Assessment of the Resistance of Drain Tube Drainage Geocomposites to High Compressive Loads

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ABSTRACT: In the late 90's, a new type of planar drainage geocomposite was developed. This product differs from other geocomposites as the drainage core is composed of multiple corrugated and perforated pipes instead of biaxial or triaxial nets. As a result, the index and performance properties for this type of structure differ from those commonly used for geonet geocomposites.

In this paper, the structure of Drain Tube drainage geocomposites is presented along with its key properties and the drainage mechanism associated with its' particular structure. The relevance of this kind of structure for high load applications is discussed. In particular, it is shown that when adequately confined in soil, the multi-tubular structure of this product allows it to sustain extremely high normal loads without significant changes in transmissivity. These observations are further discussed to demonstrate the lack of sensitivity of the product to creep when compared to other types of planar drainage geocomposite, for which lateral confinement and arching effect cannot develop. Based on these observations, creep reduction factors to be used in the design of drainage structures using a Drain Tubes geocomposite confined in soil are suggested and compared to those commonly used for other types of planar drainage geocomposites in similar situations.

1 INTRODUCTION

The design of geosynthetic drainage layers involves the selection of intrinsic material properties including hydraulic transmissivity. However, even when a required performance value is determined for specific site conditions, several safety factors must be applied to allow for the long term degradation mechanisms of geosynthetic products. Among those reduction factors is one for creep.

The magnitude of creep deformation is a function of the ratio between service load and short term compression strength. The higher this ratio is, the greater the magnitude of creep. For ratios approaching 1.0, creep can lead to the complete collapse of the product shortly after loading.

In order to consider creep at the testing stage of a project, without extending the duration of the test over very long periods, a simple method is to conduct transmissivity measurements under compressive loads determined by multiplying the service load by some safety factor (i.e. 2.0 or 2.5). This approach can be used for products which are known to be creep sensitive, such as geonet geocomposites.

For Drain Tubes planar drainage geocomposites, the creep issue cannot be handled the same way. First, it is not possible to measure a compression strength of the synthetic material that will involve the same stress pattern as the one which develops in field applications, because it is not possible to model the lateral support offered by soil confinement in an index test such as ASTM D6364. Second, based on the literature available for buried pipe design, it is possible to predict that arching effect is likely to tremendously reduce the actual normal load sustained by the pipe itself.

In order to verify that the above assumptions are valid, it was decided do conduct a series of validation tests and obtain indicative data to qualify the long term behavior of Drain Tubes planar geocomposites with respect to creep.

2 DESCRIPTION OF THE PRODUCT

Drain Tubes planar geocomposites are made of two key components (Figure 1):

- Two or three layers of non-woven geotextiles, which act either as capillary mediums or as filters. If installed over a liner, the geotextile matrix can also act as a cushion and is designed for that purpose using the same design methodologies as are typically used for geotextiles.
- A series of embedded corrugated polypropylene perforated pipes spaced at regular intervals. These patterns can vary between one pipe every two meters of width, up to four pipes per meter. These perforated pipes provide most of the drainage capability of the product. As a matter of fact, the contribution of the non-woven matrix is typically considered as an additional security.

Given this structure, it is possible to design both the transmissivity of a product and the non-woven geotextile to the specific requirements of a project, simply by selecting the appropriate component properties of the same generic product.

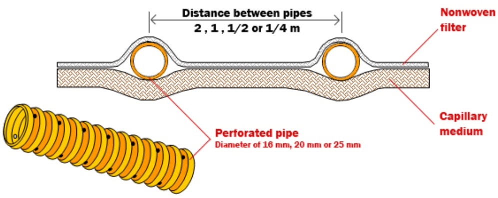

Figure 1 : Drain Tubes geocomposite Description

On top of these key materials properties, it should be noted that because of their particular structure, Drain Tubes are particularly well suited for applications where thermal expansion is a concern (i.e. at the installation stage), as their non woven matrix is not sensitive to thermal expansion and contraction. As mentioned above and further developed below, the products structure also makes it particularly appealing for high load applications, such as heap leach pads, tailing dams, and other applications involving significant high normal loads.

Unlike other planar geocomposites, the load transfer mechanism between the overlying and underlying material is only a fraction of the normal load. The pipe component of Drain Tubes geocomposite is confined by the surrounding soil, thus loads are calculated using traditional flexible pipe design methodologies (Figure 2). The soil arching effect that applies to other flexible pipes applies to Drain Tubes geocomposite as well (Figure 3).

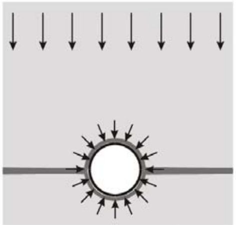

Figure 2: pipe loading mechanism

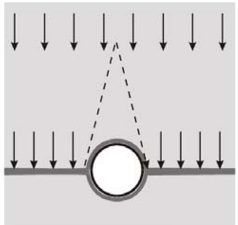

Figure 3: soil arching effect

This loading mechanism differs tremendously from that of planar geonet geocomposites. With these types of products, loads are applied to the entire surface of the product, completely transferred to the geonet structure and then to the underlying soil. There is no “shedding” effect afforded through soil arching. Consequently, traditional design approaches for creep, developed specifically for geonet geocomposites, cannot be applied to Drain Tube drainage geocomposites.

3 CREEP OF DRAINAGE GEOSYNTHETICS

For geosynthetic materials, compression creep phenomenon includes three stages, as described in Figure 4. The first stage, or primary creep, consists in a rapid deformation of the product while the load is applied. The second stage, or secondary creep, consists of a slow deformation of the product, which is related to a molecular reorganization of material, and which can occur over extended time and displacements. The third stage, or tertiary creep, precedes a brutal failure, and can occur only if the normal load is higher than some threshold value.

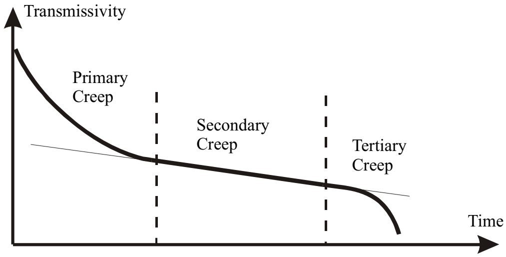

Figure 4: Creep behavior of planar drainage geosynthetics

Moreover, if creep occurs, the geometry of the product will be modified (i.e. thickness reduction for geonet geocomposites, or ovalization for pipes). This change in geometrical property will reduce either the flow surface or the hydraulic radius of the flow path, which, in both cases, will reduce the hydraulic transmissivity. As a consequence, if a change is geometry occurs, it will be detected by a change in transmissivity, which is easily measurable in the lab.

Based on this background, and assuming that arching effect and lateral confinement were likely to have a major influence on the product's behavior, the testing program was developed with the objective of verifying the stability of the product and lack of sensitivity to creep, instead of trying to detect some creep that we assume is not likely to occur.

Inversion of these targets made this evaluation much easier, considering two hypothesis:

- If the transmissivity of the product is not sensitive to normal load, then there is no change in its geometry, then there is no primary creep, and thus secondary creep is not likely to take place.
- Confirmation that there is no secondary creep over a short duration (such as 100 hours), if combined with the above verification, is sufficient to assess the lack of sensitivity of the product to creep.

This led to the development of a very simple testing program involving measurement of transmissivities under several normal loads, starting with a value as small as 500 psf (25 kPa), up to 50 000 psf (2 500 kPa), using a standard 15 minutes seating time. Then, influence of time on hydraulic transmissivity was observed using the highest normal load (50 000 psf), considering a seating time of at least 100 hours.

4 EXPERIMENTAL PROGRAM

4.1 *Testing program*

To achieve the goals identified above, it was required to conduct the following series of tests:

1- Observation of transmissivity under normal loads of 25, 50, 250, 500, 750, 1250 and 2500 kPa, with a seating time of 15 minutes.

2- Extension of the seating time up to 100 hours under a normal load of 2500 kPa (50 000 psf).

These values were selected because they are commonly used in drainage geocomposites specifications, and because they exceed the vast majority of service conditions.

4.2 *Precision of the test conditions*

A first series of tests was presented by Saunier & al. (2009) at the Geosynthetics 2009 conference in Salt Lake City. These were conducted using a 25 mm thick layer of fine sand with a polyethylene sheet as the confining media above and below the Drain Tube. In order to replicate a typical drainage condition in landfill capping applications, a 60 mil HDPE geomembrane was installed below the Drain Tube, as shown in Figure 5.

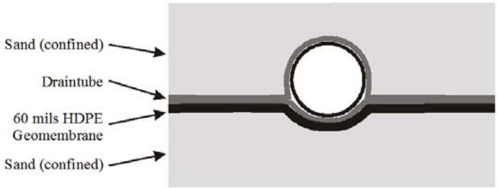

Figure 5 : Test configuration

Further analysis of the test conditions used by Saunier & al. (2009) led to the observation that the soil confinement provided by the polyethylene sheet was not appropriate because a void is likely to remain between the confined soil and the tube, at the bottom of the soil layer. This void has the following impact on the laboratory measurements:

- Under low loads, the voids remains open, which increases the measured transmissivity,
- Under high loads, the lateral confinement which should be offered by the soil is not fully mobilized. Moreover, there is some room remaining for the pipe to deform, which leads to the appearance of creep and does not adequately reflect the actual, on-site product behavior.

As a consequence, it was decided to conduct the test using sand in direct contact with the product, on the upper side. The quantity of water passing through the sand in the conditions of the test was found to represent a very small percentage of the measured flow rate, when calculated using Hazen formula to determine the sand's permeability.

However, the plastic confinement was left in the layer of soil installed under the geomembrane. It should be mentioned that the lower layer of soil was found to be necessary to allow soil confinement to take place.

On the other hand, testing the product using a thin layer of sand, i.e. less than three times the tube's diameter on the upper side, and one times the tube's diameter under the geomembrane, was also found to be misleading and prevented soil confinement from taking place. Thus, in this series of tests, it was decided to use a thick layer of sand (75 mm minimum), with the soil in direct contact with the product. Confinement of the soil on the upstream and downstream faces was made by wrapping the upper geotextile of the Drain Tube upward, leaving it under tension for a length approximately the tube's height.

The corresponding results are presented on Tables 1 and 2 as well as on Figures 6 and 7.

Table 1: Influence of normal load on transmissivity

normal load (psf)	seating time (min)	i	Trans. (m²/s)	i	Trans. (m²/s)
500	15	0.1	4.9E-03	1	1.5E-03
5,000	15	0.1	4.7E-03	1	1.4E-03
10,000	15	0.1	4.5E-03	1	1.4E-03
25,000	15	0.1	4.5E-03	1	1.4E-03
50,000	15	0.1	4.5E-03	1	1.4E-03

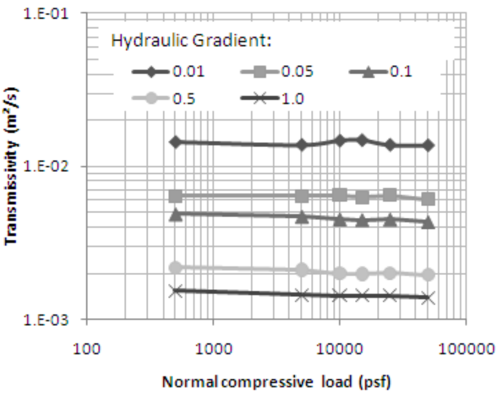

Figure 6: Effect of normal load on the transmissivity of the Drain Tube geocomposite

Table 2: Influence of time on transmissivity at 50,000 psf

normal load (psf)	seating time (hrs)	i	Trans. (m²/s)	i	Trans. (m²/s)
50,000	0.25	0.1	4.5E-03	1	1.4E-03
50,000	1	0.1	4.3E-03	1	1.4E-03
50,000	24	0.1	4.2E-03	1	1.3E-03
50,000	100	0.1	4.2E-03	1	1.3E-03

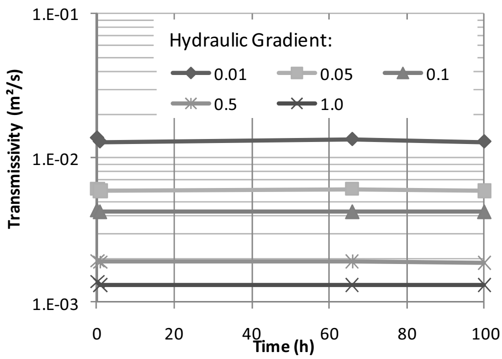

Figure 7: Effect of time on the transmissivity of the Drain Tube geocomposite

Figures 6 and 7 show that:

- Normal load has no significant effect on the short term transmissivity of the Drain Tube up to 50,000 psf.
- Time does not significantly affect transmissivity under a normal load of 50,000 psf for up to 100 hours.

5 DISCUSSION

The results presented above confirm that when properly confined in sand, normal load does not have any significant effect on the transmissivity of Drain Tubes planar drainage geocomposites up 50,000 psf. Unlike geonet drainage geocomposites, which can experience significant creep deformation during the first 100 hours, particularly with higher loads, Drain Tube did not experience any change in transmissivity over that time.

Based on these observations and the analysis of the phenomenon presented in section 3, it can be concluded that:

- Lateral confinement of the pipe by the soil is likely to take place in Drain Tube drainage geocomposite, as well as the arching effect.
- The stability of the structure is believed to be a good indicator of the lack of sensitivity of the product to creep, when it is properly confined in sand.

6 CONCLUSION

The impact of these observations on the design of drainage layers with drain Tube is, assuming that the surrounding soil can provide a suitable confinement, as follows:

- The transmissivity of Drain Tube is primarily gradient sensitive, rather than load or time sensitive, up to loads of at least 50,000 psf.
- As a consequence, a creep reduction factor of 1.0 can be reasonably considered for Drain Tube drainage design, up to 50,000 psf loading.

7 REFERENCES

ASTM book of standards Vol. 04.13

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