Chapter 5

Analysis of Porous Behaviors by Water Flow Property of Geonets by Theoretical Simulation

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Additional information is available at the end of the chapter

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Abstract

The relationship of compressive behavior according to manufacturing process parameters of geonet was investigated. We analyzed the drainage behavior of the bi- and tri-plane geonet used for the planar drainage and investigated the changes of the drainage behavior due to the restraining load. The data showed that there is no critical manufacturing factor to affect the compressive strength of the bi-planar geonet. All of these parameters can affect in a very complicated way. And the strand inclination can mainly affect to the after compressive strength, i.e., roll-over behavior. The results considering site-specific conditions of the landfill system explained the temperature has influence on the compressive behavior of the geonet. The compressive strength was reduced and the strain at yield increase gradually with the temperature for both of bi- and tri-planar geonet. Significant reductions in flow capacity were observed for the traditional bi-planar and cylindrical type geonet and this value was consistent to the compressive strength. These decreases were anticipated due to the abrupt thickness decrease of the geonet caused by roll-over. In the other hand, there was no significant decrease of transmissivity for the tri-planar geonet which has no roll-over phenomena.

Keywords: geonets, compressive behaviors, transmissivity, strand inclination, flow capacity, roll-over phenomena

1. Introduction

The application goal of geonets is mainly for planar drainage, and it is used as a medium to safely discharge the leachate generated from the landfill to the outside of the landfill. The two strands are cross-bonded to form a network structure in geonet, which serves as a drainage passage for the liquid. Geonet products of various structures are used and drainage capacity of geonet is very important because the landfill service life is determined by geonets drainage capacity when designing landfill.

Fannin [1] investigated the factors influencing the drainage capacity of geonets, and confirmed that the flow rate depends on the structure of the geonet and the drainage capacity is smaller when the strand channel and the crossing angle of the geonet are large.

Also, Zhao [2] analyzed the factors affecting the drainage performance of geonets and confirmed that the drainage capacity decreases as the hydraulic gradient and the compressive strength increase.

To investigate the behavior of geosynthetics under high normal stresses, Narejo and Rad et al. conducted a transmissivity test with normal stresses up to 2000 kPa [3–5]. From the results showed the variation of geonet transmissivity with normal stresses. Geonets behaved similarly up to 200 kPa regardless of weight. However, in the case of geonet with a small strand cross-section area thickness, the drainage performance decreases when the compressive strength increases, but the drainage performance does not decrease much even when the maximum confining load is 2000 kPa for thicker geonets. This is probably due to the fact that as the thickness of the strand cross-section layer constituting the geonet becomes smaller and the compressive strength becomes larger, the roll-over of the strand intersection of the geonet occurs more often.

Koerner [6] analyzed the roll-over phenomenon of bi-planar geonet. According to this, since the upper and lower strands constituting the geonet are not vertically bonded to each other at the cross-section areas, when the compressive strength is applied to the upper and lower layers of the geonet, the drainage capacity is large at the initial stage, the deformation of the strand joint starts to occur. This roll-over phenomenon causes a change in the drainage capacity in the upper and lower layers of the geonet, and the drainage capacity of the geonet is decreased and the drainage performance is lowered with time.

Allen [7] analyzed the effect of orientation of strand constituting geonet on drainage performance. In the case of the lower strand with small inclination angle at the cross-section area of the upper and lower strands, the roll-over phenomenon occurs more than the upper strand, and the drainage performance deteriorates.

Kopp reported that geonet drainage performance was affected by the construction site temperature when the geonet was constructed at the landfill site [8]. Pegg indicates that the drainage performance of the geonet is most affected under the circumstance at 80 or 85°C in the landfill site [9].

Therefore, when the environmental temperature is increased, the mobility of the molecular chain of the polyethylene, which is the raw material of geonet, becomes larger, and the drainage performance may be decreased due to the structural change of the geonet to the compressive strength.

In this chapter, the variation of drainage performance of geonets used for horizontal drainage is analyzed in relation to the influence of constraint load related factors.

2. Materials and performance test

2.1. Specimens

Three samples of geonets were used. The first geonet is a 5.6 mm thick high density polyethylene (HDPE) traditional bi-planar geonet. A photograph of this sample is shown in **Figure 1**.

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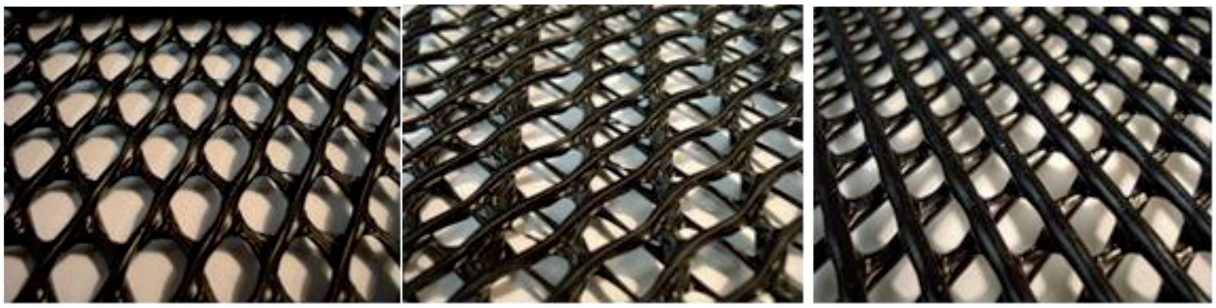

(a) (b) (c)

Figure 1. Photograph of various geonets samples: (a) bi-planar, (b) tri-planar, and (c) cylindrical type.

The second and third geonet are also HDPE, and have 8.6 mm tri-planar, 8.2 mm cylindrical type bi-planar structure, respectively. All these material are used for landfill cover and lining system drainage. Typical specifications for samples are provided in **Table 1**.

2.2. Short-term compressive test

Short-term compressive deformation testing was performed in accordance with ASTM Standard Test Method (ASTM D6364-06; Standard Test Method for Determining Short-Term Compression Behavior of Geosynthetics) [10].

The geonet specimens were placed between two steel sheets and compressed at a strain rate of 1.0 mm/min. The compressive strength was measured while varying the strain. The compressive strength of the geonet is determined by parameters such as thickness, mass per unit area, crystallinity, strand strength, bonding strength of strand, strand angle and inclination in plane, test conditions are 23, 35 and 50°C, Strain rates were 0.1, 0.5, 1.0, 5.0 and 10 mm/min. **Figure 2** shows the test pattern according to various parameters.

2.3. Transmissivity test

The horizontal permeability, transmissivity, which is the drainage performance of the geonet, was measured using the ASTM Standard Test Method (ASTM D4716/D4716M-14; Standard Test Method for Determining the In-plane Flow Rate per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using a Constant Head) [11]. And this is determined from the relationship between the number of paths per unit area and the in-plane drainage capacity, the compressive strength and the hydraulic gradient.

The short-term transmissivity test of geonet was carried out under various normal stresses and three hydraulic gradient conditions at 0.1–1.0, and the test temperature was 22–23°C. **Figure 3** shows a schematic diagram of the transmissivity test apparatus and the transmissivity value was calculated from the following equation:

$$\theta = \frac{Q}{B \times (\Delta h / L)} \quad (1)$$

where θ = transmissivity (m^2/s), Q = volume of discharged fluid per unit time (m^3/s), L = length of the specimen (m), B = width of the specimen (m) and h = difference in the total head across the specimen (m).

Property	Test method	Unit	Bi-planar	Tri-planar	Cylindrical type
Thickness	ASTM D5199	mm	5.6	8.6	8.2
Mass per unit area	ASTM D5261	g/m^2	920	1700	2300
Carbon black	ASTM D4218	%	2.3	2.2	2.3
Density	ASTM D1505	g/cm^3	0.942	0.944	0.940
Crystallinity	ASTM D2910	%	56	55	61

Table 1. Basic properties of various geonet samples.

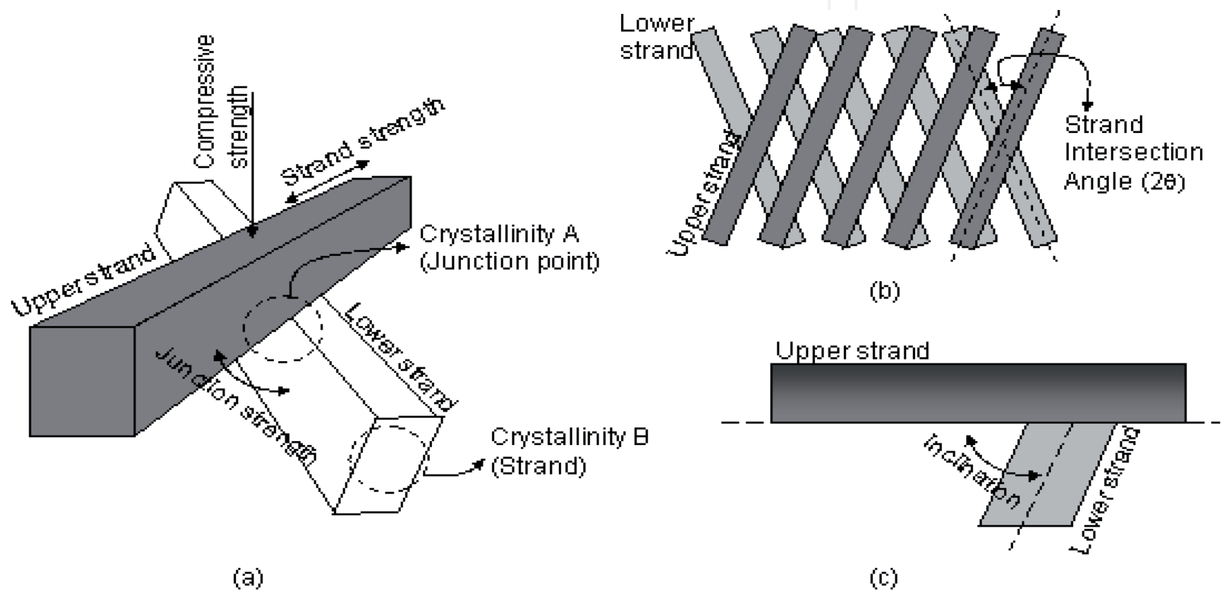

Figure 2. Schematic diagram various test parameter for determining the main factor: (a) 3-D, (b) horizontal, and (c) verticle.

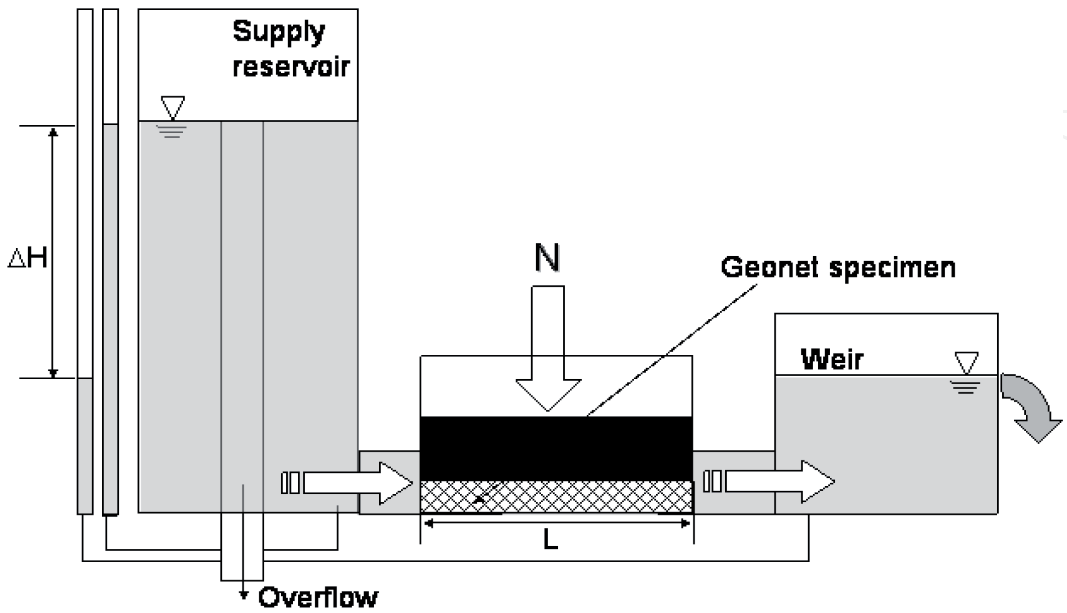

Figure 3. Schematic diagram of transmissivity test device.

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3. Results and discussion

3.1. Factors affecting the short-term compressive behavior

Figures 4–10 show the results of correlation between various manufacturing parameters and the compressive strength. The relationship between all of these manufacturing parameters of geonet and the compressive strength were not well defined through analysis of experimental values and it is assessed that the compressive strength of a geonet cannot be related to such as weight, geometrical properties, crystallinity, rib mechanical properties, etc. Only, compressive strength is determined by a combination of these factors and thus has to be controlled as any other material constant of a geonet.

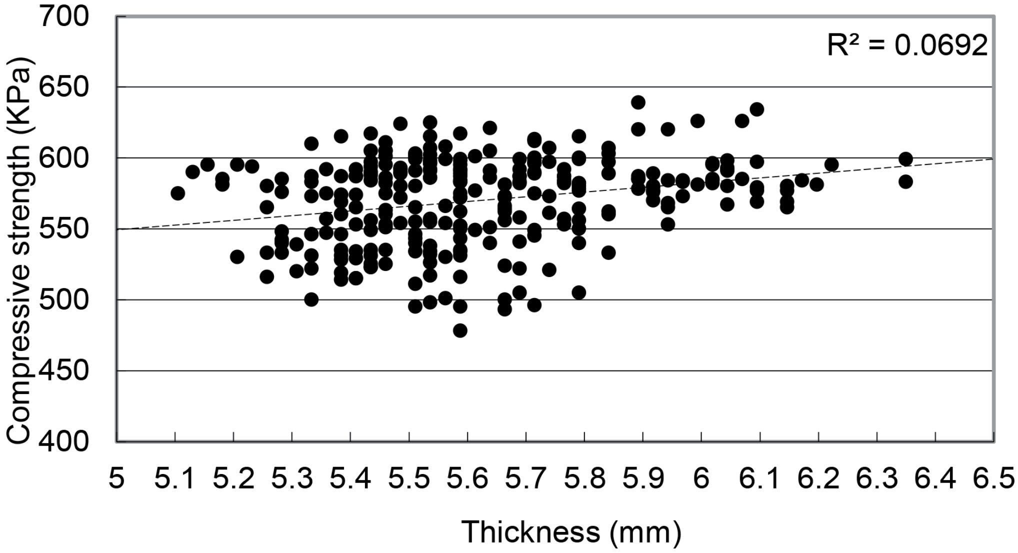


Figure 4. Plot of compressive strength vs. thickness.

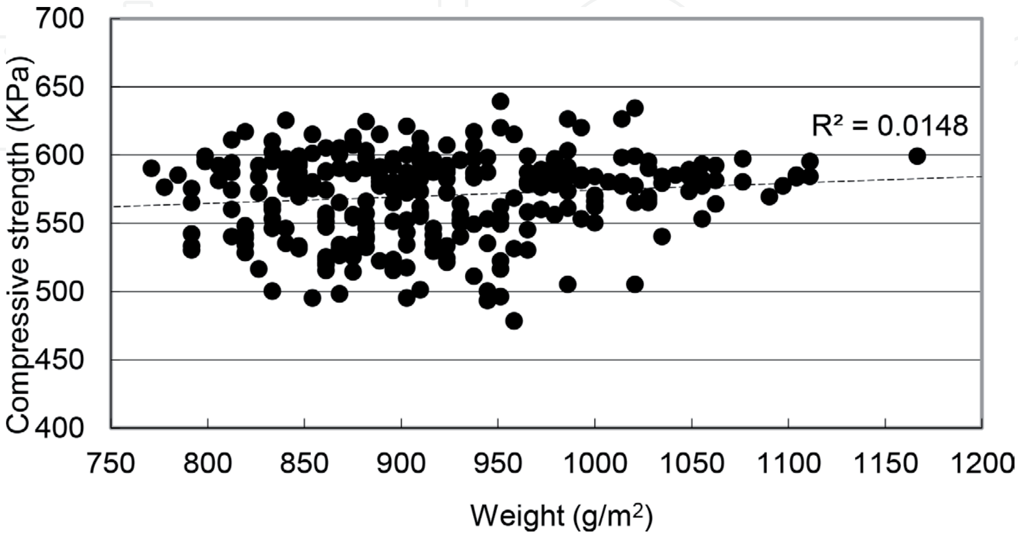


Figure 5. Plot of compressive strength vs. mass per unit area.

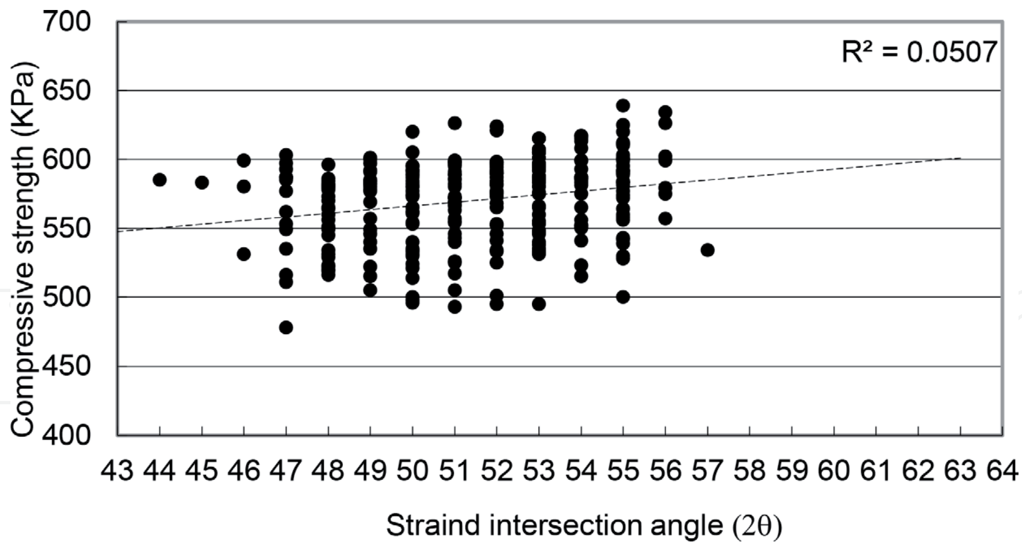


Figure 6. Plot of compressive strength vs. strand intersection angle.

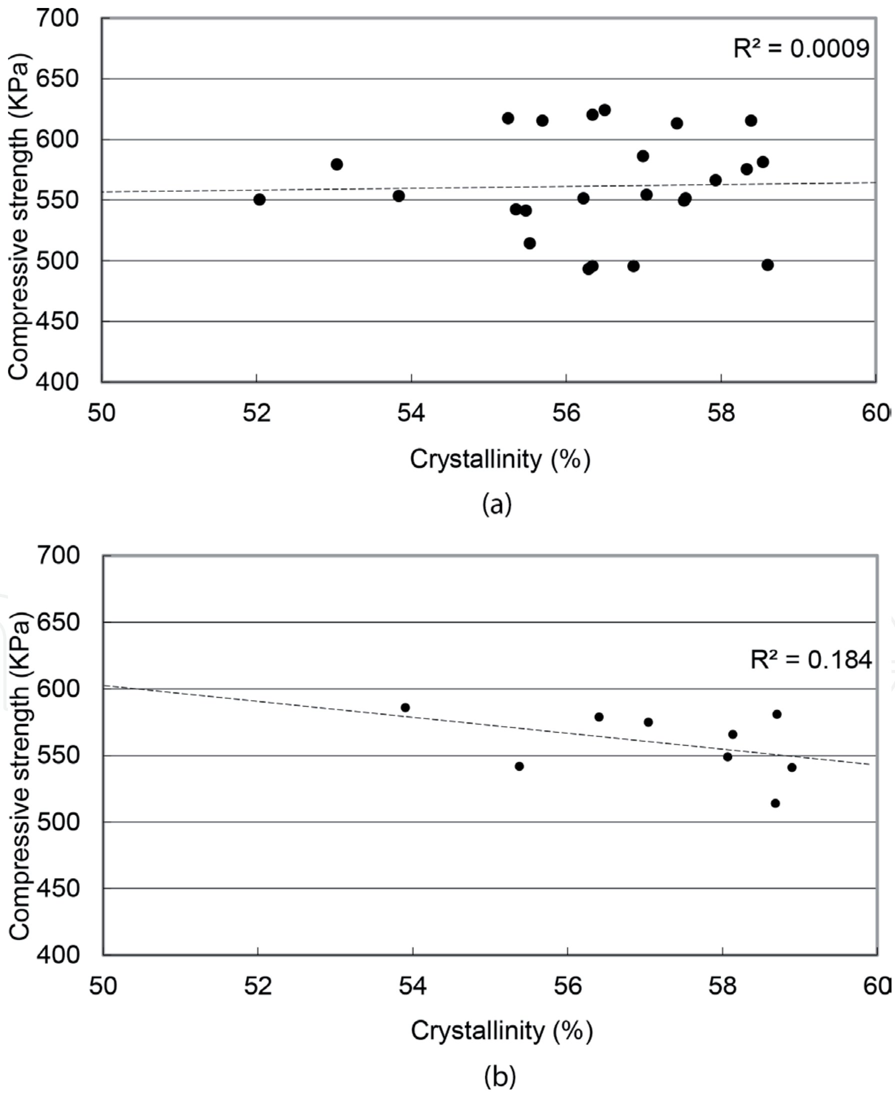


Figure 7. Plot of compressive strength vs. crystallinity: (a) at intersection and (b) at strand.

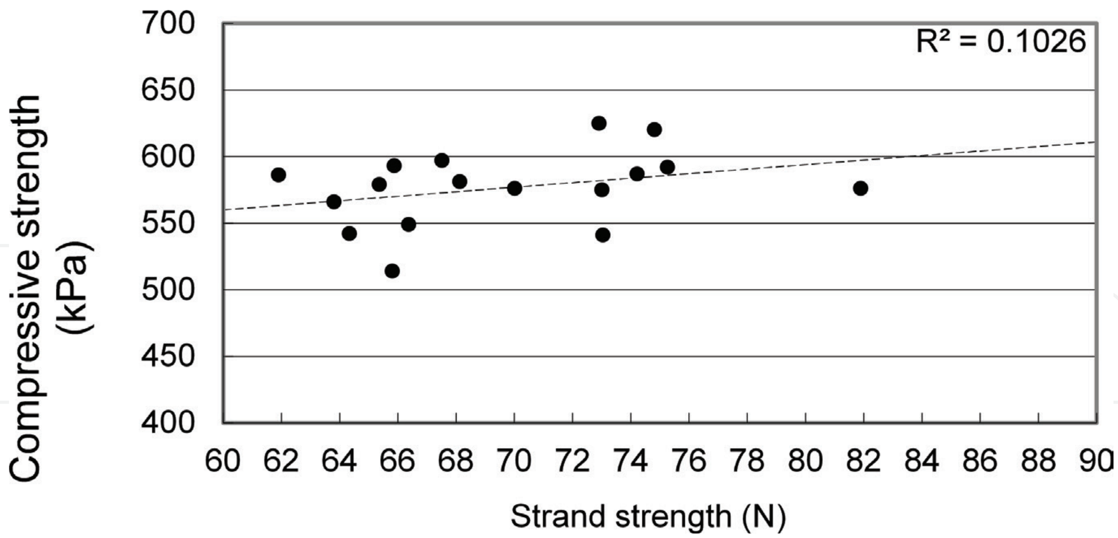


Figure 8. Plot of compressive strength vs. strand strength.

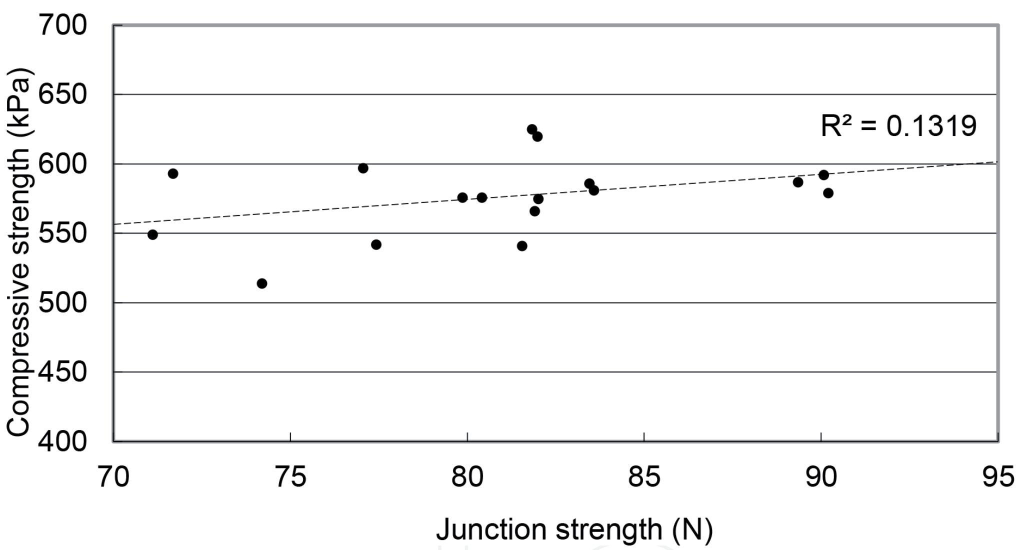


Figure 9. Plot of compressive strength vs. junction strength.

To determine the compressive strength, the strand slope associated with the range of roll-over may not affect the confining strength, since the confining strength measurement time is after the start or end point of the roll-over (**Figure 11**). In **Figure 11**, the roll-over distance of a rectangular geonet strand is longer than that of a circular stranded geonet. Additional evidence for the relationship between the strand cross-sectional shape and the rollover behavior to support this can be seen by comparing the shape of the compressive strength-strain curve of the geonet shown in **Figure 12**.

The cylindrical type exhibits a very stiff behavior even after the end of the roll-over and has very short roll-over range compare to the bi-planar which has very long roll-over region. By defining the factor that affects to the short-term compressive strength behavior of the bi-planar geonet, it should be determined that before the determining point of compressive

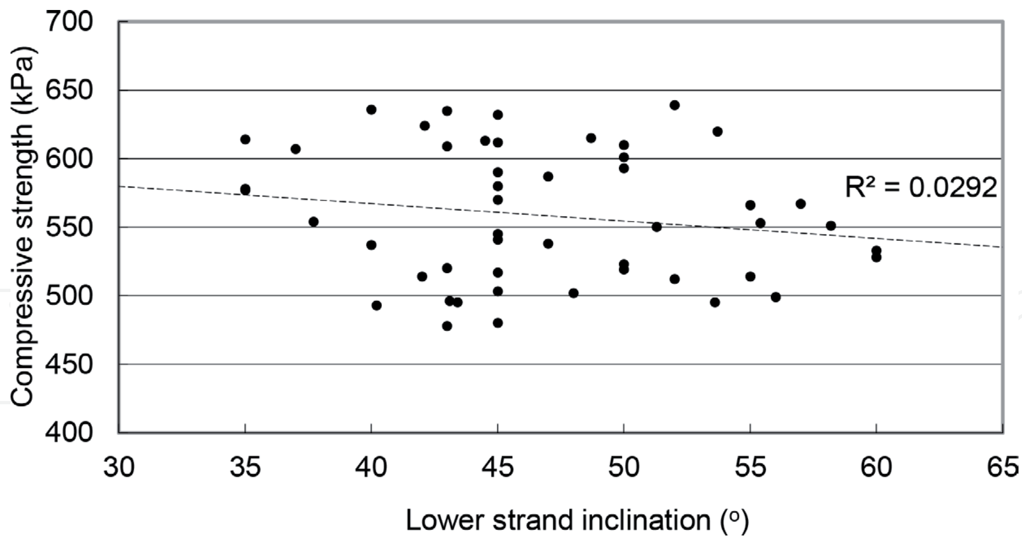


Figure 10. Plot of compressive strength vs. strand inclination.

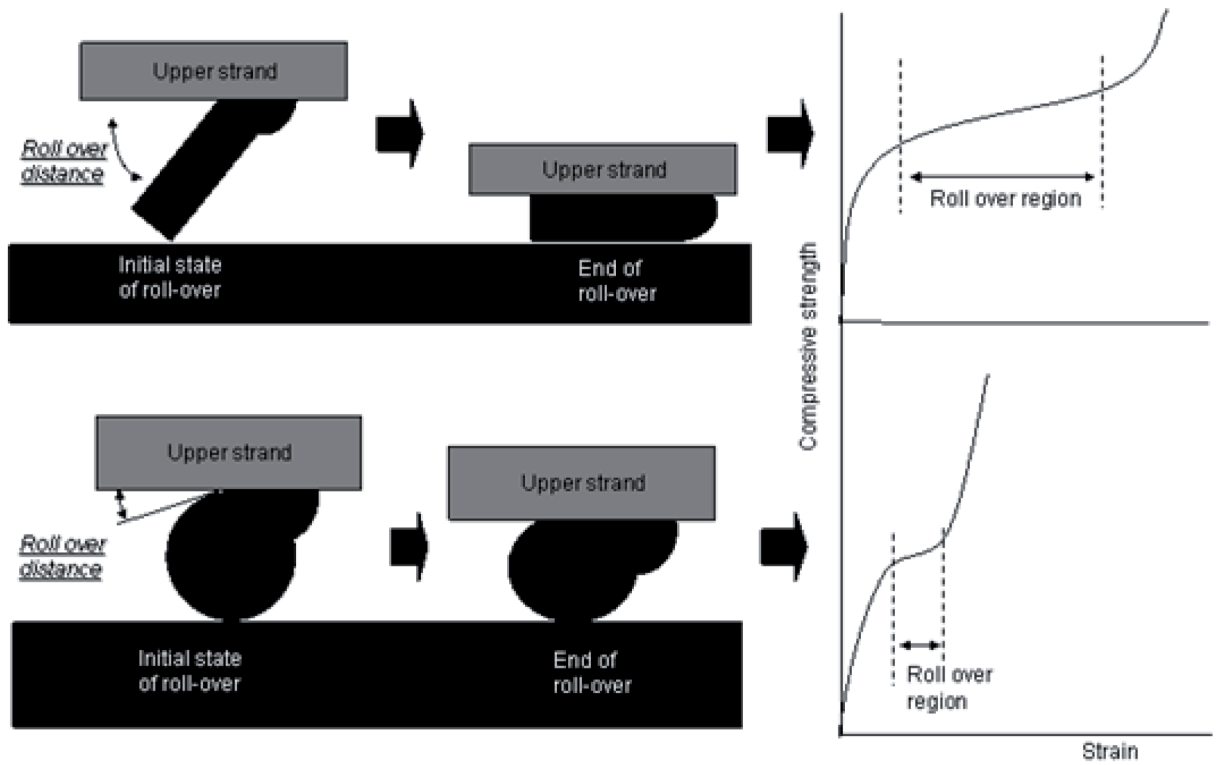


Figure 11. Relationship between strand cross sectional shape and roll-over range.

strength. Also, all of the manufacturing parameters can affect the transmissivity of the geonet and strand inclination and strand cross-sectional shape will affect the roll-over phenomenon mainly.

Therefore, it is concluded that if the cross-sectional shape of the strand is close to the circle, the roll-over region could be shortened dramatically and this advantage will contribute to the advance the long-term flow capacity of the geonet.

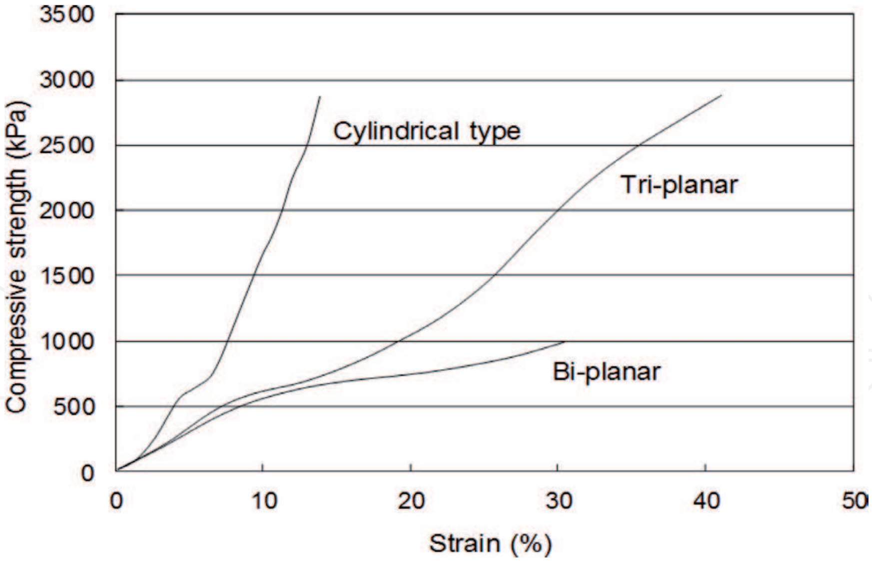


Figure 12. Plot of compressive strength-strain curves of various geonet samples.

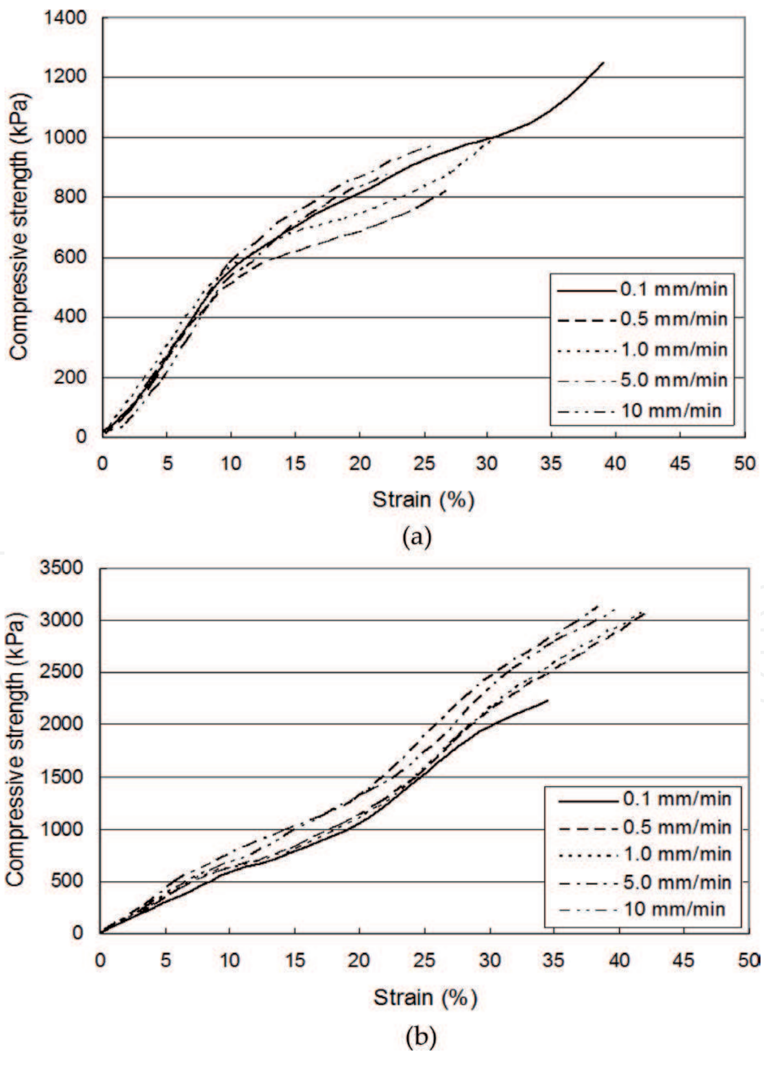
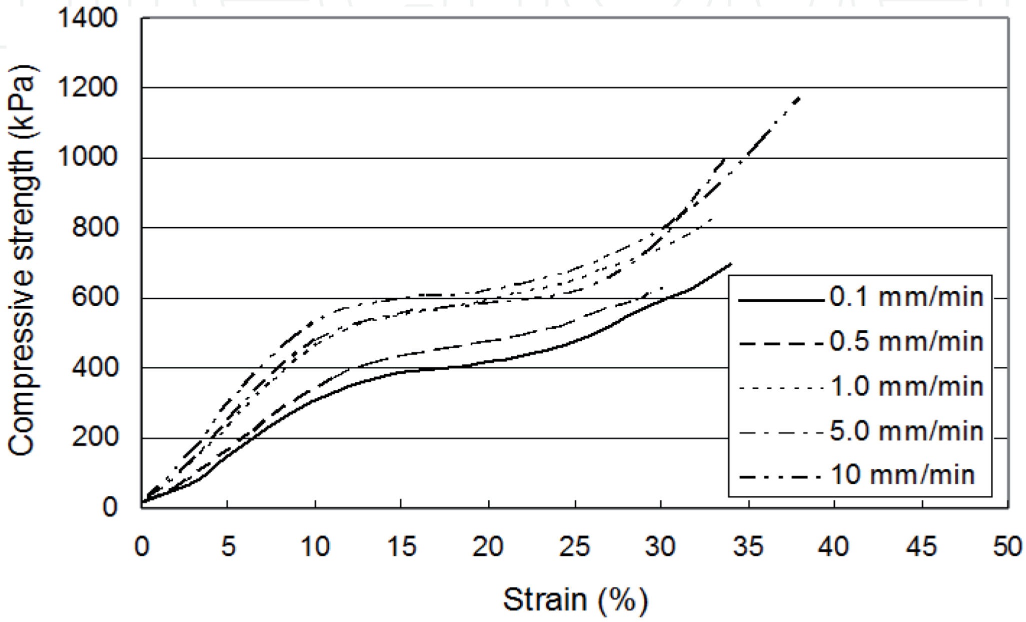


Figure 13. Plot of compressive behavior curves according to various deformation rates at 23°C test temperature: (a) bi-planar and (b) tri-planar.

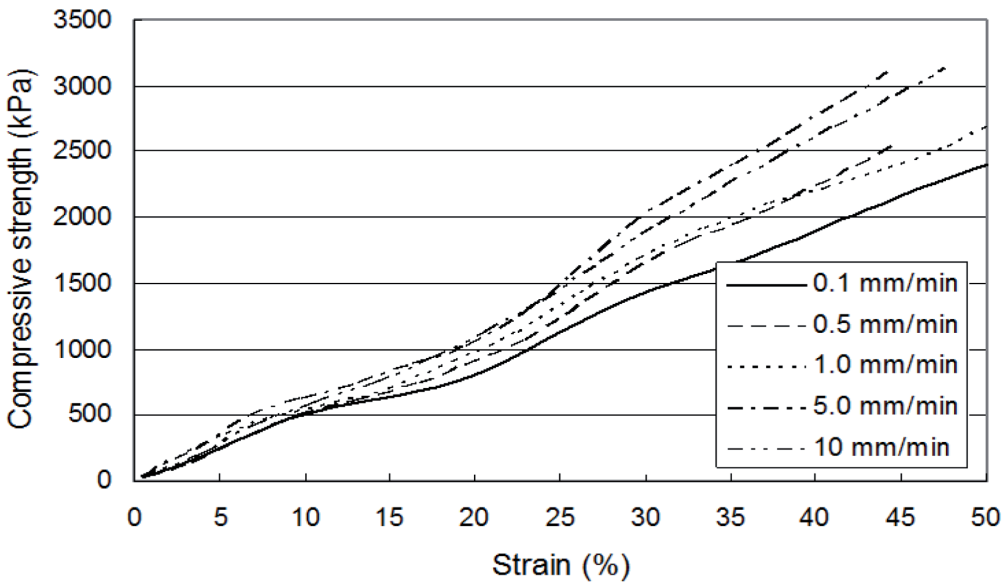
3.2. Short-term compressive behavior

Figures 13–15 show all the results of compressive strength-strain curves at different temperatures (23, 35 and 50°C) and elongation rate (0.1, 0.5, 1.0, 5.0 and 10 mm/min).

In here, the compressive strength decreases and the deformation value increases according to the temperature. And the initial slope of this curve decreases greatly with increasing temperature, and the elastic modulus with temperature increases in the given strain range.



(a)



(b)

Figure 14. Plot of compressive behavior curves according to various deformation rates at 35°C test temperature: (a) bi-planar and (b) tri-planar.

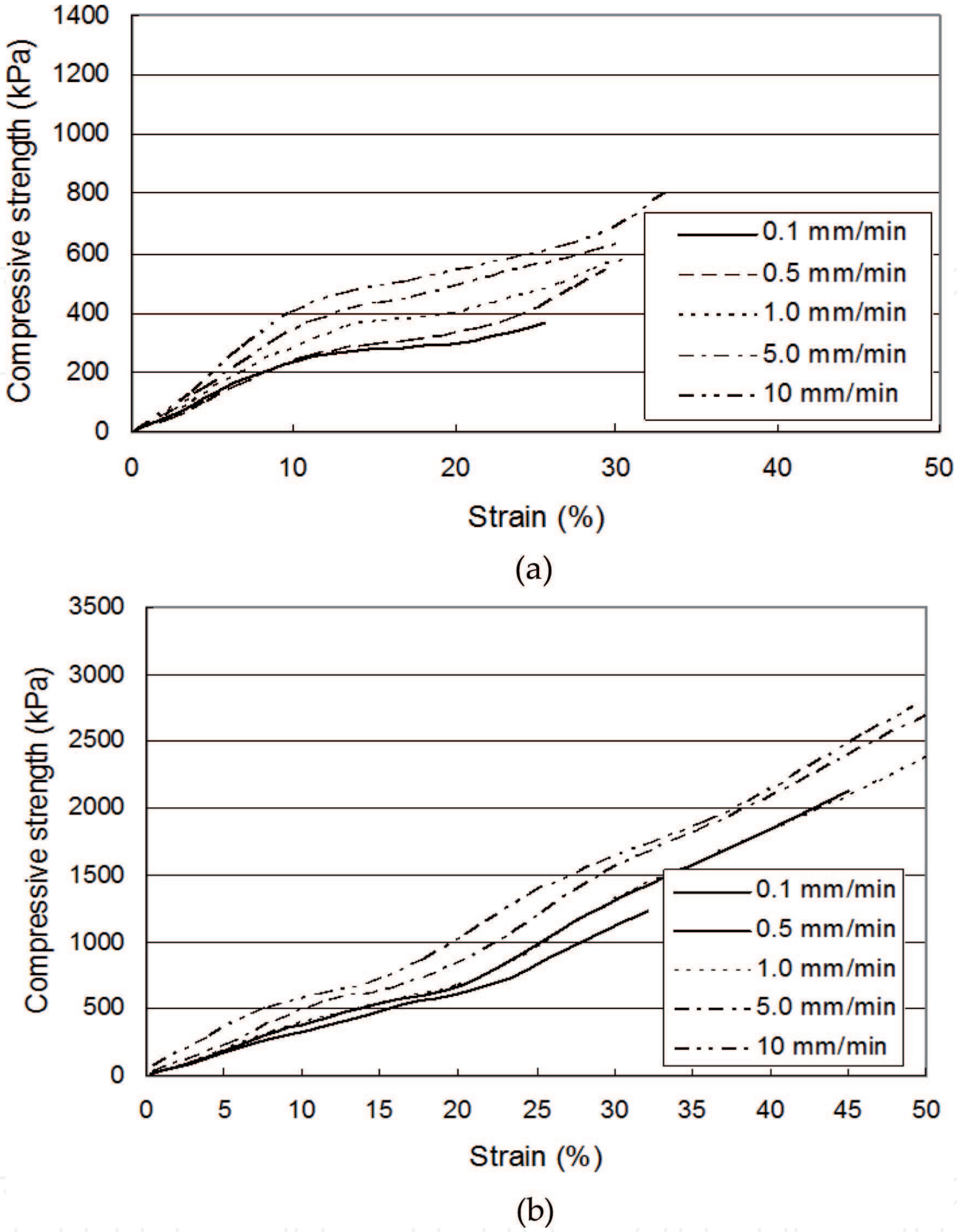
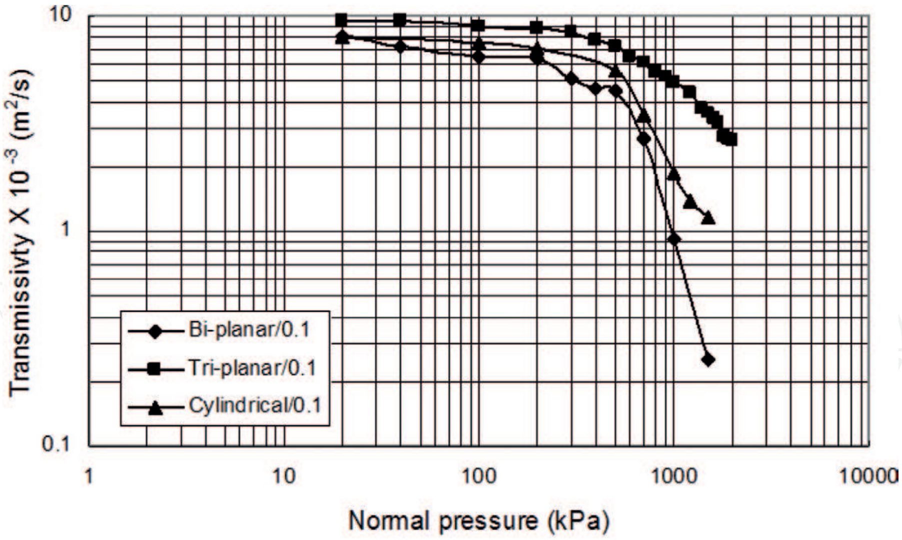


Figure 15. Plot of compressive behavior curves according to various deformation rates at 50°C test temperature: (a) bi-planar and (b) tri-planar.

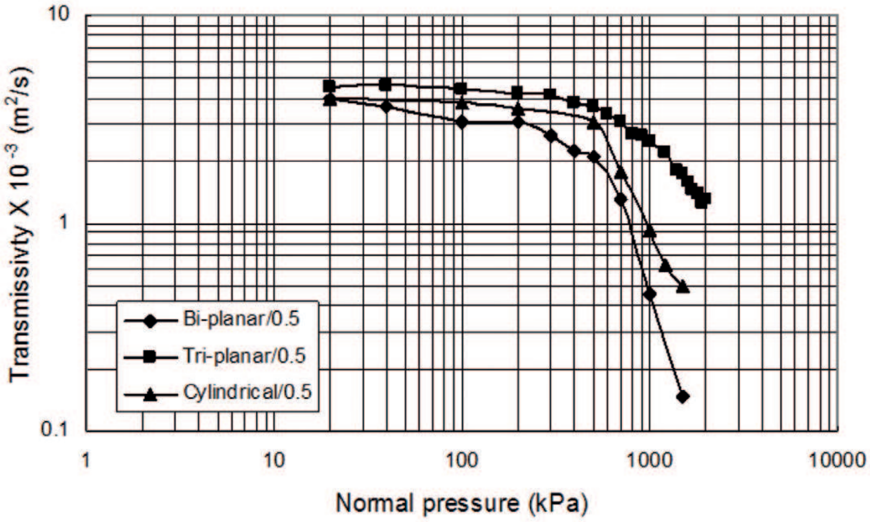
Considering the landfill's severe temperature conditions, this decrease may be affect the long-term flow capacity of the geonet drainage.

3.3. Short-term transmissivity

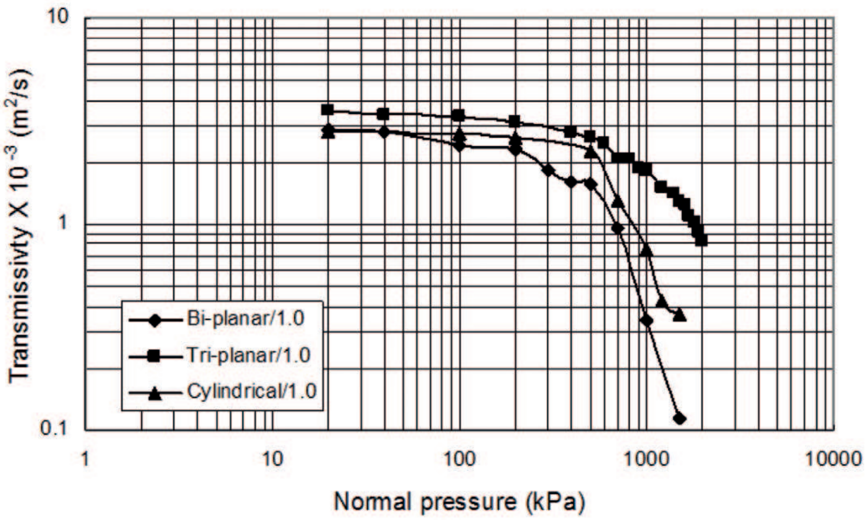
The flow capacity data as logarithm of transmissivity as a function of normal pressure (log value) is presented in **Figure 16**. This type of plot more clearly reveals the material response to applied loading conditions. **Figure 16** shows a continuous decrease in transmissivity from



(a)



(b)



(c)

Figure 16. Plot of transmissivity results of various geonet samples: (a) gradient—0.1, (b) gradient—0.5 and (c) gradient—0.5.

8.2 to 0.25, 9.53 to 2.62 and 8.2 to 1.16 ($\times 10^{-3}$) at 0.1 hydraulic gradient for bi-planar, tri-planar and cylindrical type geonet, respectively. Also in other hydraulic conditions show same trend as 0.1 hydraulic gradient. It is clear from **Figure 16** that bi-planar and cylindrical type show dramatic decrease of transmissivity above 600 kPa.

However, the cylindrical type geonet has more strong flow capacity compare to the bi-planar geonet even though there is a roll-over effect. On the other hand, the tri-planar geonet shows the excellent resistance to the thickness decrease.

The transmissivity of the tri-planar geonet is very high but decrease gradually with increasing normal pressure (compressive strength). This is due to the tri-planar geonet structure and means the stability of tri-planar geonet even though very high normal pressure (2000 kPa) and hydraulic gradient (1.0).

Therefore, it can be concluded that the triplanar geonet drainage pattern is linear and that a tri-planar geonet with a zig-zag-shaped flow pattern can discharge the liquid very effectively even when the thickness is the same as the bi-planar geonet.

From these results, it is considered that the most important factors affecting short-term flow capacity of geonet are drainage path and drainage pattern (e.g., linear or zigzag type) and geonet thickness.

4. Conclusion

The data from short-term engineering properties describe the influencing factors to the short-term compressive for the bi-planar geonet, compressive behavior under various test conditions for the bi-planar and tri-planar geonet, and the short-term flow capacity for three types of geonet under up to 2000 kPa normal pressure.

The following conclusions are drawn:

1. The compressive behavior of bi-planar geonet shows different drainage behavior before and after compression. Compared with the pre-compression, it can be affected by the strand cross-pattern after compression, and the strand inclination and cross-sectional pattern affect the roll-over behavior, resulting in a larger reduction in drainage performance.

2. Since these materials are viscoelastic in nature, compressive behavior was affected by the temperature changes. The compressive decreases were up to 40% when compared to its value for 23°C for both bi- and tri-planar geonet in very critical temperature condition (50°C).

3. The reduction of the drainage capacity depends on the structure of the geonet, and the drainage pattern is composed of a zigzag pattern rather than a straight line, or a smaller triple-planar geonet with a larger strand thickness. In this case, the roll-over effect can be minimized, and even when the compressive strength is higher than 600 kPa, the decrease of drainage capacity is smaller than that of the bi-planar geonet. And the selection of a geonet to maximize flow capacity in the long-term must consider not only the thickness of the strands but also the pattern of the liquid flow channel.

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