Long term effect of creep strength for damaged geosynthetics during construction

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ABSTRACT: The design tensile strength of geosynthetics is evaluated by considering creep reduction coefficient, safety factor of durability and damage during construction.

The damage during construction is the amount of strength lost due to pressure from the compaction roller combined with the characteristics of the fill material. Tunnel slags are sometimes used as fill material and in recent years large-scale compaction rollers have been used for improving construction efficiency. In such a situation, the damage to geosynthetics should be considered.

The geosynthetics used in this case has a high strength parallel laid fiber core encased in a polyethylene sheath.

In order to ascertain the long term effect of creep strength for damaged geosynthetics during construction, the conventional creep rupture test and an accelerated (SIM) creep rupture test were performed in accordance with ASTM D 6992.

BS 8006 2010 shows that partial material factor for installation damage during construction should also take in account the long term effects of the short term damage.

This paper describes the long term effect of creep strength for damaged geosynthetics during construction.

Keywords: Long term effect, Creep strength, Geosynthetics damaged during construction

1 INTRODUCTION

Damage resistance characteristics of geosynthetics are effected by the characteristics of the fill material and the compaction force. When fill materials consist of tunnel slag and large-scale compaction rollers are being applied to increase construction efficiency there are concerns that geosynthetics can be damaged more than in a normal conditions.

In this paper the geosynthetic Paralink was used. Paralink comprises of machine direction elements with discrete bundles of closely packed high strength polyester synthetic fibers as its core. Its core is encased in a durable sheath of polyethylene (Fig. 1.1).

Safety factors related to the damage of geosynthetics during construction (Fc) were evaluated under the following condition (Table 1.1 and Fig. 1.2). The results of the test are summarized in Table 1.2 and it is certificated by Public Works Research Center.

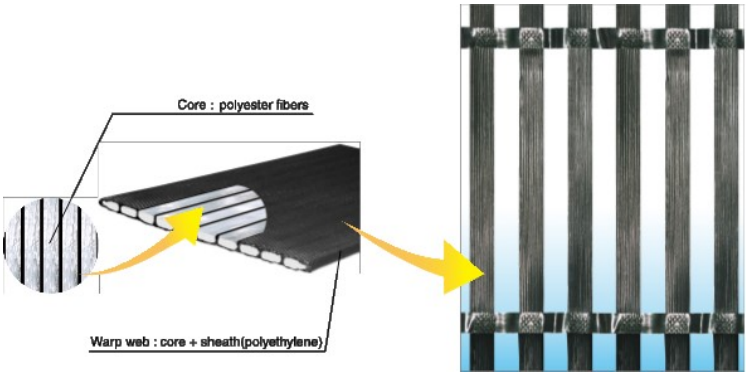

Figure 1.1 Geosynthetics:Paralink

Table 1.1 Test conditions during installation

Item	Application
Geosynthetics	Paralink 100L,300L,700L
Fill materials	Sandy soil, Gravel, Rock slag
Compacted machine	Vibration roller(Compaction force 150kN)
Number of compaction	7

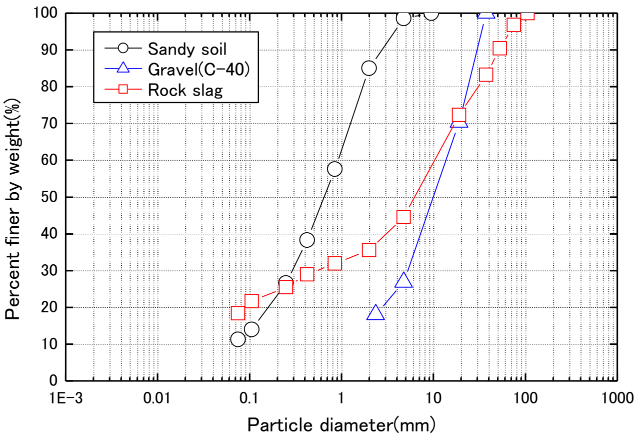

Figure 1.2 Grain size distribution of fill materials

Table 1.2 Results of damage tests during installation

Grade	Fill material	Tensile strength		Tensile strength retention ratio	Safety factor of damage
		Virgin S(kN/m)	Damaged S_D(kN/m)	R_D(%)	F_C
100L	Sandy soil	111.1	108.3	97.5	1.03
	Gravel		103.3	93.0	1.08
	Rock slug		105.0	94.5	1.06
300L	Sandy soil	329.4	322.8	98.0	1.02
	Gravel		304.4	92.4	1.08
	Rock slug		310.0	94.1	1.06
700L	Sandy soil	787.8	787.8	99.3	1.01
	Gravel		792.8	99.9	1.00
	Rock slug		791.1	99.7	1.00

For Shin-Meishin Expressway’s Takatsuki Interchange construction, West Nippon Expressway Company Ltd., by Kajima Corporation, high strength web-shaped geosynthetics with nominal maximum strength of 500kN/m (500L) were selected as a reinforcement material to counter earthquakes by resisting deformation of the bridge embankment from a large earthquake like the Great Hanshin Earthquake (Fig. 1.3) (Kawamura, et al. 2014). For this construction, damage tests were conducted under the conditions listed in Table 1.3. The severity of damage on 500L was checked after conducting the test with soft rock used as fill material (Fig. 1.4) and compaction by 8 passes of vibration roller with compaction force of 320kN. The results showed that the tensile strength retention was 81.2% (Fc=1.24) (Table 1.4). This exceeded the designed Fc of 1.03. Hence, to be on the safe side, 500L was replaced by higher strength web shaped geosynthetics of maximum nominal strength of 600kN/m (600L). Table 1.4 shows the extent of the damage to the geosynthetics by a condition of Table 1.3. And we found it was also important to verify the effect of short term damages on the long term strength of geosynthetics (BS8006:2010:fm_{212}).

Table 1.3 Test conditions during installation

Item	Application
Geosynthetics	Paralink 500L
Fill materials	Rock slag(Soft Rock)
Compacted machine	Vibration roller(Compaction force 320kN)
Number of passes	8

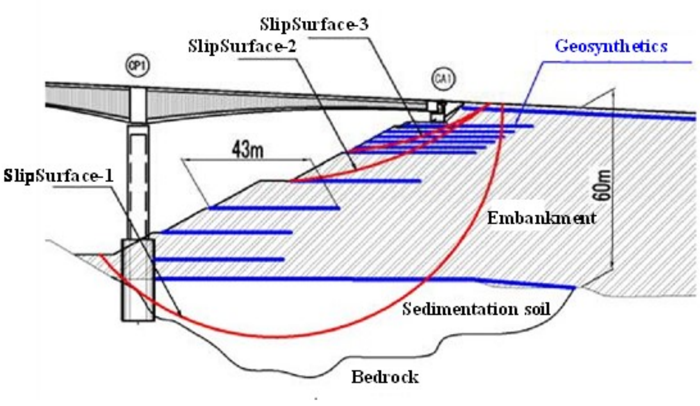

Figure 1.3 Cross section of Takatsuki Interchange (Kawamura et al. 2014)

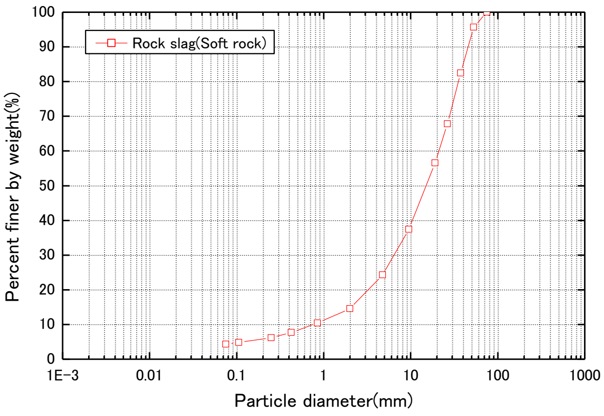

Figure 1.4 Grain size distribution of fill material

Table 1.4 Results of damage tests during installation

Tensile strength(Virgin) T=95.5(kN)			
No.	Tensile strength (Damaged) T_D(kN)	Tensile strength retention rate R_D(%)	Safety factor of damage Fc
1	78.8	82.5	1.21
2	77.9	81.6	1.23
3	81.1	84.9	1.18
4	82.2	86.1	1.16
5	68.0	71.2	1.40
Average	77.6	81.2	1.24

2 EFFECT OF SHORT-TERM DAMAGE ON LONG TERM STRENGTH

2.1 *Damage test*

As mentioned in the previous section because geosynthetics were damaged during embankment construction using coarse angular fill material and large scale compaction rollers , it was decided to conduct a damage test with similar conditions.

Fig. 2.1 shows the particle size distribution curves of the fill materials. In this test, crusher run (C-40) was used to cover the geosynthetics at a thickness of 30cm and 95% compaction ratio. Crusher run was selected instead of tunnel slag because the characteristics of tunnel slag are highly dependent on where it was generated. The photograph in 2.1 shows the compaction roller (SV512D-1 from Sakai Heavy Industry, ltd.) used for this test. The compaction force was 324kN. During the test run, it was determined that compaction ratio of 95% was achievable with 3 passes of compaction roller at maximum compaction force of 324kN. However for the actual test the roller passed 4 times.

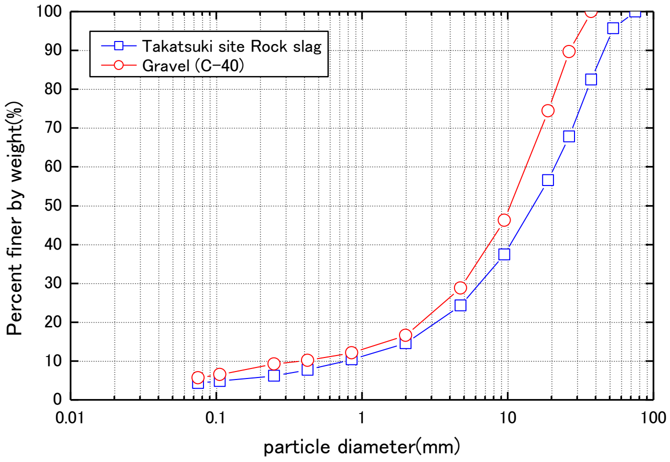

Figure 2.1 Grain size distribution of Gravel(C-40)

Photo 2.1 Compaction roller

The types of geosynthetics used as samples for this test are summarized in Table 2.1. Geosynthetics of five different nominal design strengths were used. The difference between M and L is the thickness of polyethylene sheath coating (L has ordinary thickness where M has thicker coating).

Table 2.1. Types of geosynthetics

Type	Physical features				Tensile strengths
	Nominal Width (m)	Weft spacing (mm)	Number of weft (weft/4.5m)	Weft tensile strength (kN/weft)	Nominal design strength (kN/m)
100L	4.5	180	25	18	100
300M				54	300
500L				90	500
500M				90	500
600L				108	600
600M				108	600

2.2 *Results of damage test*

After compaction, samples were exhumed, washed and severity of the damage evaluated. The severity of the damage is shown in Photo. 2.2. The severity was shown by the number of visible damages per meter.

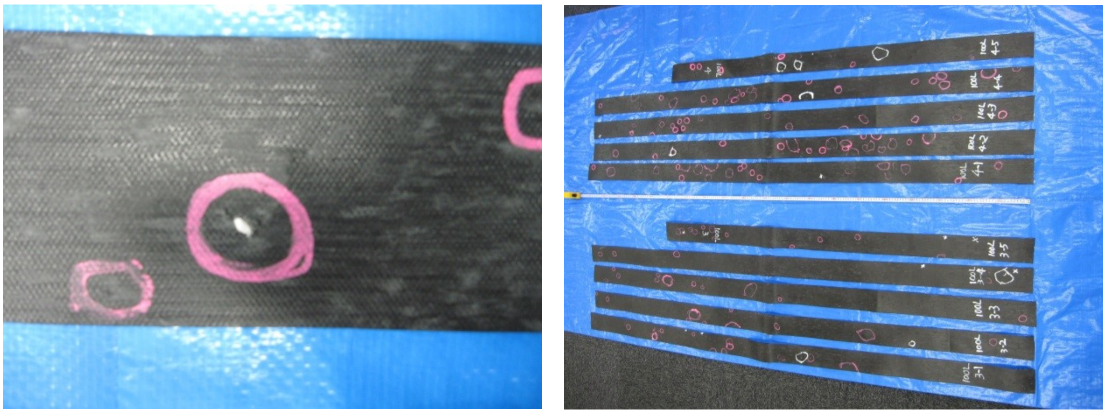

Photo 2.2 Damages caused from construction (Grade100L)

2.3 *Tensile test for the damaged sample*

A tensile strength test was conducted to evaluate Fc of the samples. This test was conducted according to JIS L 1908 "Geotextile testing method," in Japan Textile Products Quality and Technology Center.

The tensile strength results are summarized in Table 2.2. Fc varied with the type of geosynthetics. The lower strength and thinner coated 100L was affected the most out of all the samples. While the higher strength thicker coated 300M, 500L, 500M, 600L and 600M, were not affected very much by the fill and compaction force. From this test two conclusions were drawn. Firstly, a thick reinforcement with a large amount of polyester core material is not greatly damaged by gravels and 320kN compaction force. Secondly, a geosynthetics reinforcement with a thin coating, like 100L, has more damage. Since the coating thickness of 300L is similar to 100L we assumed that when the compaction force exceeds the conventional pressure of 150kN, geosynthetics with a tensile strength less than or equal to 300L would have more damage.

Table 2.2 Results of Tensile tests for damages during installation

Grade		100L	300M	500L	500M	600L	600M
Tensile strength(kN)	Virgin	18.3	59.1	95.9	95.1	112.5	113.2
	Damaged	14.7	56.2	92.6	93.7	111.3	113.6
Tensile strength retention rate R_D(%)		80.5	95.0	96.5	98.5	99.0	100.4
Safety factor of damage F_C		1.24	1.05	1.04	1.02	1.01	1.00

2.4 *Effect of short-term damage on long term tensile strength*

A creep rupture test was conducted using the damaged tested geosynthetics 100L, 300M and 500L to evaluate their long term creep characteristics.

Conventional creep rupture tests determine the long term creep characteristics by extrapolating from the 1,000hrs test results. However , for this test, the conventional creep rupture test (ASTM D5262) was also used with Stepped Isothermal Method SIM (ASTM D 6992), an accelerated test. These test can conclude the long term creep characteristics at 10^6 hrs. and 10^7 hrs. resulting in highly reliable long-term creep results. The creep rupture test were conducted in TRI/Environmental Inc. (TRI).

Before the actual creep rupture tests were performed the tensile strengths of geosynthetics before and after the damage tests were evaluated. These results are summarized in Table 2.3. This table also includes the results of tests conducted in QTEC, Japan. The TRI test results for 100L were greater than those of Japan. This was probably due to the difference in clamps that fixes the sample during the test. The results from TRI were used as the standard values for the creep rupture test.

Table 2.3. Tensile Strength test results pre and post construction.

Grade	Tensile strength (kN):TRI			Tensile strength(kN):QTEC		
	Virgin	Damaged	Fc	Virgin	Damaged	Fc
100L	18.6	17.0	1.09	18.3	14.7	1.24
300M	57.4	55.8	1.03	59.1	56.2	1.05
500M	94.9	90.5	1.05	95.9	92.6	1.04

Fig. 2.2 shows the creep strength for 100L. The creep strengths are shown as percentage ratio of the strength before the damage test. This Fig 2.2 includes results of the virgin and the exposed with damages. For the virgin, the creep reduction coefficient at 114 years (10^6 hrs.) was 70.38% compared with 65.04% for the exposed. The difference of the creep reduction coefficient between the virgin and the exposed comes from Fc (safety factor of damage during construction) and fm_{212} (material safety factor related to the effect of short term damage on long term strength). In equation below:

$$\text{(creep reduction factor of the virgin)/(creep reduction factor of the exposed)} = Fc \times fm_{212} \quad (1)$$

$70.38\%/65.04\% = 1.09 \times fm_{212}$
Therefore fm212 is regarded as 1.0.

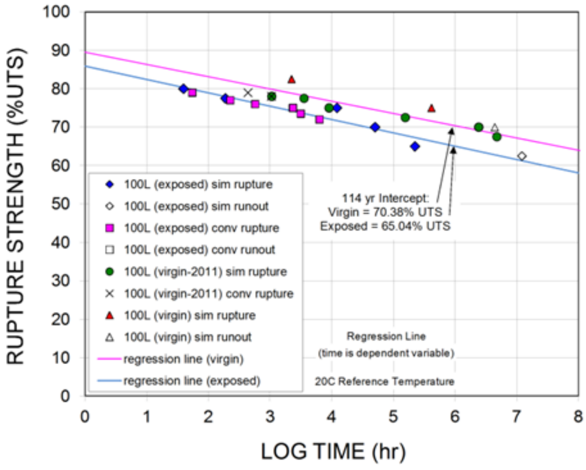

Figure 2.2 Results of creep rupture tests (Grade:100L)

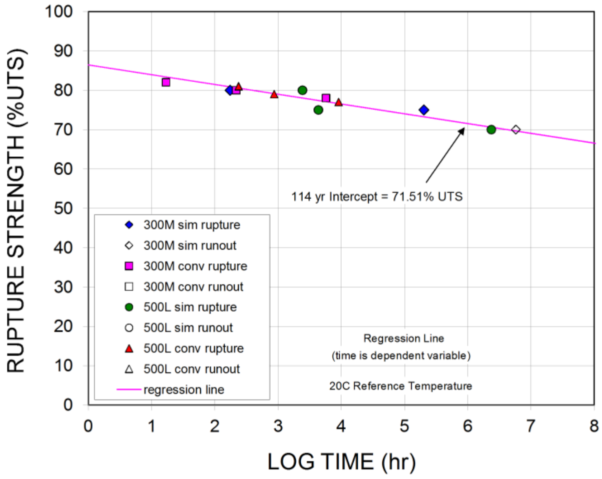

Figure 2.3 Results of creep rupture tests (Grade: 300M, 500L)

Fig. 2.3 shows the creep strength of the exposed 300M and 500L. The creep strength of the exposed 300M and 500L was 71.51%. The creep strength of the virgin product is 72%, based on equation (1),

72%/71.51%= 1.04 (average Fc of 300M and 500L) x fm_{212}

Thus fm_{212} is regarded as 1.0.

3 CONCLUSION

The damage testing was conducted with fill material comprising of coarse and angular particles (coarser than crush run C-40) along with a large-scale compaction roller. The long term creep strength of the damaged geosynthetics was evaluated using conventional creep rupture testing in addition to accelerated testing(SIM) which resulted in a highly reliable evaluation.

For performance design, it was found that it is necessary to consider fm_{212} for geosynthetics.

As seen in this paper, for future embankment projects with rock slags and large-scale compaction roller, the damage on geosynthetics should be evaluated. However, fm_{212} does not seem critical point for the Parallel laid PET fiber LLDPE coated geosynthetics tested.

REFERENCES

British Standard. 2010. Code of practice for strengthed/reinforced soil and other fills BS 8006-1:2010. British Standard Institution, London

Kawamura, Y., Kobayashi, T., Takatsuka, Y. 2014. Design and construction concerning control of displacement and deformation amount for level 2 earthquake of high embankment, 69th JSCE Annual Conf., Ⅲ-369, pp.737-738. (in Japanese)

Public Works Research Center. 2013. Technical certification for construction”Paralink”,No.1306. (in Japanese)