LONG-TERM PERFORMANCE CONSIDERATIONS FOR GEONET DRAINAGE GEOCOMPOSITES

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ABSTRACT
Drainage geocomposites have gained increasing acceptance within the engineering community as the material of choice for the lateral conveyance of liquids and gases. The hydraulic performance of these materials is typically expressed as transmissivity or flow rate at site-specific gradient, normal stress and boundary conditions. However, since these materials are visco-elastic in nature, compressive creep can significantly affect their long-term hydraulic performance. In addition to creep, there is the potential for the chemical and biological clogging of the filter geotextile and the geonet drainage core. Over the last several years, significant progress has been made in characterizing the engineering properties of geonet drainage geocomposites and developing models to predict their long-term behaviour on the basis of short-term laboratory tests. Additional work is needed in the area of chemical and biological clogging to further supplement the current information. In addition, the impact of leachate recirculation and higher temperatures in bioreactor landfills on the long-term performance of geocomposites merits further study.

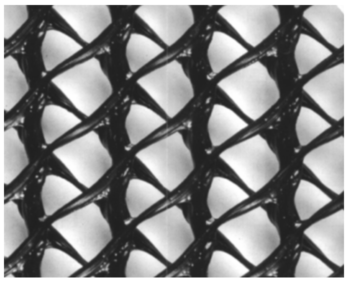
RÉSUMÉ
Drainage geocomposites have gained increasing acceptance within the engineering community as the material of choice for the lateral conveyance of liquids and gases. The hydraulic performance of these materials is typically expressed as transmissivity or flow rate at site-specific gradient, normal stress and boundary conditions. However, since these materials are visco-elastic in nature, compressive creep can significantly affect their long-term hydraulic performance. In addition to creep, there is the potential for the chemical and biological clogging of the filter geotextile and the geonet drainage core. Over the last several years, significant progress has been made in characterizing the engineering properties of geonet drainage geocomposites and developing models to predict their long-term behaviour on the basis of short-term laboratory tests. Additional work is needed in the area of chemical and biological clogging to further supplement the current information. In addition, the impact of leachate recirculation and higher temperatures in bioreactor landfills on the long-term performance of geocomposites merits further study.

1. INTRODUCTION

A geonet drainage geocomposite consists of a geonet core and a geotextile, where the geotextile is heat-laminated to one or both sides of the geonet. The geonet is made of extruded High Density Polyethylene (HDPE) in a manner that forms a relatively open structure ideal for the in-plane transmission of liquids and/or gases. The geotextile serves as a filter and separator, while the geonet core is intended to provide the lateral flow capacity. Geotextiles currently used for this purpose are almost exclusively of the nonwoven needlepunched type made from polypropylene (PP) or polyester (PE) resins. Geonet drainage geocomposites are differentiated primarily by the structure of the geonet as illustrated in Figures 1 (a) and (b).

Drainage geocomposites are used predominantly in environmental applications such as landfills and lagoons. However, there is growing interest in the use of these materials in such civil engineering applications as roadways, buildings, canals, etc. Landfills – the dominant market segment for these materials – are characterized by relatively large areas with slopes ranging from as low as 2% to as high as 33%. Specifically, there are four applications in landfills where drainage geocomposites are utilized: i) landfill cover drainage layer, ii) landfill gas vent layer, iii) landfill leachate collection and removal

(a) biplanar geonet



(a) triplanar geonet

Figure 1 Plan view of biplanar and triplanar geonets.

layer, and iv) landfill leakage detection layer. The design of each of these layer may involve the following performance properties of the drainage geocomposite: i) flow rate or transmissivity (heretofore referred to as transmissivity), ii) interface shear strength, and iii) filtration properties (including “filtration opening size” and permeability). This paper deals with only one of the above three performance characteristics, namely transmissivity.

The transmissivity of drainage geocomposites is a function of available pore-space as illustrated in Figure 2. Any mechanism that tends to reduce this pore space would decrease geocomposite transmissivity. Currently known factors include the following: i) geonet creep, ii) geotextile intrusion into the core structure, iii) chemical clogging within the core, and iv) biological clogging within the core. The reader should note that the concern with biological and chemical clogging of the drainage geocomposite core is differentiated here from a similar concern for the drainage geocomposite filter geotextile. Although mechanisms involved may be similar, the testing and design must be performed separately for the filter and drainage media.

Figure 2 Cross-section of a biplanar drainage geocomposite.

2. TRANSMISSIVITY AND REDUCTION FACTORS

Transmissivity is defined as the flow rate of water transmitted through a unit width of the product under a specific hydraulic gradient as measured in a laboratory test. The transmissivity test is performed using the type of equipment shown schematically in Figure 3. For the test to provide a transmissivity value that can be used in design, the specimen top and bottom boundaries as well as the gradient should be the same as in the field. The test is typically continued for a reasonably long enough time to include the effect of initial compression, and intrusion of geotextile into the geonet structure. The current state-of-the-practice in the US is represented by GRI GC8 which requires the test to be continued for 100 hours. The resulting value is then modified to include the effect of creep, chemical clogging and biological clogging as in Equation 1 (from GRI GC8, 2001):

$$\theta_{allow} = \frac{\theta_{100}}{RF_{cr} x RF_{cc} x RF_{bc}} \qquad [1]$$

where θ_{allow} = allowable transmissivity for the specific product being considered (m^2/sec), θ_{100} = 100-hour performance transmissivity from actual test, RF_{cr} = reduction factor for creep of the geonet core, RF_{cc} = reduction factor for chemical clogging, RF_{bc} = reduction factor for biological clogging.

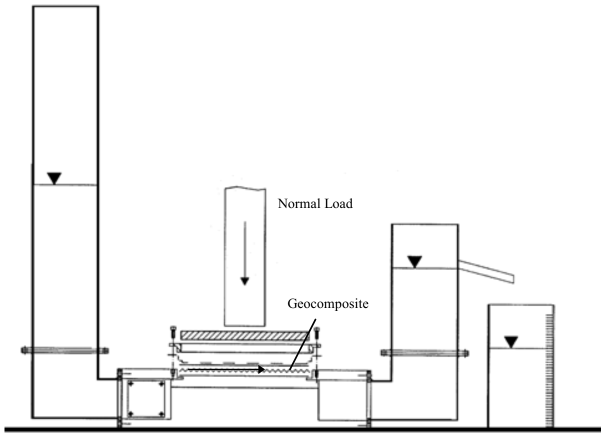


Figure 3 Schematics of the transmissivity test (Richardson et. al., 2000).

It must be noted here that certain versions of Equation 1 use such additional reduction factors as geotextile intrusion into the geonet structure and for “particulate clogging” of the geonet core. It is the author’s opinion that a reduction factor for intrusion may not be necessary as the performance transmissivity test already includes this effect. The concern regarding particulate clogging of drainage core can, and should, be addressed by proper geotextile filter design so that fines do not pass the geotextile in the first place. This should then be supplemented with proper construction quality assurance (CQA) procedures that minimize infiltration of dust into the drainage core during the installation process.

The allowable value of transmissivity from Equation 1 must then be compared with “required transmissivity” to calculate a factor of safety as provided in the equation below:

$$FS = \frac{\theta_{allow}}{\theta_{req}} \qquad [2]$$

where FS = factor of safety for drainage, and θ_{req} = required transmissivity (m^2/sec) for a specific project.

The three reduction factors in the denominator of Equation 1 along with the performance transmissivity value (θ_{100}) determine whether a particular product is acceptable for a given project. It is recognized that this decision can be only as good as the quality of the data used to arrive at the reduction factors. The state-of-the-practice, limitations of current approach and the need for future research on reduction factors is discussed in the following sections.

2.1 Reduction Factor for Creep, RF_{cr}

Reduction factor for creep is intended to account for the time-dependent compression of the geonet core component of the geocomposite. It should be based on actual testing of the geonet core component of the geocomposite. Geonets can be tested for creep according to one of the two methods currently being used in the industry: a) conventional method, and b) accelerated method. The main difference between the two procedures is the test temperature. In conventional creep method, tests are performed at ambient temperature of around 20 degrees Celsius or any other site-specific temperature. In the accelerated procedure, the testing is performed at several elevated temperatures and the resulting data is then extrapolated to the ambient temperature through time-temperature superposition. Further details of creep testing and the associated calculations can be found in Narejo & Allen (2004). The advantage of the accelerated testing over conventional methods is that the required information can be obtained within hours versus the 14 months required by the conventional tests. Moreover, accelerated testing means that different product formulations and variations can be evaluated economically and within a reasonable time, and more data can be generated for statistical analysis.

Irrespective of whether accelerated or conventional creep testing is performed, the resulting information is of the form presented in Figure 4. For the product and test conditions represented by Figure 4, creep rate is constant at any given normal stress. However, the creep rate increases with an increase in normal stress. Since the creep rate is linear on a semi-log scale, the curves can be extended to obtain thickness at the design life of a project, say 50 years. This value of thickness can then be used to calculate the creep reduction factor, RF_{cr} (Narejo & Allen, 2004) for site-specific stress. Depending on the quality of the product, this creep reduction factor is typically around 1.1 to 1.2 for low stress (<50 kPa) but can be close to 2 for pressures higher than 700 kPa (Narejo & Allen, 2004).

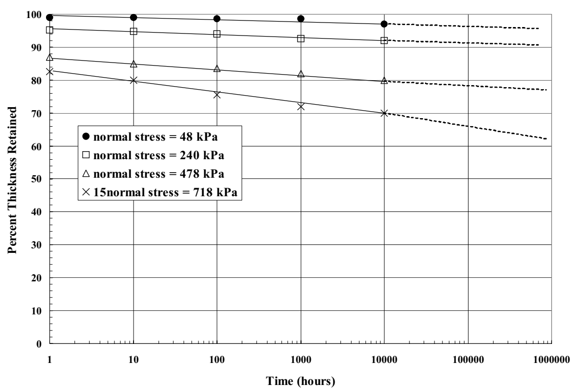


Figure 4 Typical creep response of biplanar geonets.

The creep of geonets is influenced significantly by the physical properties and structure of the geonet, including rib structure, mass, thickness, etc. As such, creep data for geonets is typically specific to products and its generalization is currently not possible.

2.2 Reduction Factor for Chemical Clogging, RF_{cc}

Chemical clogging of drainage materials in landfills results from chemical processes such as the precipitation of calcium carbonate, manganese carbonate and other insoluble substances (e.g., sulfides, chlorides and silicates). A reduction factor for chemical clogging, RF_{cr}, is intended to account for the influence of chemical clogging on the transmissivity of drainage geocomposites. Current industry practice, at least within the US, is to use reduction factors for chemical clogging proposed in the textbook *Designing with Geosynthetics* (Koerner, 1998) and GRI procedure GC8. The values are reproduced in Table 1.

Table 1 Chemical clogging reduction factors (*from* Koerner 1998 and GRI GC8).

Application	**Reduction Factor for Chemical Clogging (RF_{cc})**
Landfill covers	1.0 to 1.2
Primary leachate collection	1.5 to 2.0
Secondary leachate collection	1.1 to 1.5

2.3 Reduction Factor for Biological Clogging, RF_{bc}

Biological clogging refers to the growth of micro-organisms on and within the drainage media. Biological growth depends on the presence of a suitable bio-chemical environment and nutrients which sustain growth. The biomass growth within the drainage media would reduce the opening size and, hence transmissivity. A reduction factor for biological clogging, RF_{bc}, is used to account for the influence of the biological clogging on geocomposite transmissivity. Currently, the only sources of reference on biological clogging of drainage geocomposites are the geosynthetics textbook – *Designing with Geosynthetics* – and GRI GC8. Suggested reduction factors for biological clogging from these two sources are cited in Table 2.

Table 2 Biological clogging reduction factors (*from* Koerner, 1998, and GRI GC8).

Application	**Reduction Factor for Biological Clogging (RF_{bc})**
Landfill covers	1.2 to 3.5
Primary leachate collection	1.1 to 1.3
Secondary leachate collection	1.1 to 1.3

3. CRITIQUE OF REDUCTION FACTORS AND RECOMMENDATIONS FOR FURTHER RESEARCH

Reduction factor for creep can be tested in the laboratory with a reasonable degree of confidence as the site conditions can be conveniently modelled. The main variable in creep testing is normal stress, which is determined from the layout and the final contours of the site. As such geosynthetic manufacturers have been testing geonets for creep and a reasonable amount of data already exists. Unfortunately, creep results for geonets are product-specific and each commercially available geonet must be evaluated separately. The SIM Method offers a technique which can help generate a significant amount of data at a reasonable cost. However, manufacturers must demonstrate the validity of this method by performing comparable tests with the conventional technique.

Chemical and biological clogging is very difficult to model in the laboratory. The main reason for this is that the bio-chemical environment for each site may be different. Hence it is difficult to develop a test program the results of which can then be applied uniformly to the design process. It is for this reason that most of the published literature on this topic is of qualitative nature as far as its utilization during the design process is concerned. There is a need for more extensive testing that examines the basic process of clogging in what may be idealized or extreme conditions. This information may then be used to make an "educated guess" about a particular site based on anticipated waste stream and hydrologic conditions.

4. ELEVATED TEMPERATURES AND LEACHATE RECIRCULATION

Bioreactor landfills involve leachate recirculation to accelerate decomposition of the waste mass. Leachate recirculation poses two important challenges to the use of drainage geocomposites: i) elevated temperatures, and ii) higher flow requirements. Elevated temperatures would tend to increase reduction factors for creep, thus lowering the allowable transmissivity. However, the required transmissivity itself may need to be increased beyond that for conventional projects to account for a higher flow of liquid through the drainage layer. Not much is known at this time about the response of drainage geocomposites to leachate circulation. Much research needs to be done in this area to develop recommendations for the design purpose.

5. SUMMARY AND RECOMMENDATIONS

The long-term hydraulic performance of drainage geonets and geocomposites depends on many material as well as site characteristics. A performance transmissivity test provides a 100-hour transmissivity or flow-rate value which can then be further modified to account for site-specific and time-dependent factors. In this regard, there are three specific reductions factors of creep, chemical clogging and biological clogging. Geosynthetic manufacturers have been performing creep tests on their products to develop information on creep reduction factors. However, very limited information is available on biological clogging and chemical clogging of drainage materials. Manufacturers and academics should collaborate to develop further information in this regard. It must be recognized that a model that represents "general" application conditions is very difficult to develop. On the other hand, the tendency to use extremely aggressive conditions in the models provides little practical information for designer. Instead, it may be useful to perform idealized set of testing which can then be analyzed to develop general recommendations for the purpose of design.

6. REFERENCES

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