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Applicability evaluation of geogrids in Reinforcement System

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ABSTRACT: The purpose of this study is to compare and confirm the test results in accordance with the draft of GCI-PCP (Geosynthetic Certification Institute's – Product Certification Program) that assessed the manufacturing and quality systems of products evaluates manufactured products. To prepare the certification, We tested the 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. by GCI-PCP recommended test methods. By reviewing the test results, the evaluation value of each item was satisfied with the recommended requirement value ranges of GCI-PCP draft for uniaxial geogrids.

1 INTRODUCTION

GSI-Korea is basically managed under the same system as same as GSI with GAI, GEI, GRI, GCI, GEI etc. For one of the GSI-Korea development businesses, GCI-PCP of uniaxial geogrids with fabrication type was done in 2003. In this study, we assessed the manufacturing and quality systems of uniaxial geogrids to certify with GCI-PCP of GSI. Also, we evaluated the essential items of draft 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.. Reduction factors by creep behavior, installation damage, chemical degradation, and biological degradation were determined. Finally, we compared these test result values to the certification requirement and confirmed the quality of uniaxial geogrids.

2 GEOGRIDS AND TEST ITEMS IN GCI-PCP

Tables 1 and 2 show the specifications of uniaxial geogrids with fabrication type. Table 3 shows the test items and certification requirement values to be satisfied with the draft of GCI-PCP for uniaxial geogrids.

Table 1. Specification of TRIGRID® WR series.

Item	Fabrication Type	Material	Aperture Size (mm)		Roll Width	Roll Length	Weight (g/m^2)
			MD	CD	(m)	(m)	
6T/3T	Woven	PVC coated	20	20	2	50	380
10T/3T		Polyester yarn	20	20	2	50	560

Table 2. Specification of TRIGRID® KR series.

Item	Fabrication Type	Material	Aperture Size (mm)		Roll Width	Roll Length	Weight (g/m^2)
			MD	CD	(m)	(m)	
6T/3T	Knitted	PVC coated	20	20	4	50	230
10T/3T		Polyester yarn	20	20	4	50	390

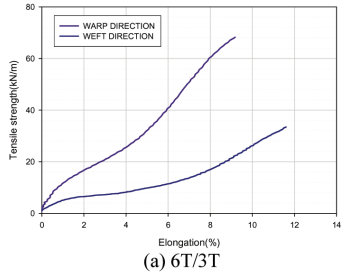
Table 3. Test items and certification requirement.

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 50 kPa
Direct Shear		ASTM D 5321	30 at 50 kPa
Reduction Factor	Creep	GRI GG 4(b)/ ASTM D 526	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 500 hrs
	Molecular weight	GRI GG 7	minimum 25,000 gm/mol
	CEG	GRI GG 8	maximum 30 mmol/kg

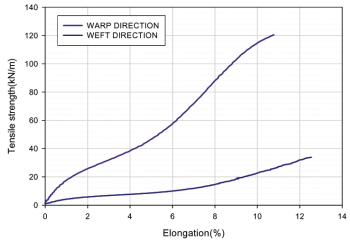
3 TEST RESULTS AND ANALYSIS IN GCI-PCP

3.1 *Tensile property*

Figures 1 and 2 show tensile properties of each test specimen must be over the quality control strength requirements of each product.

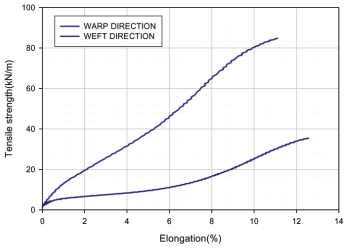


(a) 6T/3T

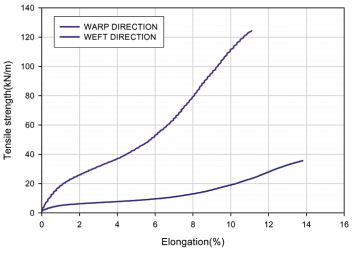


(b) 10T/3T

Figure 1. Tensile property of TRIGRID® WR series.



(a) 6T/3T



(b) 10T/3T

Figure 2. Tensile property of TRIGRID® KR series.

3.2 *Junction efficiency*

Junction strength must be over the 10% of single rib tensile strength and each product satisfied this requirement in Table 4.

Table 4. Junction property of TRIGRID® WR and KR series.

Junction Property	TRIGRID WR Series 6T/3T	10T/3	TRIGRID KR Series 6T/3T	10T/3T
Junction Strength,(N/m)	173.5	339.5	278.0	359.7
Junction Efficiency (%)	10.1	10.1	16.3	11.7

3.3 *Interaction coefficient*

Interaction coefficient between concrete sand and geogrids must be above 0.8 at 50 kPa normal stress. Interaction coefficient of each product meets the requirement at 50 kPa normal stress in Tables 5~8.

Table 5. Interaction property of TRIGRID® WR 6T/3T.

	Normal stress (kPa)		
	10	30	50
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

Table 6. Interaction property of TRIGRID® WR 10T/3T.

	Normal stress (kPa)		
	30	50	70
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

Table 7. Interaction property of TRIGRID® KR 6T/3T.

	Normal stress (kPa)		
	10	30	50
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

Table 8. Interaction property of TRIGRID® KR 10T/3T.

	Normal stress (kPa)		
	30	50	70
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

3.4 *Direct shear properties*

The friction angle between concrete sand and geogrids must be over 30°at 50 kPa 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 50 kPa normal stress. The friction angles of each product meet the requirement in Tables 9~12.

Table 9. Friction angle of TRIGRID® WR 6T/3T.

Normal stress (kPa	30	50	70
Maximum shear stress (kPa)	32.3	46.3	62.6
Friction angle		37.2	

Table 10. Friction angle of TRIGRID® WR 10T/3T.

Normal stress (kPa)	30	50	70
Maximum shear stress (kPa)	36.3	50.2	64.2
Friction angle		35.0	

Table 11. Friction angle of TRIGRID® KR 6T/3T.

Normal stress (kPa)	30	50	70
Maximum shear stress (kPa)	38.8	57.0	70.4
Friction angle		38.3	

Table 12. Friction angle of TRIGRID® KR 10T/3T.

Normal stress (kPa)	30	50	70
Maximum shear stress (kPa)	40.2	52.7	68.3
Friction angle		35.1	

4 REDUCTION FACTOR

Partial factor of reduction of geogrids must be lower value as listed below by GCI-PCP

① by creep deformation – 1.9
② by installation damage – 1.3
③ by chemical degradation – 1.2
④ by biological degradation – 1.2

4.1 *By creep deformation, RF_{CR}*

Reduction factor of installation damage, RF_{ID} of TRIGRID® WR and KR is 1.54. Creep reduction factor of each products meet the requirement, minimum 1.9 in Figures 3~4.

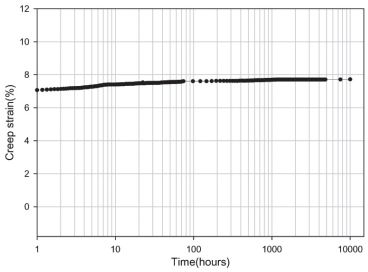


Figure 3. Creep strain curve of TRIGRID® WR 6T/3T at quality control strength 65%.

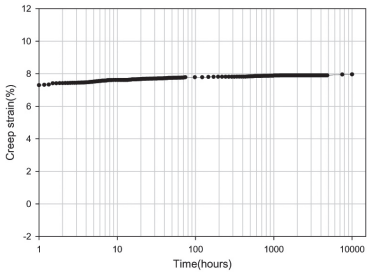


Figure 4 Creep strain curve of TRIGRID® KR 10T/3T at quality control strength 65%.

4.2 *By installation damage, RF_{ID}*

Reduction factor of installation damage, RF_{ID} of TRIGRID® WR and KR is 1.05~1.07. Reduction factor of installation damage for each products meet the requirement in Table 13~14.

Table 13. RF_{ID} of TRIGRID® WR series.

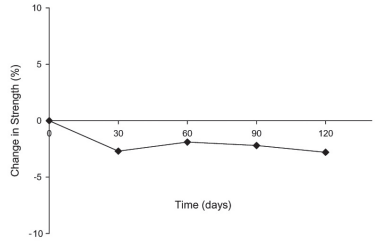
	6T/3T	10T/3T
Original tensile strength, kN/m (t/m)	68.1 (6.95)	120.1 (12.26)
Exhumed tensile strength, kN/m (t/m)	63.7 (6.50)	114.9 (11.72)
RF_{ID}	1.07	1.05

Table 14. RF_{ID} of TRIGRID® KR series.

	6T/3T	10T/3T
Original tensile strength, kN/m (t/m)	84.9(8.66)	124.3(12.68)
Exhumed tensile strength, kN/m (t/m)	81.2(8.28)	105.4(10.75)
RF_{ID}	1.07	1.05

4.3 *By chemical degradation, RF_{CD}*

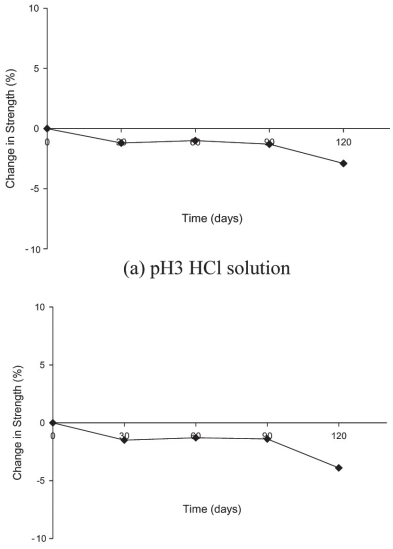
Reduction factor of chemical degradation, RF_{CD} = 1.03 at pH3, RF_{CD} = 1.03 at pH10 for TRIGRID® 6T/3T WR and RF_{CD} = 1.03 at pH3, RF_{CD} = 1.04 at pH10 for TRIGRID® 10T/3T KR is 1.01. Chemical resistance reduction factor of each products meet the requirement in Figure 5~6.



(a) pH3 HCl solution

(b) pH10 $Ca(OH)_2$ solution

Figure 5. Strength retention of TRIGRID® WR 6T/3T at 50°C incubation with pH solution.



(a) pH3 HCl solution

(b) pH10 $Ca(OH)_2$ solution

Figure 6. Strength retention of TRIGRID® KR 10T/3T at 50°C incubation with pH solution.

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, minimum 1.2.

4.5 *By UV resistance*

Percent retention of tensile strength must be over 70% at 500 hrs exposure. Tensile strength retention of each product meet the requirement in Tables 15~16,

Table 15. Strength retention of TRIGRID® WR series after UV exposure.

	6T/3T	10T/3T
Tensile strength before exposure N/rib (kgf/rib)	1722.8 (174.4)	3372.4 (344.6)
Tensile strength after exposure N/rib (kgf/rib)	1328.9 (135.6)	2454.9 (250.5)
Strength retention (%)	77.1	72.5

Table 16. Strength retention of TRIGRID® KR series after UV exposure.

	6T/3T	10T/3T
Tensile strength before exposure N/rib(kgf/rib)	1790.1 (175.8)	3377.1 (345.4)
Tensile strength after exposure N/rib(kgf/rib)	1385.8 (141.4)	2435.3 (248.5)
Strength retention (%)	81.1	72.1

4.6 *Number average molecular weight*

Number average molecular weight of each polyester yarn for manufacturing geogrid products meet the requirement, minimum 25,000 gm/mol in Table 17.

Table 17. Number average molecular weight of TRIGRID® WR and KR series after UV exposure.

	PET YARN (TRIGRID® WR Series)	PET YARN (TRIGRID® KR Series)
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 30 mmol/kg in Table 18. 5

Table 18. CEG of TRIGRID® WR and KR series.

	TRIGRID® WR Series	TRIGRID® KR Series
CEG(mmol/kg)	23.5	20.1

CONCLUSION

To certify the performance of TRIGRID® series, the tests of GCI-PCP draft for uniaxial geogrids was adopted by GSI Certification system. 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 uniaxial geogrids. The final goal of this study is to apply this result to develop the MQC/MQA system for uniaxial geogrids.

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