Analysis of geogrid engineering performance by certification points of view

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ABSTRACT: To prepare the certification of uni- and bi-axial geogrids, important engineering performances were evaluated in accordance with GCI-PCP recommended test methods. Evaluation items were divided into test items in accordance with important properties of uni- and bi-axial geogrids, respectively, By reviewing and checking the test results, it is confirmed that all the evaluation value of each item was satisfied with the recommended requirement value ranges of GCI-PCP certification guide. Through this consideration of GCI-PCP, it is possible to make an economic and optimum installation design guide for uni- and bi-axial geogrids in construction field application.

1 INTRODUCTION

For geogrids, there are many engineering performance to be dependent on the serviceability such as tensile properties, junction efficiency, pullout property, direct shear property, creep behavior, installation damage, chemical degradation, biological degradation, UV stability, number average molecular weight, carboxyl end group etc. (ASTM D35 2008). For retaining wall and slope construction method, experimental construction and measurement were discussed and reanalyzed.

In this study, firstly, we compared these test result values to the certification requirement and confirmed the quality of uni-axial geogrids. Secondly, direct shear test and pull-out test are adopted to estimate frictional behavior and long-term design allowable tensile strength of bi-axial geogrids is estimated. All the test methods of this study were done to certify with GCI-PCP. (Geosynthetics Institute 2008)

2 GEOGRIDS AND TEST ITEMS IN GCI-PCP

Table 1 and 2 show the specifications of uni- and bi-axial geogrids with fabrication type. In Table 2, bi-axial type geogrids are new type geogrids made of fiber-reinforced polymer strips with woven structure and welded junctions.

In here, GGWR-1 and -2 mean the design strength 60kN/m and 100kN/m, respectively. This is as same as GGKR-1 and -2. Table 3 shows the test items and certification requirement values to be satisfied with the draft of GCI-PCP for uni-axial geogrids.

Table 1. Specification of uni-axial georids

Geogrid	Fabrication Type	Material	Aperture Size (mm)		Weight (g/m^2)
			MD	CD	
GGWR-1	Woven	PVC coated Polyester yarn	20	20	380
GGWR-2			20	20	560
GGKR-1	Knitted	PVC coated Polyester yarn	20	20	230
GGKR-2			20	20	390

Table 2. Specifications of biaxial geogrids

Manufacturing Process		Material	Submitted Aperture Size (mm)		Width (m)	Length (m)	Weight (g/m^2)
			MD	CD			
GGBX-1	Welding	PET/PP	40	40	1.5	50	353.5
GGBX-2	Welding	PET/PP	40	40	1.5	50	310.5

Table 3. Test items and certification requirement for uni-axial geogrids

Test Item	Test Method	Certification Requirement
Tensile Strength and Elongation	ASTM D 6637 method B	Short-term strength of each specimen must be over the quality control strength

Junction Efficiency		GRI GG 2	10%
Interaction Coefficient		GRI GG 5	0.8 at 50kPa
Direct Shear		ASTM D 5321	30 at 50kPa
Reduction Factor	Creep	GRI GG 4(b) / ASTM D 5262	1.9
	Installation damage	GRI GG 4(b) / ISO TR 10722-1	1.3
	Chemical degradation	GRI GG 4(b) / ASTM D 5322	1.2
	Biological degradation	GRI GG 4(b) / ASTM D 3083	1.2
Durability	UV stability	ASTM D 4355	70% at 500hrs
	Molecular weight	GRI GG 7	minimum 25,000gm/mol
	CEG	GRI GG 8	maximum 30mmol/kg

3 RESULTS AND DISCUSSION

3.1 *Tensile and junction properties*

The test was performed in general accordance with the ASTM D 6637-01: Standard Test Method for Determining Tensile Properties of Geogrids by the Single or Multi-Rib Tensile Method - Method B –.

Table 4 shows the tensile strength of uni- and bi-axial geogrids and tensile strength of both geogrids must be over the quality control strength requirements of each product. Junction strength must be over the 10% of single rib tensile strength and each product satisfied this requirement in Table 4. Also, it is seen that GGBX-1 and -2 have the similar tensile properties in both MD and CMD.

Table 4. Junction property of uni-axial geogrids

Junction Property	GGWR		GGKR	
	-1	-2	-1	-2
Junction Strength, (N/m)	173.5	339.5	278.0	359.7
Junction Efficiency (%)	10.1	10.1	16.3	11.7

3.2 *Interaction coefficient*

Interaction coefficient between concrete sand and geogrids must be above 0.8 at 50kPa normal stress. Interaction coefficient of each product meets the requirement at 50kPa normal stress as shown in Table 5.

Table 5. Interaction property of geogrids

(a) uni- axial geogrids

Geogrid	Test item	Normal stress (kPa)		
		10	30	50
GGWR-1	Maximum pullout force(kN/m)	10.8	31.1	52.1
	Displacement(mm)	82	72	69
	Soil friction angle(˚)	35.0		
	Interaction coefficient(C_i)	0.96	0.93	0.93
GGKR-1	Maximum pullout force(kN/m)	34.1	57.4	79.3
	Displacement(mm)	83	77	65
	Soil friction angle(˚)	35.0		
	Interaction coefficient(C_i)	1.01	1.02	1.01

(b) bi-axial geogrids

Geogrid	Tset item	Normal stress (kPa)		
		30	50	70
GGWR-2	Maximum pullout force(kN/m)	10.2	30.4	48.6
	Displacement(mm)	78	80	73
	Soil friction angle(˚)	35.0		
	Interaction coefficient(C_i)	0.91	0.90	0.87
GGKR-2	Maximum pullout force(kN/m)	32.5	51.5	73.5
	Displacement(mm)	64	70	75
	Soil friction angle(˚)	35.0		
	Interaction coefficient(C_i)	0.97	0.92	0.94

3.3 *Direct shear properties*

The friction angle between concrete sand and geogrids must be over 30°at 50kPa normal stress and the friction angle of each products meet the requirement. The friction angle was determined by slope of the plot from maximum shear stress versus applied normal stress.

The friction angle between concrete sand and geogrids must be over 30°at 50kPa normal stress. The friction angles of each product meet the requirement as shown in Table 6.

Table 6. Friction angle of uni- and bi-axial geogrids

Geogrid		Friction angle(˚)
GGWR	-1	37.2
	-2	35.0
GGKR	-1	38.3
	-2	35.1

4 REDUCTION FACTOR

4.1 *By creep deformation, RF_{CR}*

Fig. 1 and 2 show the typical examples of creep strain curves of uni- and bi-axial geogrids. Reduction factor of creep deformation, RF_{CR} of GGWR and GGKR geogrids is 1.54, respectively. Creep reduction factor of each products meet the requirement, less than1.9 as shown in Table 2.

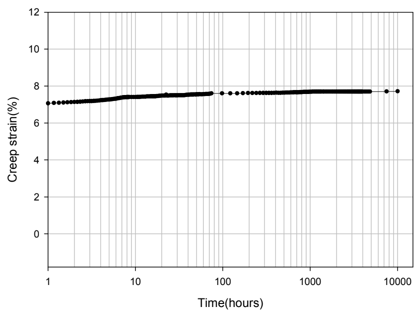

Figure 1. Creep strain curve of GGWR-1 at quality control strength 65%

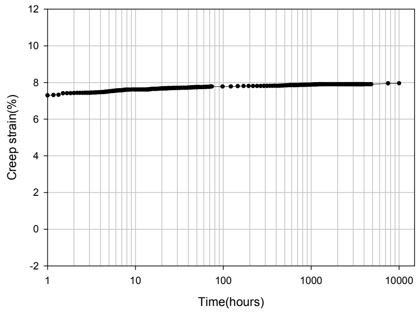

Figure 2. Creep strain curve of GGKR-2 at quality control strength 65%

4.2 *By installation damage, RF_{ID}*

Reduction factor of installation damage, RF_{ID} of GGWR and GGKR is 1.05~1.07. Reduction factor of installation damage for each products meet the requirement in Table 7.

Table 7. RF_{ID} of uni- and bi-axial geogrids

Geogrid		Original tensile strength, kN/m	Exhumed tensile strength, kN/m	RF_{ID}
GGWR	-1	68.1	63.7	1.07
	-2	120.1	114..9	1.05
GGKR	-1	84.9	81.2	1.07
	-2	124.3	105.4	1.05

4.3 *By chemical degradation, RF_{CD}*

Reduction factor of chemical degradation, RF_{CD}=1.03 at pH3, RF_{CD}=1.03 at pH10 for GGWR-1and RF_{CD}=1.03 at pH3, RF_{CD}=1.04 at pH10 for GGKR-2 is 1.01.

4.4 *By biological degradation, RF_{BD}*

Reduction factor of biological degradation, RF_{BD} of TRIGRID® 6T/3T WR and 10T/3T KR is 1.01. Biological resistance reduction factor of each products meet the requirement, less than 1.2.

4.5 *By UV resistance*

Percent retention of tensile strength must be over 70% at 500hrs exposure. Tensile strength retention of each product meet the requirement in Table 8,

Table 8. Strength retention of uni- and bi-axial geogrids after UV exposure

Geogrid		Tensile strength, N/rib		Strength Retention, %
		Before exposure	After exposure	
GGWR	-1	1722.8	1328.9	77.1
	-2	3372.4	2454.9	72.5
GGKR	-1	1790.1	1385.8	81.1
	-2	3377.1	2435.3	72.1

4.6 *Number average molecular weight*

Number average molecular weight of each polyester yarn for manufacturing geogrid products meet the requirement, minimum 25,000gm/mol in Table 9.

Table 9. Number average molecular weight of GGWR and GGKR after UV exposure

	GGWR-1 and -2	GGKR-1 and -2
Number average molecular weight (gm/mol)	30254.7	28907.7

4.7 *Carboxyl end group (CEG)*

CEG of each polyester yarn for manufacturing geogrid products meet the requirement, minimum 30mmol/kg in Table 10.

Table 10. CEG of TRIGRID® WR and KR series

	GGWR-1 and -2	GGKR-1 and -2
CEG(mmol/kg)	23.5	20.1

4.8 *Pull-out interaction coefficient*

The test was performed in general accordance with the ASTM D 6706-01: Standard Test Method for Measuring Geosynthetic Pullout Resistance in Soil on GGBX-1 and -2.

TRI/Environmental, Inc.'s (TRI's) large-scale pull-out box is a custom-made apparatus measuring, nominally, 762mm wide×610mm high×1.52m long. Soil is placed beneath and above the geosynthetic layer. Horizontal force is then applied to the geosynthetic and the force required to pull the geosynthetic out of the soil is recorded.

Pullout resistance is obtained by dividing the maximum load attained by the test specimen width. Table 2 shows the pull-out properties of bi-axial geogrids. Interaction coefficient must be 0.8 and each product satisfied this requirement.

Table 11. Pull-out properties of bi-axial geogrids

Pull-out Property	GGBX-1		GGBX-2	
	MD	CD	MD	CD
Maximum Pull-out Force (kN/m)	23.8	21.5	14.30	19.03
Pull-out Interaction Coefficient (C_i)	1.49	1.35	0.90	1.19
Requirement Value	0.8			

4.9 *Direct shear properties*

The test was performed in general accordance with ASTM D 5321-02: Standard Test Method for Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic

Friction by the Direct Shear Method on GGBX-1 and -2.

The rate of shear was applied at a constant rate of horizontal displacement with 1mm/min and maximum shear displacement is 10.2cm. The applied normal stress in this test was 30, 50, 70kPa. The backfill soil was concrete sand as described in Table 12.

Table 12. Characteristic of concrete sand

Characteristics	Value
Maximum Dry Density (g/cm^3)	1.809
Dry Density at 95% Compact (g/cm^3)	1.719
Optimum Moisture Content (%)	10.9
Moisture Content at 95% Compact (%)	5.8
Soil Friction Angle (°)	38

The angle of friction was determined by slope of the plot from maximum shear stress versus applied normal stress. The friction angle between concrete sand and geogrids must be over 30°at certain stress. The friction angles of each product meet the requirement as in Table 13.

Table 13. Shear properties of bi-axial geogrids

Geogrid		Direction	Property	Normal stress (kPa)		
				30	50	70
GGBX	-1	MD	Mximum Shear Stress (kPa)	20.9	33.3	49.4
			Coefficient of Friction	0.714		
			Angle of Friction (°)	35.5		
		CMD	Mximum Shear Stress (kPa)	20.7	34.1	48.5
			Coefficient of Friction	0.695		
			Angle of Friction (°)	34.8		
	-2	MD	Mximum Shear Stress (kPa)	20.2	32.3	47.8
			Coefficient of Friction	0.690		
			Angle of Friction (°)	34.6		
		CMD	Mximum Shear Stress (kPa)	20.7	32.8	48.0
			Coefficient of Friction	0.6839		
			Angle of Friction (°)	34.4		

4.10 *UV stability*

To determine the Ultra-violet resistance of geogrid, ASTM D 4355-02: Standard Test Method for Deterioration of Geotextiles by Exposure to Light, Moisture and Heat in a Xenon Arc Type Apparatus was used.

The total exposure time is 500hours and the exposure cycles as follows: 102 min of light only (black panel temperature 65±3□, relative humidity 50±5%), followed 18 min of water spray and light. After exposure tensile strength were measured by ASTM D 6637 B method.

Percent retention of tensile strength should meet over 70% at 500hrs UV exposure and each product meet the requirement of specified class as shown in Table 14.

Table 14. Retention for tensile strength of biaxial geogrids after UV testing

Geogrid		Direction	Weathering		Retention
			Before	After	
GGBX	-1	MD	23.0	22.5	97.9
		CMD	32.3	33.0	102.0
	-2	MD	43.5	44.1	101.3
		CMD	42.4	43.1	101.6

5 CONCLUSION

To certify the performance of uni- and bi-axial geogrids, GCI-PCP was adopted. Evaluation items were tensile properties, junction efficiency, pullout property, direct shear property, creep behavior, installation damage, chemical degradation, biological degradation, UV stability, number average molecular weight, carboxyl end group etc.. Through the test results, we confirmed the evaluation value of each item was satisfied with the recommended requirement value ranges of GCI-PCP draft for uni- and bi-axial geogrids.

The final goal of this study is to apply this result to develop the MQC/MQA system for uni-axial geogrids. The bi-axial geogrids having good properties has been developed and is suited for pavement and any kind of soil reinforcement application.

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