Behavior of “Draintube” Drainage Geocomposites under High Compression Load

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ABSTRACT
In the late 90’s, a new type of drainage geocomposite was developed. This product differs from traditional geocomposites as the drainage core is comprised of multiple corrugated and perforated pipes instead of a planar drainage media. As a result, index and performance properties for this type of structure differ from those commonly used for planar drainage geocomposites.

In this paper, “Draintube” drainage geocomposite is presented along with its key properties and the drainage mechanism associated with its particular structure. The major factors affecting its engineering properties are also presented. These will show that when adequately confined in soil, the particular structure of this product allows it to sustain extremely large 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 conventional drainage geocomposites.

Based on these observations, creep reduction factors to be used in the design of drainage structures involving a ‘Draintube’ drainage geocomposite confined in soil are suggested. The suggested creep reduction factors for “Draintube” are then compared to those commonly used for conventional 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.

Creep intensity is a function of the ratio between service load and short term strength. The higher this ratio, the greater the magnitude of creep is. For ratios approaching 1, creep can lead to the complete collapse of the product. For that reason, transmissivity measurements are typically conducted under compressive loads that are multiplied by a safety factor to take into account a creep ratio. Furthermore, an additional creep reduction factor is applied to the measured transmissivity.

This approach is used for products which are susceptible to creep, such as geonet geocomposites. In the case of ‘Draintube’ drainage geocomposites, the structure of the product makes it difficult to observe this creep phenomenon as it is not possible to measure compressive strength in the same way as a geonet geocomposite or other planar drainage media, i.e. per ASTM D6364. It is thus impossible to define threshold values for creep and long term transmissivity of “Draintube” type products.

This paper intends to define the long term behavior of “Draintube” with respect to creep. To do so, after briefly introducing the key engineering properties of the product, the selected approach proceeds as:
- measure the influence of normal loads on the hydraulic properties of the product;
- determine whether creep can be observed after 100 hours.

It is assumed that if the normal load has only a slight influence on the hydraulic properties and thus the geometric properties of the pipe, then it is not sensitive to creep. Knowing that primary creep occurs during the first minutes or hours of loading, this hypothesis can then be confirmed through observation of the creep behavior for short term duration. It is during this period that the most significant deformations occur (Figure 1).

Based on these results, a threshold value is determined. This becomes the normal load used in the creep test. This threshold value is the actual service load to which “Draintube” can be exposed before creep becomes a consideration as a potential degradation mechanism.
2 DESCRIPTION OF THE PRODUCT

“Draintube” geocomposite, described in Figure 2, is composed of two layers of non-woven geotextile in a matrix. One acts as a capillary medium, the second as a filter. The two layers are needle-punched to each other. Corrugated polypropylene pipes are then inserted between the capillary layer and filter at regular intervals. These pipes, which provide most of the drainage capability of the product, are perforated in a regular pattern, with two perforations per valley at 180 degree spacing and rotated 90 degrees per valley.

3 FACTORS INFLUENCING THE ENGINEERING PROPERTIES OF THE PRODUCT

3.1 Transmissivity

Unlike other types of geocomposites or granular drainage layers (i.e. sand), water flow from the surrounding environment to “Draintube” is not planar. Drainage design utilizing “Draintube” requires selection of the appropriate spacing for the multiple collector pipes within the granular drainage layer that is typically associated with it.
Given that the calculation of distance and related flow capacity required for these collector pipes is precise, software was developed to help design engineers adapt their design to the particular properties of this product. A full description of this software was previously given by Arab & al (2004).

To identify the specific product properties necessary for an application (e.g. pipe diameter and spacing), the software essentially considers the overall transmissivity of "Draintube", as measured per ASTM D4716 in a confined soil environment. This is further described in this paper. After this property is determined on a 250 mm wide specimen with a given pipe diameter, the equivalent transmissivity of the entire drainage layer can be determined by calculation given the geometric properties of the product: with one pipe per meter, the actual transmissivity is defined as the measured transmissivity divided by 4, with two pipes per meter, divide by 2 and with four pipes per meter the measured value shall be used as-is.

Another important feature of designing with "Draintube" is determining the appropriate performance criteria necessary to either maintain the drainage pipe in an unsaturated condition or to control the maximum water head in the drainage layer. The definition of transmissivity is thus not a simple laboratory measurement per ASTM D4716, but part of an entire design process that the software facilitates.

It should be noted that because of its particular structure, the product is not influenced by temperature (i.e. thermal expansion facilitating the development of wrinkles) and thus that the overall transmissivity is not likely to be influenced by construction concerns. If appropriate precautions are taken during backfilling operations, the confinement offered by the surrounding soil and the particular shape of the product will ensure preservation of the hydraulic properties after installation without consideration of many of the reduction factors which must be used for traditional drainage geocomposites, e.g. geotextile intrusion.

3.2 Filtration Properties - Filtration Opening Size and Permittivity

As with traditional drainage geocomposites, water enters the drainage core through a filter media. This filter media is selected based on specific filtration engineering properties as with any other filter. These properties typically include permeability and filtration opening size.

Another important feature of filtration design with "Draintube" is the reliability of the engineering properties. Because the filter layer is joined to the capillary medium through needle-punching, with no thermal treatment or bonding and this process is employed only in the areas away from the collection pipe, the actual filtration properties of the delivered product are fully maintained in the area around the pipe. This feature applies to any geotextile filter used since the same methods and equipment set-up are employed.

3.3 Protection of Geomembranes

The geotextile component of "Draintube" provides a minimal contribution to the hydraulic performance of the product. Thus the geotextile is typically selected based upon application requirements. "Draintube" installed between two layers of soil will typically include a light geotextile meeting the filtration requirements described above. When "Draintube" is installed over a geomembrane, a heavier geotextile meeting the engineering requirements for geomembrane protection is selected.

3.4 Interface Friction Properties

The design of drainage geocomposites typically includes consideration of the risk of component delamination under high loads, or interface friction slippage. Since the two layers of geotextile in "Draintube" are intimately bound together through needle-punching, internal delamination is unlikely. Veneer stability and other design issues involving friction characteristics are solely controlled by the interface friction properties of the non-woven geotextile.

4 BEHAVIOR UNDER HIGH LOAD

4.1 Test program

One of the fundamental differences between "Draintube" and other drainage geosynthetics is the structure of the product. This structure consists of two non-woven layers which provide very little to the global drainage capability of the product, and a perforated pipe which provides most, if not all, of its performance. As a result, investigation of the long term hydraulic efficiency of the product must be focused on the behavior of the pipe.

Unlike traditional planar geocomposites, the load transfer mechanism between the overlying and underlying material is only a fraction of the normal load. The pipe component of "Draintube" is confined by the surrounding soil, thus loads are calculated
using traditional flexible pipe design methodologies (Figure 3). The soil arching effect that applies to other flexible pipes applies to "Draintube" as well (Figure 4).

![Figure 3: pipe loading mechanism](image3)

![Figure 4: soil arching effect](image4)

This loading mechanism is completely different from that used for geocomposites with geonet cores. With those types of geocomposites, loads are applied to the entire surface of the product and are completely transferred into the geonet structure. There is no "shedding" effect afforded through soil arching. Consequently, traditional design approaches for creep, developed specifically for geonet geocomposites, are not relevant.

In order to observe the behavior of "Draintube" drainage geocomposites exposed to high normal loads and to estimate their long term behavior, a research program was developed. Two major aspects were investigated:

1. The influence of normal load on transmissivity, with measurements of transmissivity under 5,000, 10,000, 15,000 and 25,000 psf loads.
2. The influence of time on transmissivity, with measurements of transmissivity after 15 minutes, 1 hour, 24 hours and 100 hours under a 10,000 psf load. The value of 10,000 psf was selected because it is commonly used in drainage geocomposites specifications, and because it exceeds a vast majority of the service conditions met by these products.

The tests were conducted using a 25 mm thick layer of fine sand with a polyethylene sheet as the confining media above and below the "Draintube". In order to replicate a typical drainage condition in landfill capping applications, a 60 mil HDPE geomembrane was installed below "Draintube", as shown in Figure 5. The results are presented in Figures 6 and 7 and summarized in Tables 1 and 2.
Table 1: Influence of normal load on transmissivity

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<th>Transmissivity (m²/s)</th>
<th>gradient</th>
<th>Transmissivity (m²/s)</th>
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</table>

Figure 6: Effect of normal load on the transmissivity of “Draintube” geocomposite
Table 2: Influence of time on transmissivity

<table>
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<th>Transmissivity (m²/s)</th>
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</table>

ASTM D4716 (Water Transmissivity)
Draintube FT4 DT20
Sand / Draintube / 60 mils HDPE / Sand
Creep Behavior

Figure 7: Effect of time on the transmissivity of “Draintube” geocomposite

Figures 6 and 7 show that:
- Normal load had only a minimal effect on the transmissivity of “Draintube” up to 25,000 psf. Overall, the reduction in transmissivity is less than 30% for loads between 5,000 to 25,000 psf.
- Time does not significantly affect transmissivity under a normal load of 10,000 psf for 100 hours.

5 DISCUSSION

The results presented above confirm the hypothesis that normal loads have an insignificant effect on “Draintube’s” transmissivity. Transmissivity is also time independent over the first 100 hours of testing, when primary creep would be expected to occur.

With less than a 30% variation in transmissivity up to loads of 25,000 psf, the influence of normal load on the measured transmissivity was not in line with the hypothesis made at the early stages of the project, nor with the observation of time independence. However, further investigation led to the following observations:
- the presence of a geomembrane under “Draintube” creates a critical condition where there is a “slip” plane under the pipe. When combined with an open void between the pipe and the geomembrane, compression of the pipe can occur. This applies to the application of “Draintube” for capping applications where the geocomposite is installed.
above an HDPE geomembrane. However, this approach is conservative with respect to the application of “Draintube” between two layers of granular material, such as in athletic field drainage, some mining applications, etc.

The test set-up of the transmissivity apparatus does not allow thicker layers of soil to be used for two reasons. The first reason is that there is not sufficient space vertically. The second reason is that as the thickness of the soil layer is increased, friction between the soil and the vertical walls of the apparatus influences the transfer of the normal load. As a result, the soil arching effect described in Figure 4 can not be fully realized. These equipment limitations increase sample compression during testing, resulting in reduced measured values of transmissivity, much smaller than the ones observed in the field.

As a result, the observations made during this project are believed to be conservative when compared to the expected field performance of the product. The minimal reductions in performance observed over the 100 hour test duration, combined with the increased effects of normal load caused by the particular conditions of the test (arching effect minimized due to the limitations of the apparatus) suggest that creep deformation is unlikely to occur in this particular product.

6 CONCLUSION

When confined in soil under a normal load of 10,000 psf, the transmissivity of “Draintube” was not affected by creep over a testing period of 100 hours. Therefore, when designing for the long term transmissivity of a “Draintube” drainage geocomposite, a Factor of Safety for creep ($F_{Scr}$) of 1.0 can be used for normal loads up to 10,000 psf.

Additional research is needed to confirm the products behavior for normal over 10,000 psf. This should include evaluation of the product in such a way that the soil arching effect that is likely to take place in normal field conditions can be mobilized in the laboratory. This will involve slight improvements or changes to existing testing techniques.

REFERENCES

