Materials and new testing

New Horizons in Earth Reinforcement – Otani, Miyata & Mukunoki (eds)

Durability evaluation of various geogrids by index and performance tests

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ABSTRACT: This study is focused on the test method that used for evaluating the long-term design strength of the various type of geogrid and suggestion of improved test method. Estimated long-term creep deformation indicate that the 65% of T_{ult} loading level is the optimum value that satisfying the creep criteria (curve becomes asymptotic to a constant strian line, of 10% or less) in the case of woven geogrid and 60% in warp knitted geogrid and 30 ~ 35 % in membrane drawn geogrid. All the tested geogrids showed the good resistance under chemical, biological and UV circumstances. The total reduction factor was determined by creep deformation, installation damage, chemical and biological degradation. Creep data interpretation is performed by using performance limit strain. From this procedure we can obtain more accurate reduction factor by creep deformation at the aim design life.

1 INTRODUCTION

Rheological models were adapted in order to describe the creep of geosynthetics(Navarrete, 2001; Mano and Sousa, 2001). For the study related to the installation damaged geosynthetics, more site performance tests were accomplished compared to index test. Several studies have suggested that the level of damage induced by construction to a polymer geogrid is a function of the following primary factors (Giroud 2002, DeMerchant 2002, Lin and Shi 2001); geogrid thickness, compacting effort and lift thickness, type and weight of construction equipment used for fill spreading, type and weight of compaction of backfill, angularity of backfill, etc. In this study, to estimate the RF (reduction factor) values, short-term tensile test, creep test, installation damage test and durability test were performed and the test result compared among geogrids. To review the index test results, more site-specific and material specific test and data analysis methods were proposed especially through creep deformation, installation damage, and chemical and biological resistance test.

2 EXPERIMENTAL

2.1 *Preparation of geogrids*

Three types of geogrids were employed in this study. The textile type of geogrid is divided into woven geogrid and warp knitted geogrid again and made of polyester high tenacity yarn coated with PVC (polyvinyl chloride) resin. The membrane drawn type geogrid is made of melted high density polyethylene with uni-directional conformation. So, for better comparison of these two types of geogrids, geogrids having same nominal strength (e.g., 8 ton/m, 10 ton/m) are selected as references. And, all the tests were performed to only longitudinal directions because the uni-directional drawn geogrid samples were used in this study.

2.2 *Evaluation of engineering properties*

To evaluate more optimum tensile strength of geogrid, ASTM D4595, wide-width tensile test method was adopted. ASTM D5262 was used to determine the creep deformation behavior of geogrid under constant temperature and load condition. Installation damage test was done under consideration the real installation field conditions. Chemical resistance test were performed by modified EPA 9090 standard. For biological resistance test, samples were incubated in two types of conditioned box which was filled with weathered granted soil and sewage sludge. The tensile strength values before and after incubation were determined by GRI test method GG-1.

3 RESULTS AND DISCUSSION

3.1 *Tensile properties*

Tensile strength of each specimens are higher than its product strength about 4 ~ 13%. In the case of warp knitted type geogrid specimens, the extra tensile strengths are above 13% to the design strength, and about 4 ~ 12% higher in woven type geogrids. And the tensile strength of membrane drawn type geogrids are higher than the products strength about 8 ~ 13%. From these extra tensile strengths, we may say that the additional factor of safety has been connoted in the geogrids. Also, the tensile strain at the ultimate strength are about 11.0 ~ 14.0%, 9.0 ~ 12.0% and 8 ~ 12% about the each geogrid samples. All of the geogrids in this study showed the good elongation properties. However, in the case of membrane drawn type geogrid, the additional elongation possibility exists in its inner structure. Figures 1 ~ 3 show the results of tensile test of each geogrid samples.

3.2 *Creep deformation behaviors*

To obtain master curves for long-term creep deformation, time-temperature superposition principle was applied. Conventional ambient creep test results and accelerated test are shown for each geogrid samples in Figures 4 ~ 6. From these test results, we can estimate the strain values that the curve becomes asymptotic to a constant strain line, of 10 percent or less. In the case of textile geogrids, each woven and warp knitted geogrids have 60% of UTS (ultimate tensile strength). And, the 30% and 35% of UTS is asymptotic to a line of 10 percent in membrane drawn type geogrid. From the creep testing, it was observed that polyester geogrids resist creep strain better than HDPE (high density polyethylene) geogrids at similar temperatures and load levels, However, for both HDPE and polyester geogrid specimens the increase in temperature and load level have a strong effect on the creep strain behavior, relatively larger for HDPE specimens. The increase in load level also increase the amount of creep strain in the specimens, but the influence is not as large as that due to the temperature. However, higher the temperature, the larger is the influence of the increase in load level.

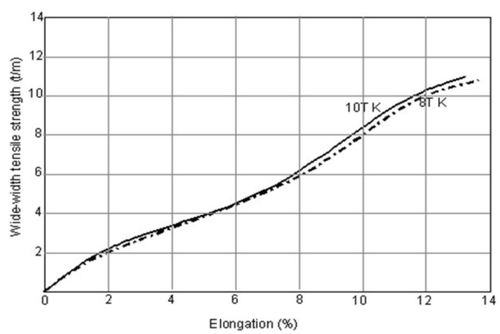


Figure 1. Wide-width tensile strength-elongation curves of warp knitted geogrids (longitudinal direction).

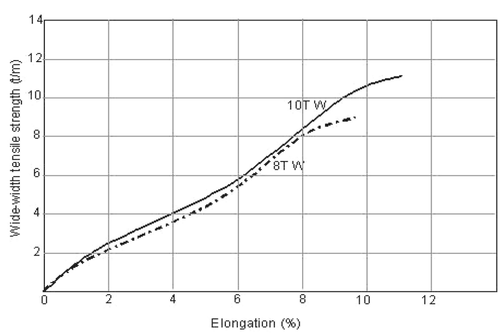


Figure 2. Wide-width tensile strength-elongation curves of woven geogrids (longitudinal direction).

3.3 *Installation damage*

Table 1 showed the strength retention of geogrids by installation damage.

The weathered granite soil having less than 20 mm particle size was used in this test. From these results it was confirmed that there were some tensile strength decreases in each samples, in the case of textile geogrid, about 6 ~ 7% strength decreases were founded for each textile geogrids (woven and warp knitted type). And strength decreases about 1.4 ~ 2.2% were observed in membrane drawn geogrid samples.

3.4 *Chemical resistance*

In the case of membrane drawn geogrid which was made by HDPE, there was merely small amount of decease (+0.7% (increase) ~ −2.6 (decrease)) in both acidic and alkaline conditions. While in the cases of

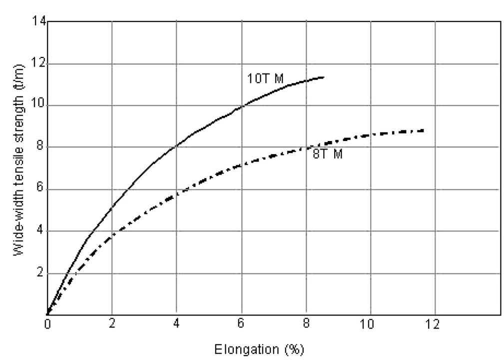
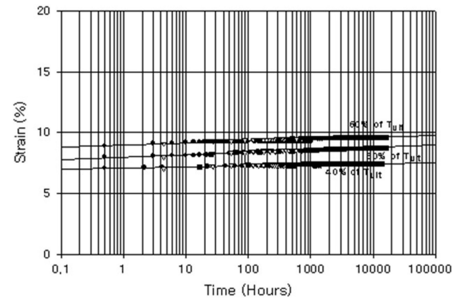
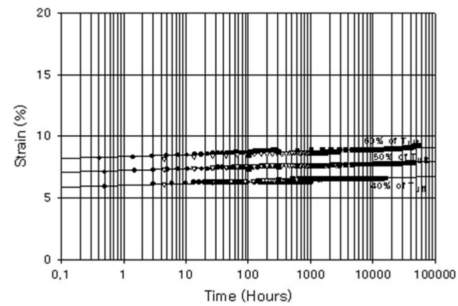


Figure 3. Wide-width tensile strength-elongation curves of membrane drawn geogrids (longitudinal direction).

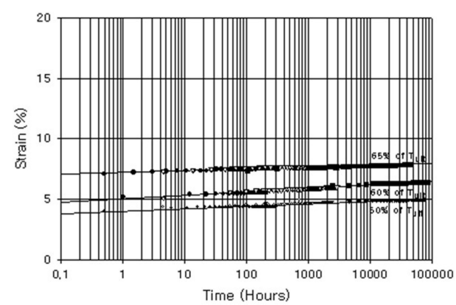


(a) 8TK

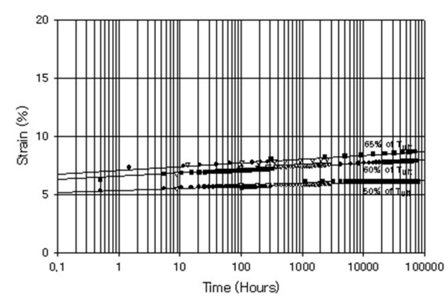


(b) 10TK

Figure 4. Creep deformation curves of warp knitted geogrids.



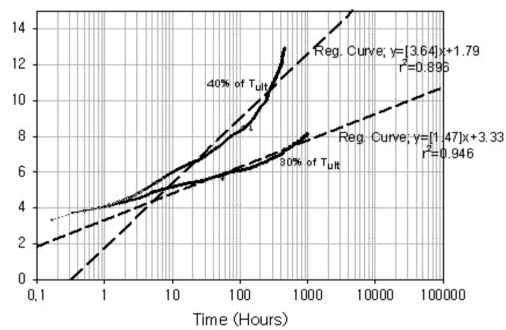
(a) 8TW



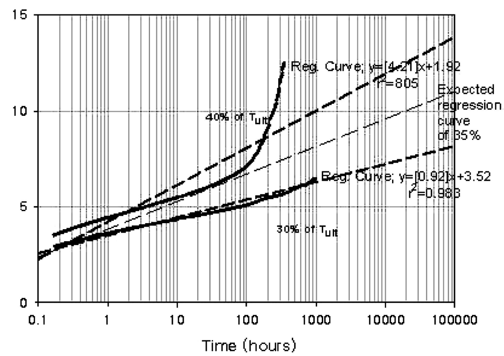
(b) 10TW

Figure 5. Creep deformation curves of woven geogrids.

the textile geogrids, it resulted in very similar tendency with the membrane drawn geogrid in acidic conditions but the tensile strength decreased about max. 45% in severe alkaline condition, NaOH, pH = 13, especially in knitted type geogrid. However, the strength decrease of woven type geogrid resulted in a reduction (%) as 17%, and this is smaller value compared with the results of knitted type geogrid. However, the actual site-specific condition (pH = 8.5 ~ 9.5) is considered, both type of geogrids can be used without problems and related durability safety factor for any soils having pH = 9.



(a) 8TM



(b) 10TM

Figure 6. Creep regression curves of membrane drawn geogrid.

Table 1. Wide-width tensile properties of geogrids after installation damage test (longitudinal direction).

Geogrid	Strength reduction (%)
8TK	7.7
10TK	10.6
8TW	5.9
10TW	10.9
8TM	1.3
10TM	2.1

Table 2. Reduction factors of warp knitted geogrids.

Geogrid specimen reduction factor		8TK	10TK
RF_{ID}		1.09	1.12
RF_{CR}		1.67	1.67
RF_D	RF_{CD}($pH \leq 9$)	1.05	1.05
	RF_{BD}	1.0	1.0
	Total RF_D($pH \leq 9$)	1.05	1.05
Total RF		*2.0*	*2.0*

Table 3. Long-term design strength of warp knitted geogrids.

	Geogrid specimen	
Property	8TK	10TK
Nominal tensile strength (t/m)	8	10
Total RF	2.0	2.0
Long-term design strength (t/m)	*4.0*	*5.0*

3.5 *Biological Resistance*

There are some decrease of strength for the exposed sampled (<3.0%), but these values can be contained within specimen variation and test errors. From these results it can be concluded that all of these geogrid samples are not affected by any of biological affects.

3.6 *Total reduction factor and long-term design strength*

Tables 2 ∼ 7 shows the total reduction factor and long-term design strength by creep deformation, installation damage, chemical and biological degradation. So, the long-term design strength of the geogrids will be reduced by this reduction factors. In designing with geogrid reinforcement, considering of these reduction factor and applying to designing process is very important for more safe structure within the aimed design life time. The GRI test method GG-4 that used world widely is applying to determine the reduction factors in this study.

Table 4. Reduction factors of woven geogrids.

Geogrid specimen reduction factor		8TW	10TW
RF_{ID}		1.12	1.12
RF_{CR}		1.54	1.54
RF_D	RF_{CD} ($pH \leq 9$)	1.05	1.05
	RF_{BD}	1.0	1.0
	Total RF_D($pH \leq 9$)	1.05	1.05
Total RF		*1.90*	*1.90*

Table 5. Long-term design strength of woven geogrids.

	Geogrid specimen	
Property	8TW	10TW
Nominal tensile strength (t/m)	8	10
Total RF	1.90	1.90
Long-term design strength (t/m)	*4.21*	*5.26*

Table 6. Reduction factors of membrane drawn geogrids.

Geogrid specimen reduction factor		8TM	10TM
RF_{ID}		1.05	1.05
RF_{CR}		3.3	2.8
RF_D	RF_{CD}($pH \leq 9$)	1.0	1.0
	RF_{BD}	1.0	1.0
	Total RF_D($pH \leq 9$)	1.0	1.0
Total RF		*3.46*	*2.94*

Table 7. Long-term design strength of warp knitted geogrids.

	Geogrid specimen	
Property	8TM	10TM
Nominal tensile strength (t/m)	8	10
Total RF	3.46	2.94
Long-term design strength (t/m)	*2.3*	*3.4*

4 CONCLUSION

In this study, the engineering properties related with the total reduction factor were evaluated by creep deformation, installation damage, chemical and biological degradation. For warp-knitted type geogrids, total reduction factor is estimated as 2.00. Installation reduction factors under the grain condition of <19 mm, was estimated as 1.09 and 1.12 respectively (8TK, 10TK). Warp knitted geogrid has low resistance to the alkaline circumstance ($pH > 12$) and high temperature. The biological resistance of the warp knitted geogrid was estimate that it has very strong resistance to the biological environment. For woven type geogrids, the total reduction factor is estimated as

1.90. Estimated long-term creep deformation indicates that the 65% of T_{ult} loading level is the optimum value that satisfying the creep criteria. Installation reduction factors under the grain condition of < 19 mm, was estimated as 1.12. In the case of low alkaline conditions (= site-specific conditions), it has satisfied resistance to its circumstance. The biological resistance of the woven geogrid was estimate that it has very strong resistance to the biological environment. The total reduction factor of membrane drawn geogrids having different nominal strength (8TM, 10TM) is estimated as 3.46 and 2.94 respectively. Estimated long-term creep deformation from creep test results indicate that the 30% (8TM) and 35% (10TM) of T_{ult} loading level is the optimum value that satisfying the creep criteria. Installation reduction factors under the grain condition of <19 mm, was estimated as 1.0. Also, membrane drawn geogrid had high resistance to the critical alkaline and acidic conditions because of its polymeric property of HDPE. The biological resistance of the membrane drawn geogrid was estimate that it has very strong resistance to the biological environment.

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