safety of geosynthetic reinforcements.

And the reduction factors of geosynthetic reinforcements for applications should be as following.

$$FS = RF_{ID} \times RF_{CR} \times RF_{CD} \times RF_{BD} \quad (4)$$

where, RF_{ID} = reduction factor for installation damage, RF_{CR} = reduction factor for creep deformation, RF_{CD} = reduction factor for chemical degradation, RF_{BD} = reduction factor for biological degradation.

In the equation (4), RF_{ID} and RF_{CR} are very important factors which influence the long-term design strength of geosynthetic reinforcements.

Therefore, it can be written by the following equation if consider this:

$$T_{allowable} = T_{design}\left[\frac{1}{RF_{ID} \times RF_{CR}}\right] \quad (5)$$

where, T_{design} = long-term design strength of geosynthetic reinforcements.

3 EXPERIMENTAL

3.1 *Preparation of samples*

Geogrid of 8 ton/m design strength made with polyester high tenacity filament were used in this study, which were manufactured by warp knitting process.

3.2 *Wide-width tensile strength*

Wide-width tensile strength of geogrid was tested in accordance with ASTM D4595.

3.3 *Installation damage*

ISO/TR 10722-1:1998(E) was used to test the installation damage for geogrid and the degree of installation damage was estimated by the strength retention before and after installation.

3.4 *Creep deformation test*

3.4.1 *Accelerated creep test*

This creep test was performed according to ASTM D5262. Three loading levels were used at 40, 50, and 60% of the design strength of the geosynthetic reinforcements.

Test period was kept constant for 1,000 hours with 20, 35, 50°C, respectively.

3.4.2 *SIM(stepped isothermal method) creep test*

The GRI GS10 test method used in this study and Table 1 shows the overview of the creep test by the SIM creep test.

Figure 1 shows the apparatus of accelerated and SIM creep tests.

3.4.3 *Newly Designed(ND) creep test*

New creep test equipment was designed as Figure 2. In here, load control system by servomotor was adopted instead of dead weight system.

Creep test by ASTM D5262 was applied as same as accelerated creep test.

Table 1. Overview of the short-term creep test by the SIM

Items	Contents
Equipment	Tensile creep tester
Temperature	26, 40, 54, 68, 82 °C (5 steps)
Step of temperature.	14 °C
Loading level	60% of ultimate tensile strength
Test time(each step)	10,000 sec (total 50,000 sec)

Figure 1. Apparatus of accelerated and SIM creep tests

Figure 2. Photograph of ND creep test equipment and specimen clamping part

4 RESULTS AND DISCUSSION

4.1 *Tensile strength before and after installation*

Tensile strength of 8 ton/m warp-knitted type geogrid in the machine and cross machine directions are represented in Table 2 before and after installation.

From this, it is seen that no tensile strength change is in geogrid before and after installation test.

Table 2. Tensile strength of geogrid before and after installation

Installation / Direction	Tensile Strength(ton/m)	
	Before	After
Machine Direction	10.45	10.03
Cross Machine Direction	3.82	3.76

4.2 *Creep deformation behaviors*

4.2.1 *For accelerated creep test*

Figure 3 shows the for creep strains of geogrid with various loading levels. It is known that 60% of $T_{ultimate}$ is the maximum creep load by considering the limit creep strain 10% with additional loads.

For accelerated creep test, the additional load would not be constant to consider the thermal change of specimen with temperature.

Therefore, the larger load will be applied to the geogrid with higher temperature and the ultimate strength of geogrid will be decreased to compare the real load.

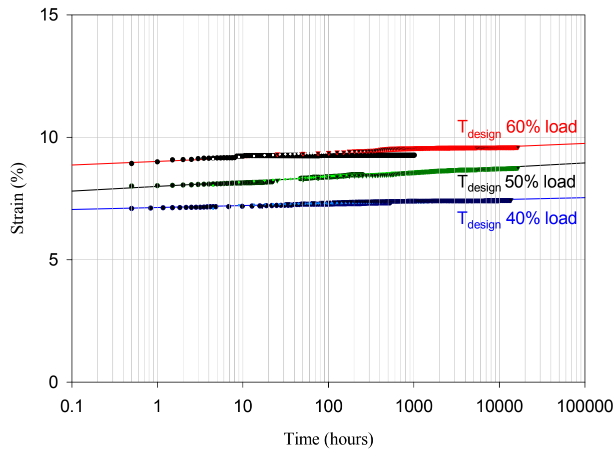

Figure 3. Master curves for creep strains of geogrid with various loading levels

4.2.2 *For SIM creep test*

Table 3 shows the shift factor of SIM creep test of geogrid. Figure 4 and 5 show the creep modulus curves and master curves for creep strains of geogrid with various loading levels.

From this result, the additional load for SIM creep test would be constant to consider the thermal change of specimen with temperature to compare the accelerated creep test.

And, the constant creep load will be applied to the geogrid with higher temperature and the ultimate strength of geogrid will be more stable.

4.2.3 *For ND creep test*

Figure 6 shows the for creep strains of geogrid with various loading levels by ND creep tester. In here, the limit creep strain of geogrid is increased to compare the former accelerated and SIM creep test results.

Especially, these phenomena are clearly shown for the same additional creep load. For considering the limit creep strain 10%, the maximum additional creep load is almost up to the 75% of $T_{ultimate}$.

This difference is very significant result and the main cause of this is due to the additional load control system and panel of ND creep test in Figure 7.

As explained before, **3.4.3**, the load control system by servomotor could be keeping the constant creep load without regard to the temperature to compare the dead weight system.

Namely, the deviations of additional creep load by thermal change of specimen with temperature could be optimized and minimized by ND creep tester.

From this, it is seen that the limit creep load will increase to the geogrid by ND creep tester and the ultimate strength of geogrid will be increased.

Table 3. Shift factor versus temperature for SIM creep test for geogrid

Temperature (^{o}C)	Shift factor (log a_T)
26	0
40	-1.22
54	-2.48
68	-3.70
82	-4.95

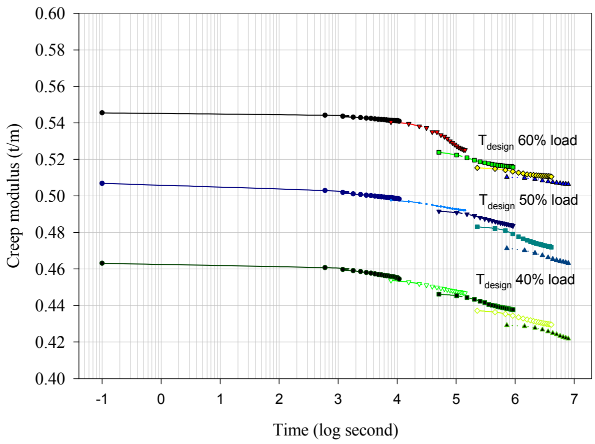

Figure 4. Creep modulus curves of geogrid with various loading levels

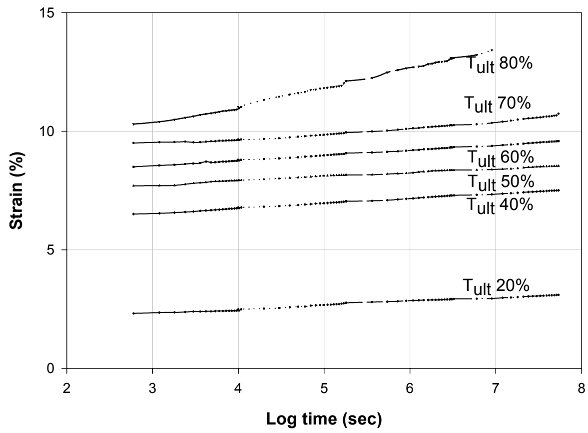

Figure 5. Master curves for creep strains of geogrid with various loading levels

5 LONG-TERM DESIGN STRENGTH

Table 4 and 5 show the reduction factors for installation damage and creep deformation and total factor of safety by these reduction factors, respectively.

Table 6 shows the long-term design strength of geogrid by total factor of safety.

From this, it is seen that the long-term design strength of geogrid would be different by creep test method even if same design strength geogrid.

Of course, this is the charge of the designer to select the best way to determine the optimum reduction factor for creep deformation.

Finally, ND creep test must be modified and compensated to clearly set up through the correct and detailed test results in spite of current excellent creep deformation data in this study.

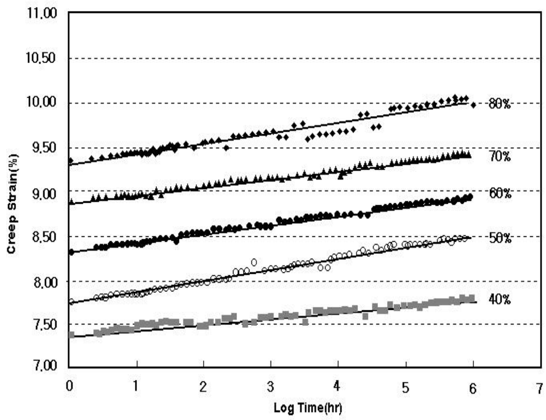

Figure 6. Master curves for creep strains of geogrid with various loading levels

Figure 7. Additional load control system and panel of ND creep test

Table 4. Reduction factor for installation damage and creep deformation of geogrid

Creep Test / Condition	Accelerated	SIM	ND
Installation Damage	1.05	1.05	1.05
Creep Deformation	2.17	2.12	1.94

Table 5. Factor of safety by reduction factors of geogrid

Creep Test	Accelerated	SIM	ND
Factor of Safety	1.87	1.82	1.54

Table 6. Long-term design strength of geogrid by total factor of safety

Creep Test	Accelerated	SIM	ND
Long-term Design Strength (ton/m)	1.87	1.82	1.54

6 REFERENCE

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