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Drainage geocomposite workshop

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A number of recent designer's columns have focused on the design of drainage geocomposites (Richardson and Zhao, 1998), so only areas of concern are discussed here. Two design considerations requiring the most consideration by a designer are: 1) assumed rate of fluid inflow draining into the geocomposite, and 2) long-term reduction and safety factors required to assure adequate performance over the service life of the drainage system.

In regions of the United States that are not arid or semi-arid, a reasonable upper limit for inflow into a drainage layer can be estimated by assuming that the soil immediately above the drain layer is saturated. This saturation produces a unit gradient flow in the overlying soil such that the inflow rate, r, is approximately equal to the permeability of the soil, k_{soil}. The required transmissivity, θ, of the drainage layer is then equal to:

$$\theta = r^*L/i = k_{soil}{}^*L/i$$

where L is the effective drainage length of the geocomposite and i is the flow gradient (head change/flow length). This represents an upper limit for flow into the geocomposite. In arid and semi-arid regions of the USA saturation of the soil layers may be an overly conservative assumption, however, no alternative recommendations can currently be given.

Regardless of the assumed r value, a geocomposite drainage layer must be designed such that flow is not inadvertently restricted prior to removal from the drain. **Figure 1** shows a final cover side slope design that allows the pore water pressure drain to daylight just above a side slope swale. This reduces the effective length, L, of the drain and therefore the required transmissivity. However, the flow capacity of a geocomposite drain is equal to the transmissivity times the flow gradient. Examining **Figure 1**, this means that the flow capacity of the near horizontal portion of the drain ($i \approx 0.02$) is less than 1/8 of the drain that flows into it ($i > 0.16$). Obviously this creates a potential for backup of liquid in the drain and possible blow out of the drain. This potential can be eliminated by either increasing the transmissivity of the flat portion of the drain or by the use of outlet pipes to supplement or eliminate the near horizontal drainage geocomposite.

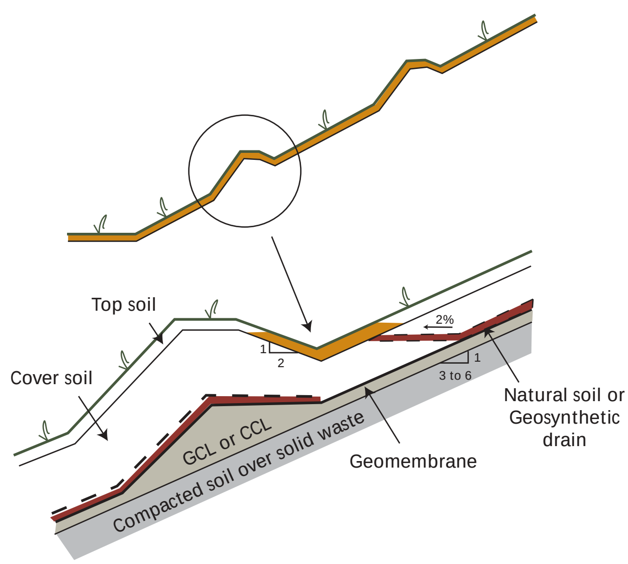

***Figure 1**. Final cover side slope drain.*

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Geocomposite drain testing

A designer must consider the hydraulic capacity of the drain, e.g., transmissivity, the interface friction provided at the surfaces of the geocomposite, and the internal shear strength of the geocomposite. Transmissivity of the geocomposite is measured using the ASTM D-4716 test. This test allows for varying flow gradients, varying normal loads, and varying boundary conditions on the surfaces of the geocomposite. This flexibility in testing allows a design engineer to simulate field conditions but also creates a nightmare for testing laboratories and manufacturers. Considerable discussion at the seminar focused on aspects of testing that are not generally known to designers but do impact the service properties of geocomposite drains.

Impact of creep

The thickness and flow capacity of geonets continues to decrease with time under a constant load application. The rate of decrease is influenced by the polymer of the geonet (particularly the density), the structure of the geonet, the duration of the loading, and the boundary conditions. A method of accelerating the evaluation of this compression creep using elevated temperature testing is currently being refined to allow the laboratory load duration to fully simulate actual service life. This approach is called time-temperature superposition via the Stepped Isothermal Method (SIM). **Figure 2** shows projected creep compression curves for a number of available geonets. Note that one of the geonets has a very nonlinear compression curve that would make it impossible (and nonconservative) to predict long-term service conditions based on short term tests. The verification of SIM accelerated creep testing should therefore be a high priority of the industry. The Geosynthetic Institute (GSI) has drafted a standard for tensile creep testing via SIM that can be used as a guide for compression creep testing.

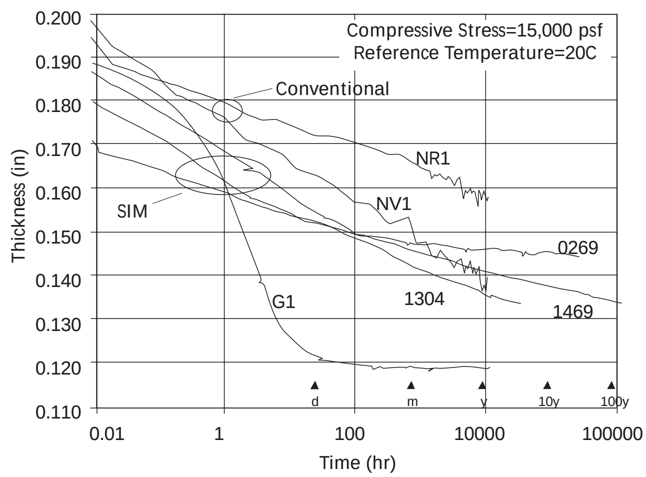

***Figure 2**. SIM Testing of geonet thickness.*

Impact of density

A majority of specifications current require the density of the polyethylene to be greater than 0.94. In reality, geonets are made with density ranging from 0.935 to 0.965 g/cm^3. The higher densities are less expensive and more rigid, but have a greater potential for long-term stress cracking. The opposite is true for geonets having lower density. Thus, all performance tests of geonets, particularly transmissivity and direct shear, should report the specific gravity of the net tested. This should be confirmed in construction quality assurance testing of geonet placed in the field. The designer should also be aware that the potential for stress crack failure of the geonet increases with increasing density.

Impact of regrind versus virgin polymer

Geonets were historically produced using regrind of defective sheet products and factory trimmings. Over the past decade, the growth of the market has meant that an increasing percentage of geonets are produced using virgin polymer. Many project specifications now routinely require the use of virgin polymers in geonets. Examination of long-term transmissivity test data does indicate a difference in performance between identical geonets made with virgin versus regrind polymers. The test data does not indicate that virgin polymers provide better performance, only different performance. Thus it may be more important for the designer to allow both but clearly require that the type of polymer used in the field is consistent with that used in the laboratory. This can be easily accomplished by tightening the density specifications or requiring reporting of fingerprint parameters such as carbon black content and dispersion, and oxygen induction temperature (OIT).

Peel versus direct shear strength

The use of polypropylene geotextiles and polyethylene geonets to form drainage geocomposites results in a very difficult bond for manufacturers. The similarity in melt temperatures of the two polyolefins provides a very narrow temperature window that the process must maintain. If the melt temperature is too high, the geotextile can melt through. If the melt temperature is too low, then the bond will be weak. The upper limit of the peel strength of polyprolylene geo-textiles and polyethylene geonets is 2.5 pounds per in. (ppi). This is very low compared with the 9-13 ppi that is achieved when bonding polyester geotextiles and polyethlyene geonets. Unfortunately polyester geotextiles are not available in quantity today. The actual shear stress that can be carried at the geotextile/geonet interface will also be influenced by the degree of soil intrusion into the grid. Thus conservative design would be to perform a short term direct shear test of the interface with parallel testing and reporting of the peel strength of the test geocomposite.

Hydraulic gradient considerations

Given that typical landfill liner bases are commonly constructed on 2% minimum slopes, it is not unusual for designers to request the transmissivity test be performed at a gradient, i, of 0.02. This means the head difference over the 12-in. sample length is only 0.36 in. Examination of historical transmissivity test data clearly shows that the standard deviation, or scatter, in measured transmissivities dramatically increases as the gradient decreases. This scatter can be reduced by the use of precise electrical transducers to measure the change in pressure across the sample. Additionally, the designer should remember that it is conservative to use a transmissivity value measure at a gradient larger than field conditions. Thus transmissivity values obtained with a gradient of 0.1 will have less scatter than those obtained at i=0.02 and will be conservative if used in the design of 2% slopes. Hence, ASTM D4716 testing below i = 0.1 is not recommended.

Transmissivity reduction factors

It was observed that appropriate long-term service reduction factors are product-specific and, following the precedent of the soil reinforcement industry, can be determined using a limited test “program.” This follows the method proposed by GSI (Koerner, 1998) as follows:

$$FS = \frac{\theta_{allow}}{\theta_{req'd}}$$

$$\theta_{allow} = \frac{\theta_{ultimate}}{RF_{in} \cdot RF_{cr} \cdot RF_{cc} \cdot RF_{bc}}$$

where FS is the overall safety factor for drainage, θ_{allow} is the allowable transmissivity of the drainage geocomposite, $\theta_{req'd}$ is the required transmissivity (e.g., for MTG= $3*10^{-5}$ m^3/sec-m), $\theta_{ultimate}$ is the transmissivity measured in accordance with ASTM D4716 between two steel plates, and RF are service reduction factors described as follows:

RF_{in}= reduction factor for elastic deformation, or intrusion of the adjacent geotextile/soil into the drainage channel.

RF_{cr}= reduction factor for creep deformation of the drainage core and/or adjacent geotextile/soil into the drainage channel.

RF_{cc}= reduction factor for chemical clogging and/or precipitation of chemicals in the drainage core space.

RF_{bc}= reduction factor for biological clogging in the drainage core space.

RF_{cr} can be evaluated using the accelerated creep strain tests and RF_{in} may soon be evaluated using three "typical" soils to standardize comparisons and minimize site specific testing. Clogging related reduction factors remain very fluid dependent and must currently rely on the designer's judgement. Additional reduction factors for things such as root penetration of drains used in final covers are also currently being evaluated.

Summary of "things to do"

By the end of the seminar there was a general consensus that the use of geocomposite drainage products would be greatly enhanced if we could accomplish the following:

• Develop a set of standard boundary soils so that long-term test data useful to the designer could be developed by manufacturers. This would lead to a reduced emphasis on testing using on-site soils.

• Develop a quick index compression test to provide load versus thickness data for use in acceptance testing of drainage geocomposites.

• Confirm the applicability of SIM accelerated creep testing so that the long-term performance of drainage geocomposites on critical applications can be confirmed.

Individually these can be used to determine the change in thickness over time and the flow that corresponds to a given thickness. Together these can be used to accurately predict the long-term transmissivity.

All participants at the seminar agreed that drainage geocomposites currently play a critical role in all waste containment systems. Given their short history, this critical role speaks well of the value of such products.

It was also clear that the industry would benefit greatly from regularly scheduled exchanges between designers, manufacturers and regulators regarding all aspects of geosynthetics used in landfill systems. The authors would like to thank George Koerner of GSI and Aigen Zhao of Tenax for their review of this paper.

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