Effect of geometry of different types of geosynthetics for drainage

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Keywords: geonet, geocomposite, geometric structure, roll-over, lay-down

ABSTRACT: The effect of cross-sectional geometry of three bi-axial geonet drainage materials were investigated at different compressive loading conditions. The three geonet drainage materials were evaluated: (i) geonet composed of vertical ribs (GN-VR), (ii) geocomposite consisting of vertical rib geonet sandwiched between two non-woven geotextiles (GC-VR), and (iii) geonet composed of circular ribs (GN-CR). The results of compressive tests indicate that the geometry structures had a strong influence on the compressive behavior of the geonets and geocomposite. The stress-strain curve of GN-VR exhibited a pronounced peak, whereas the compressive stress increased gradually with strain for GN-CR and GC-VR. The peak in the stress-strain curves of GN-VR was caused by the abrupt lay-down of the upper layer ribs in the geonet. The discrepancy of stress-strain curves between GN-VR and GC-VR was due to the interface fraction between nonwoven geotextile and geonet in GC-VR. The geotextile provided resistance to the abrupt lay-down of the ribs and led to a more gradual process of lay-down. In GN-CR, the roll-over of the upper ribs and compression of lower ribs were observed. Due to the circular cross-section of the ribs, the roll-over phenomenon occurred gradually under compressive loading.

1 INTRODUCTION

High density polyethylene (HDPE) drainage materials such as geonet and geocomposite are widely used as drainage components in the leachate collection and removal system (LCRS) and the leak detection system (LDS) of landfills. In such applications, the geosynthetic drainage materials are subjected to a static compressive stress from the landfill waste. Thus, the cross-plane compressive strength of the drainage materials is essential in sustaining the in-plane drainage property.

However, under compressive loading, the geonet undergoes deformation or even collapse of rib structure (e.g., lay-down) causing a decrease in the drainage capability (Koerner 2005). Based on the Darcy's law, the flow rate through the geonet or geocomposite decreases with thickness as expressed by Eq. (1):

$$q = k\ i\ A = k\ i\ (W \times t) \qquad \text{(Eq. 1)}$$

where, q = flow rate
k = hydraulic conductivity
i = hydraulic gradient
A = cross sectional area
W = width of drainage material
t = thickness of drainage material

Therefore, it is necessary to understand the compressive behavior of drainage materials, especially, the potential changes of the cross-sectional configuration of the geonet in responding to different compressive loads.

In this paper, compressive behavior of two geonets and one geocomposite were evaluated: (i) geonet composed of vertical ribs (GN-VR), (ii) geocomposite consisting of vertical ribs geonet sandwiched between two geotextiles (GC-VR), and (iii) geonet composed of circular ribs (GN-CR). All of them are HDPE bi-planar geonets. The two layers of geotextile in the geocomposite are needle-punched nonwoven polypropylene (PP) geotextiles which are thermally bonded onto the top and bottom of the same type of geonet as GN-VR. The compressive behaviors of these three cross sectional configurations were evaluated by compression tests together with sequential photographs taken during the test. The photographs were used to explain the compression stress/strain curve profile.

2 TEST MATERIAL

The physical properties of the geonets and geocomposite are showed in Table 1. Their cross sectional structures are depicted in Figure 1. As presented in Figures 1(a) and 1(b) for GN-VR and GC-VR, respectively, the majority of the upper and lower ribs have already inclined without subjecting to compressive loading, and the inclined angle varies from location-to-location of the geonet.

Table 1. Physical properties

Property	GN-VR	GC-VR	GN-CR
Density (g/cm^3)	0.95	0.95 (geonet)	0.95
Mass per unit area (kg/m^2)	0.98	1.5	1.2
Thickness (mm)	5.1	7.0	7.0
Approximate Strand spacing (mm)	10	10	10

Density, mass per unit area, and thickness were measured by ASTM D792, ASTM D5261, and ASTM D5199, respectively. Also, the density values were incorporated with carbon black. Strand spacing between two strands was directly measured.

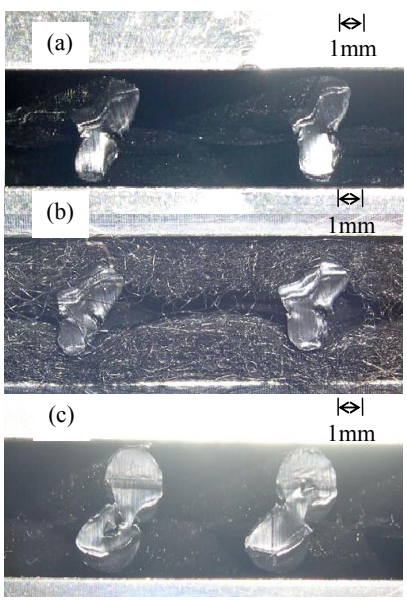


Figure 1. Cross-sectional views of drainage geosynthetic materials: (a) GN-VR; (b) GC-VR; and (c) GN-CR

3 COMPRESSIVE TEST AND BEHAVIOR

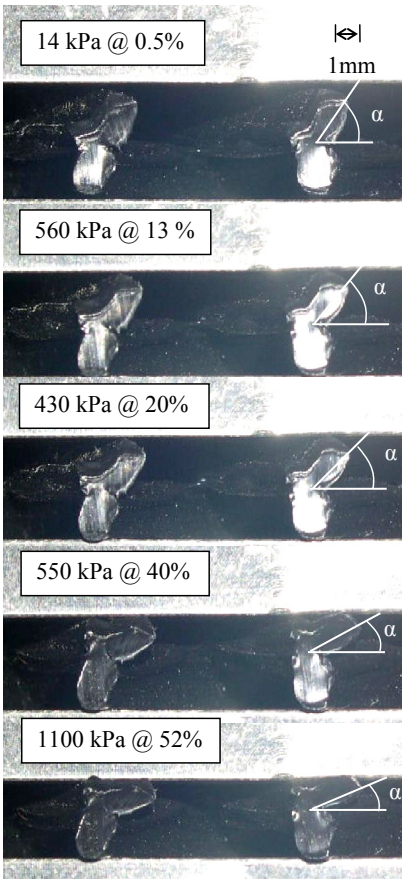
The compressive behavior was evaluated according to ASTM D 6364 test procedure. The dimensions of the test specimens were 102.4 mm (4 in.) x 102.4 mm (4 in.). The loading was applied at a strain rate of 10% of the thickness per minute. To illustrate the changes in cross section geometry, the cross section of the drainage materials was photographed at different stress levels during the compressive test. Three sets of photographs for GN-VR, GC-VR, and GN-CR are presented in Figures 2a, 3a, and 4a, respectively.

The stress-strain curve associated with each set of photographs is presented in Figures 2b, 3b, and 4b. A pronounced peak was revealed in the compressive stress/strain curve of GN-VR in Figure 2b, and it was caused by the abrupt lay-down of the upper ribs in the geonet (Yeo and Hsuan, 2007). For GC-VR and GN-CR, no distinguish peak was observed in their stress/strain curves; the compressive stress increases gradually with strain as shown in Figures 3b and 4b. The interface friction between geotextile and upper ribs provided resistance to the abrupt lay-down of the ribs, leading to a gradual lay-down of the upper ribs. In GN-CR, the geometric circular shaped of the ribs was probably the reason for the gradual roll-over response rather than the abrupt phenomenon. The roll-over phenomenon of the upper ribs can be verified by the movement of "marking line" in Figure 4a. In addition, compressive deformation was also taken place at intersection region between upper and lower ribs. Note, the terms of "lay-down" and "roll-over" referred in this paper are used for vertical rib geonet and circular rib geonet, respectively.

Based on Figures 2a and 3a, the inclined angles of upper ribs in GN-VR and GC-VR were measured at different compression loads to demonstrate the relationship between applied stress and inclined angle of ribs (Figure 5a). The profiles of stress against inclined angle curves are similar to the corresponding stress-strain curves (Figures 2b and 3b). The pronounced peak stress (i.e., ~ 560 kPa) of GN-VR in Figure 5a is similar to that in the stress-strain curve (Figure 2b). This verifies that the peak stress represents the critical stress required for abrupt lay-down of upper rib in GN-VR.

Using the appearance "marking line" on the upper ribs of GN-CR as the reference, the roll-over angle was measured under different compressive stresses. The graph plotting stress against roll-over angle is presented in Figure 5b. The profile of stress against angle curve is also similar to that of the stress-strain curve.

(a) Sequence of photographs



(b) Stress-strain curve

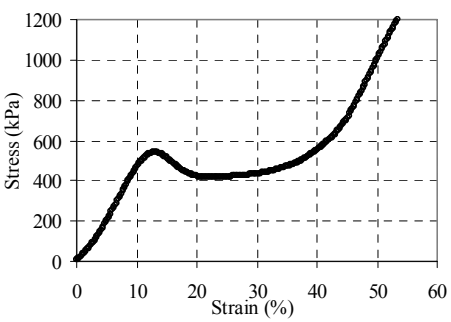
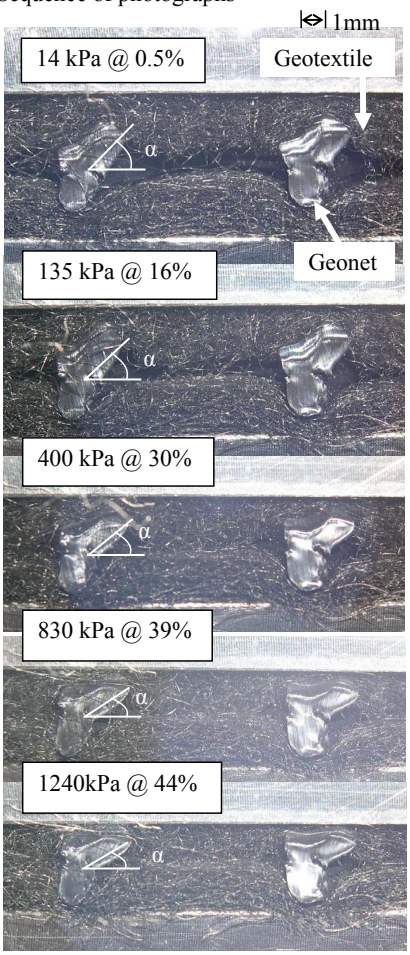


Figure 2 – (a) A sequence of images of the cross-sectional area of the bi-planar vertical rib geonet under different increasing stresses (α: inclined angle of the upper ribs) (Yeo and Hsuan, 2007) and (b) a stress-strain curve

(a) Sequence of photographs



(b) Stress-strain curve

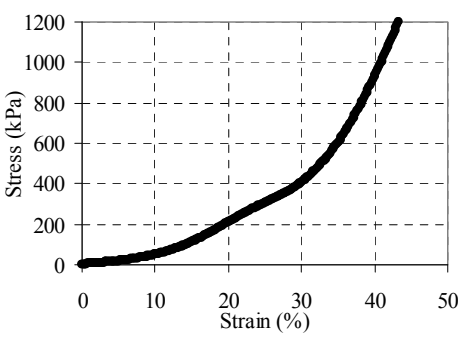


Figure 3 – (a) A sequence of images of the cross-sectional area of the bi-planar vertical rib geocomposite under increasing stresses (α: inclined angle of upper ribs) and (b) a stress-strain curve

(a) Sequence of photographs

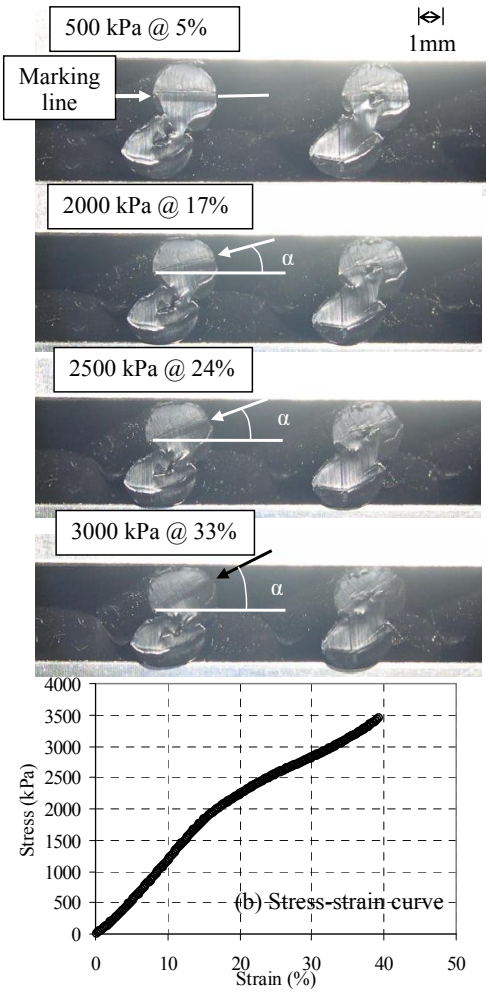


Figure 4 – (a) A sequence of images of the round-type rib geonet (α: angle of the upper ribs) and (b) a stress-strain curve

4 CONCLUSIONS

The compressive behavior of two different geonets and one geonet composite were evaluated by associating the stress-strain curves with the rib deformation. It was found that the cross-sectional geometry of the rib had a significant impact on the compressive behavior of the geonet.

The stress-strain curve of GN-VR presented a pronounced peak corresponding to the abrupt lay-down of the rib. For the geocomposite, GC-VR, the localized interface friction between the compressible geotextile and ribs prevented the abrupt lay-down of the ribs. For GN-CR, roll-over of the upper ribs was observed; however, the movement occurred gradually together with the compression deformation at the lower ribs.

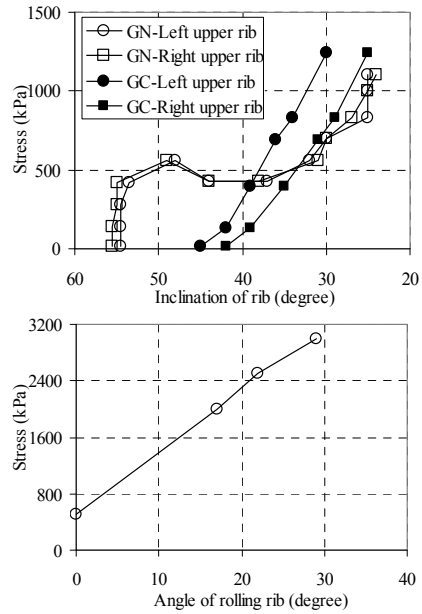


Figure 5 – (a) Angles of lay-down ribs from GN-VR and GC-VR and (b) angles of roll-over ribs from GN-CR

ACKNOWLEDGEMENT

The research project was sponsored by the Geosynthetic Institute (GSI). Appreciation is given to Ms. Rebecca Flynn of Geosyntec Consultants for the review.

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