Experimental study on the field installation damage and pullout resistance of pocket-lug-type geosynthetics

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ABSTRACT: Reinforced earth wall is designed to place the horizontal stiffener in the earth behind the retaining wall to constrain the horizontal displacement as well as reduce the earth pressure on retaining wall. Reinforced earth wall was first introduced to Korea in early 1980s and has been used at the sites in line with the de-velopment of various geotextile stiffeners. Stiffener developed shall be incorporated into the design for reinforced earth wall after evaluating the deformation characteristics, damage during construction and a long-term durability and tensile strength. Then though development of reinforced earth wall is on the rise recently, safety verification for various methods remains behind which has caused the problems including collapse after installation. The stiffener used for reinforced earth wall is categorized into a strip-type, grid-type, sheet-type and cell-type, depending on their shape. Generally, a strip-type and grid-type are mostly used for permanent structure and A lug-type is known to have had a superior pullout resistance comparing to normal types. The stiffener is also categorized, depending on elasticity, into elastic stiffener and non-elastic stiffener and elastic stiffener has a superior pullout resistance than a non-elastic stiffener. To verify the performance of a pocket-lug-type geosynthetics developed in this study, comparative test was con-ducted using Geostrip and Geogrid and advantage/disadvantage was evaluated. The test to identify the pullout resistance and the damage during construction was conducted. Tensile strength of a pocket-lug-type geosynthetics developed in this study was relatively higher while the damage during construction was less. Consequently, a pocket-lug-type geosynthetics with less strength-reducing factor appeared to have had a superior performance and thus cost efficient design could be achieved.

Keywords: Reinforced earth wall, Pocket-lug-type, pullout resistance, Installation damage

1 INTRODUCTION

Typically, the reinforced earth wall with panel-type wall facing is installed using Geosynthetic Strip or Steel strip, and the reinforced earth wall with block-type wall facing is installed using GeoGrid. In Korea, reinforced earth wall with block-type wall facing using Geogrid was first introduced in mid-1990s, and has been still popular due to relatively easy installation and low material cost. However, this type causes the overlap in installing Geogrid for reinforced earth wall at the corner of slope. And the aggregate, if mixed in backfill material, may cause the damage to Geogrid by punching that would possibly result in failure of maintaining the design strength. Furthermore, it causes the difficulty in making the wall facing in various types and thus hard to improve the appearance of the earth wall. Thus, the study to improve the aesthetic effect of the reinforced earth wall has been in process. And the study on type of reinforcing material which could be applied commonly to wall facing parts was conducted. Consequently, advantages of strip type reinforcement have appeared and a variety of Geostrip has been under development in Korea.

Reinforced earth wall is stabilized to pull-out resistance between the ground and reinforcement. And pull-out resistance is categorized into frictional resistance and bearing resistance depending on type of reinforcement (Bishop and Anderson, 1979). Strip type reinforcement generates the pull-out resistance by frictional resistance on boundary between the ground and reinforcement which is considered in designing the reinforced earth wall. The study on installing transverse members on strip type reinforcement to increase the pull-out resistance was conducted. Furthermore, the study on evaluating the pull-out resistance of toothed shape steel strip reinforcement by changing the shape of Steel Strip reinforcement was also conducted. As shown in the cases, Steel Strip type reinforcement is able to bear the large load as well as increase the soil stiffness generally but is costly and has difficulties in manufacturing, transporting and installing. Flexible Strip type reinforcement is often extended due to low frictional resistance with the soil. Frictional resistance may be increased by extending the fiber reinforcement, which however increases the backfill volume, causing the problem with the installation and cost.

2 MATERIALS

The study on three types of material was conducted and the materials are outlined as Table 1. Developed Geosynthetic Strip (named Pocket Tie) and Geosynthetic Strip are manufactured in a way of sheathing Polyethylene terephthalate thread on Polyethylene. Geogrid is manufactured in a way of sheathing Polyethylene terephthalate thread on Polyvinyl chloride. 20kN grade material which is commonly used at the site was selected and Geogrid which is applied widely was selected among those used in similar situation.

Table 1. Material properties for Experiments.

	Materials	Unit weight	Width	Quality indication Strength	Remark
Developed Geosynthetic Strip	Polyethylene + Polyethylene terephthalate	132 g/m	89.1mm	20 kN	Pocket Tie™
Geosynthetic Strip	Polyethylene + Polyethylene terephthalate	198 g/m	88.9 mm	20 kN	
Geogrid	Polyvinyl chloride+ Polyethylene terephthalate	402 g/m2	-	80 kN	Knitted

Developed Geosynthetic Strip (Pocket Tie) has embossed grooves that increase the passive resistance frictional force of to-be-embedded Geosynthetic Strip on top and at bottom alternately. The width of a line was same or similar with existing Geosynthetic Strip and same material was used. Figure 1 shows the reinforcement used in this study.

(a)Developed Geosynthetic Strip (1 line) (b) Geosynthetic Strip (1 line) (c) Geogrid

Figure 1 Shape of Materials

3 EXPERIMENTS

3.1 *Tensile strength test*

Tensile strength of Geosynthetic Strip and Geogrid was measured in accordance with KS K ISO 10319. Instron's Model 5584 with maximum capacity 150kN was used for the test and a non-contact type Video-Extensometer was used to measure the strain at a time. Tensile strength was measured with a strain rate of (20 ± 5) %/minute according to ISO 10319. To measure the strain till the specimen is ruptured, strain was measured every 100mm after marking on gauge. Figure 2 shows the test equipment of tensile strength of fiber reinforcement.

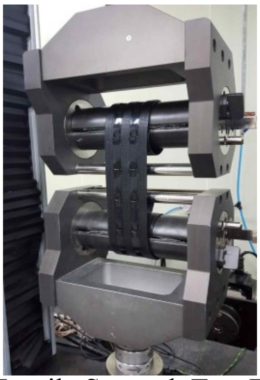


Figure 2 Tensile Strength Test Equipment

3.2 *Pullout test*

Resistance of a geosynthetic to pullout from soil is determined using a laboratory pullout box. In this test (ASTM D 6706), a geosynthetic is embedded between two layers of soil, horizontal force is 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 by the test specimen width. The test is performed while subjected to normal compressive stresses which are applied to the top soil layer. This test method produces test data, which can be used in the design of geosynthetic-reinforced retaining walls where resistance of a geosynthetic to pullout under simulated field conditions is important. The test results may also provide information related to the in-soil stress-strain response of a geosynthetic under confined conditions
Test conditions are :

① Displacement rate = 1 mm/min
② Normal force = 50, 100, 150 kPa
③ Dimensions of geosynthetic specimen within the pullout box = length : 1200 mm, width : whole width
④ Soil classification = standard sand (relative density : 85%, water content : atmosphere)

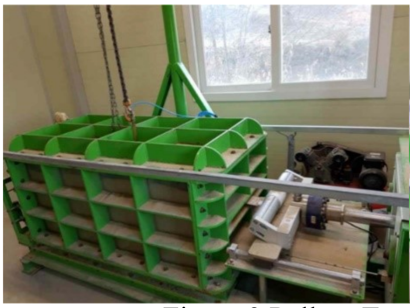


Figure 3 Pullout Test Equipment

3.3 *Field test for installation damage evaluation*

Coarse backfills and heavy compaction loads can damage geosynthetics, causing an immediate reduction in strength. The effect of installation damage on geosynthetics reinforcement strengthand deformation should be determined from the results of installation damage tests in accordancewith ASTM D5818 and ISO 13437. The installation damage tests should simulate the installation conditions as closely as practicable to the installation conditions anticipated in the geosynthetic structure.

3.3.1 *Full-scale installation conditions*

Full-scale installation damage tests were carried out as performance tests under the installation conditions anticipated in the geosynthetic structure in accordance with ASTM D5818 and ISO13437. Test procedures are shown in Figure 4 and installation conditions are as follows:

a. Test site size and number of samples: 2.0 m (width) × 5 m (length), minimum 20 samples for tensile test

b. Subgrade backfill

① height of fill material : 20 cm

② compaction method : one time without vibration and four times with vibration (30 Hz)passing the compactor

c. Backfill over the geosynthetics

① height of fill material : 20 cm

② spreading soil method : using an excavator

③ compaction method : one time without vibration and four times with vibration passing the compactor

d. compactor

① compactor weight : 10 ton

② model name : 3410, HAMM

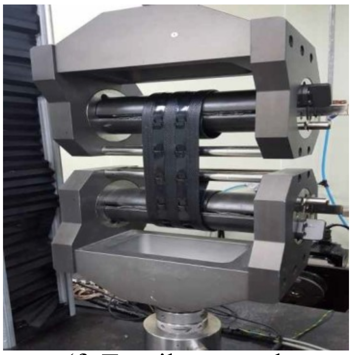
(a) Place and compact the preparatory fill layer

(b) Place the woven geosynthetics

(c) Place the fill layer

(d) Compact the fill layer

(e) Exhume the woven geosynthetics



(f) Tensile strength test

Figure 4. Procedures for Full-scale Installation Damage Test

3.4 *Backfill soil*

We have used backfill soils with sand which are usually using in geosynthetic construction site. The particle sizes and distribution of backfill soils with different particle sizes were analyzed by Korea Conformity Laboratories according to KS F 2302.

4 RESULTS AND DISCUSSIONS

Tensile strength test of the material in original state was conducted over 5 times and the mean values are as described in Table 2.

Table 2 Tensile strength of materials (Original ones)

	Strength	Strain	Remark
Developed Geosyn-thetic Strip	24 kN/m	10.9 %	Pocket Tie™
Geosynthetic Strip	23 kN/m	12.2 %	
Geogrid	71.7 kN/m	10.6 %	Knitted

Average resistance method is generally used to evaluate the pullout stress. It's assumed that maximum pull-out strength generated in the process of pull-out is distributed over entire area of embedded reinforcement. Mean pullout stress is applied to equilibrium analysis which is used in designing the reinforced earth wall. Pullout stress is expressed as below.

$$\tau = \frac{P}{2 \times L \times W}$$

Where, W: Width of the specimen used for pull-out test (m)
L : Length of the specimen used for pull-out test (m)
P : Maximum pull-out strength of Geosynthetics (kN)

Table 3shows the pullout test result. Pullout test of 3 types of material was conducted at same Normal Stress. Maximum Pullout Force was in order of Geogrid, Developed Geosynthetic Strip and Geosynthetic Strip, which are divided by entire area of the reinforcement to obtain the Pullout stress and as a result, Developed Geosynthetic Strip appeared to have had the greatest effect.

Table 3 Results of pullout test

	Normal Stress	Maximum Pullout Force	Pullout stress
Developed Geosynthetic Strip	50 kPa	8.9 kN	41.9 kPa
Geosynthetic Strip	50 kPa	5.9 kN	27.7 kPa
Geogrid	50 kPa	17.3 kN	28.8 kPa

The specimens subjected to installation damage were retrieved by exhumation system to minimize additional damage. Installation damaged specimens were tested for tensile tests in accordance with ISO 10319. The result is expressed as the ratio of the mean strength of the undamaged material to the mean tensile strength of the damaged material. The retained tensile strength with backfill soil is shown in Table 4. The reduction factor to allow for the effect of mechanical damage for the site conditions used, RFID (Installation Damage Reduction Factor), should be expressed as the ratio of the mean tensile strength of the undamaged material to the mean tensile strength of the damaged material.

Table 4 Results of pullout test

Developed Geosynthetic Strip (Pocket Tie™)		
Backfill Soil	40 mm	100 mm
Tensile Strength after installation damage	23.8 kN/m	20.0 kN/m
Retained Strength	99.5 %	83.3 %
Installation Damage Reduction Factor	1.01	1.20
Geosynthetic Strip		
Backfill Soil	40 mm	100 mm

Tensile Strength after installation damage	22.3 kN/m	20.6 kN/m
Retained Strength	96.7 %	89.3 %
Installation Damage Reduction Factor	1.03	1.12
Geogrid		
Backfill Soil	40 mm	100 mm
Tensile Strength after installation damage	53.8 kN/m	23.4 kN/m
Retained Strength	56.4 %	24.6 %
Installation Damage Reduction Factor	1.77	4.07

Viewing the evaluation of damage to the material at the site, Developed Geosynthetic Strip indicated 99.5% with 40mm aggregate in Retained Strength and 83.3% with 100mm aggregate, demonstrating the superior performance as Geosynthetic Strip. Geogrid indicated no significant loss in performance due to punching by aggregate. Viewing the result, it indicated 56.4% with 40mm aggregate and 24.6% with 100mm aggregate. When applying Geogrid, it's necessary to be careful to prevent the aggregates from being mixed during backfill and as the loss in strength is significant, careful attention shall be given during design.

5 CONCLUSION REMARKS

Traditional Geogrid has difficulties in attaching various types of wall facing, particularly in corners and moreover, punching by aggregate which may be mixed in the process causes the loss of strength significantly. That is, more caution is required in the process of design and installation to avoid the aggregate during backfill. Flexible reinforcement such as Geosynthetic strip tends to be deformed significantly even at low vertical stress condition which may cause the reinforcement to be pulled out by small load. A lug-type that has passive resistance to pull-out force proved to have eliminated such partial stress concentration and increased the resistance in general. Moreover, it secured sufficient frictional force to enhance the stability without extending the length and width of the reinforcement. When using Developed Geosynthetic Strip to reinforced earth wall, it's safer from punching than Geogrid and has more pull-out resistance effect than traditional Geosynthetic Strip, thereby reducing the number of reinforcement and increasing the cost efficiency.

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KS F 2302 Test method for particle size distribution of soils

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