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Geocomposite drainage layers in landfills, part 1 of 4: Introduction

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A significant amount of literature and technical data has been published related to designing with geocomposite drainage layers in landfills. The *GFR* Designer's Forum series has performed a notable effort to summarize the technical design issues and approaches that are available in the literature. Significant *GFR* articles include:

- "Composite drains for side slopes in landfill final covers, June/July 1998, by Richardson and Zhao
- "Lateral drainage systems over landfill barrier systems: Flat slopes," August 1998, by Zhao and Richardson
- "The design of geonets in landfill leak-detection systems," September 1998, by Zhao and Richardson
- "Drainage Geocomposite Workshop," January/February 2000, by Richardson et al.
- "Lateral drainage design update–Part 1, January/February 2002, by Richardson et al.
- "Lateral drainage design update–Part 2," March 2002, by Richardson et al.
- "Geocomposite drains: what the eye can't see beyond lamination," January/February 2003, by Richardson and Boschuk
- "Designing with GRI Standard GC8," August 2003, by Narejo and Richardson
- "Geocomposite drains in paper-pulp landfill covers," June/July 2004, by Richardson et al.

This article, and its three, forthcoming companion articles, are intended to be a continuance of the spirit of the previous articles in summarizing the state of the practice in designing with geocomposites in landfills. The subjects of this present mini-series are as follows:

- Summarize design applications and critical design issues for each application using geocomposites in landfills (Part 1).
- Present a critical extension of the use of geocomposites below landfill covers where they will serve not only to collect landfill gas, but to control seeps, especially on bioreactor landfills (Part 2).
- Provide additional data and an expanded design approach for addressing long term creep and hydraulic requirements, taking into account staged landfill development, when using geocomposites in leachate collection systems at the base of landfills (Part 3).
- Summarize a rational design and construction quality assurance (CQA) approach for specifying and monitoring peel strength between the geocomposite drainage cores and the outer heat-bonded geotextiles (Part 4).

Photo 1. Slumps and erosion rill on a 2H:1V slope of a paper mill sludge landfill. From Richardson et al. (2004).

Summary of design applications

The range of design applications for geocomposites in landfills has been discussed well in the aforementioned articles. **Table 1** provides a summary of applications along with the critical functions they perform and important parameters needed for design. New additions to the list of applications are collecting seeps below landfill covers and re-introducing leachate into landfills.

The use of geocomposites to collect seeps below the geomembrane in a landfill final cover has been found to be very significant for landfills where liquids (namely leachate) are reintroduced. The subject ties in nicely with the concept of providing a gas pressure relief layer below the final cover. This topic will be discussed more completely in Part 2 of this series.

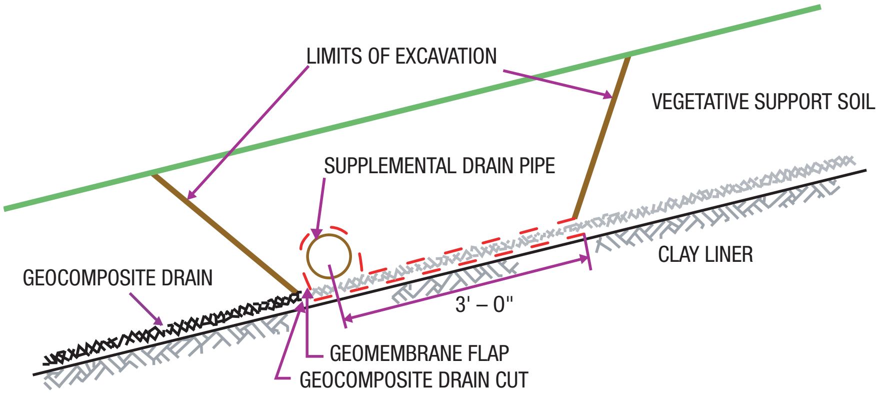

Figure 1. Supplemental drainage intercepts. A geomembrane flap is required to force the water draining in the geocomposite into the pipe. From Richardson and Boschuk (2003).

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Landfill application for geocomposites	Critical functions performed by geocomposite	Important design parameters for the geocomposite[1]	Relevant *GFR* Designer's Forum article
Cover system drainage layer	• Preserve veneer stability • Reduce surface erosion potential	• Long-term in-soil (LTIS) transmissivity • Long-term reduction factors, esp. for biological clogging • Soil filtration • Internal and interface shear strength	Richardson and Zhao (1998); Richardson et al. (2002a, b); Richardson and Boschuk (2003); Part 4 of this series
Gas removal and seep collection below covers	• Preserve veneer stability • Enhance environmental containment by controlling random seeps	• LTIS transmissivity • Internal and interface shear strength • Long term reduction factors	Richardson and Zhao (1998); Part 2 of this series
Primary leachate collection and removal	• Maintain low hydraulic head on primary liner system by providing efficient leachate collection and removal system	• Transmissivity (diff. requirements for diff. life stages) • Long-term reduction factors especially for biological and chemical clogging, and creep • Soil filtration • Internal and interface shear strength	Zhao and Richardson (1998a); Richardson et al. (2002a & b); Part 3 of this series
Secondary leachate collection and removal	• Relatively quick and efficient conveyance of fluids that leak past the primary liner to the sump	• LTIS transmissivity • Long-term reduction factors, esp. for biological clogging • Soil filtration • Internal and interface shear strength	Zhao and Richardson (1998b); Richardson et al. (2002a & b)
Leachate recirculation	• Distribution of recirculated fluids into the waste mass	• In-soil transmissivity • Long-term reduction factors, esp. for biological clogging • Soil filtration	This article
Landfill internal drainage function	• Preserve slope stability by providing drainage sink for pore water fluids	• In-soil transmissivity • Long-term reduction factors, esp. for biological and chemical clogging • Soil filtration • Internal and interface shear strength (maybe not critical)	Richardson et al. (2004)

Table 1. Summary of design applications and important design parameters for geocomposites in landfills.

[1] The list of important design parameters is intended to highlight those parameters that are typical of most design situations, but may not be complete for all design situations.

The use of geocomposites to assist with the recirculation of fluids in a landfill has not been previously discussed, nor is it planned to be discussed in this mini series other than this brief mention. The authors are aware that it is the subject of some research and an introductory paper on this topic will be presented at Geo-Frontiers 2005 in January, Austin. (See pages 49– for Geo-Frontiers information. Copies of the proceedings may be ordered directly from the American Society of Civil Engineers, www.asce.org.)

An interesting point regarding **Table 1** is the outward similarity of the important design parameters, even though the critical function being served is unique for each application. It is notable that long-term in-soil (LTIS) transmissivity and the selection of appropriate long-term reduction factors are critical to the design of almost every application. Internal and interface shear strength is also a consistently important design parameter. For the transmissivity and shear strength design parameters, as well as the long-term creep reduction factor, it is critical to evaluate the design properties at the appropriate effective stresses that are expected to occur in a project-specific design.

Needs for further research and refinement

The January/February 2000 *GFR* Designer's Forum (Richardson et al.) listed outstanding issues that still need more definition related to designing with geocomposites. At the time, the following issues were identified:

- Develop a set of standard boundary soils for developing long term test data.
- Develop a quick index compression test related to load vs. thickness for acceptance testing of geocomposites.
- Confirm the applicability of the stepped isothermal method (SIM) testing for estimating long-term creep potential of geocomposites under load.

The aim of carrying out research on these issues was to help provide an accurate predictions of long-term transmissivity. Work on these issues since the publication of that article includes a proposed formula for a creep reduction factor based on a 10,000-hour compressive creep data as

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described by Giroud et al. (2000), and additional work regarding SIM testing, some of which will be presented in Part 3 of this series.

Currently, the area that could probably benefit the most from additional research would be the appropriate values to use for the reduction factors (RFs) and the overall factor of safety (FS). The most complete discussion of this issue to date is Richardson et al. (2002b). It is noted that the selection of appropriate long-term reduction factors is still somewhat arbitrary; thus, subject to debate. For example, Richardson et al. suggest that 1.5 be the upper limit of the reduction factor for biological clogging of drainage layers of landfill caps, while GRI-GC8 recommends an upper limit of 3.5. This alone is more than a factor of 2.

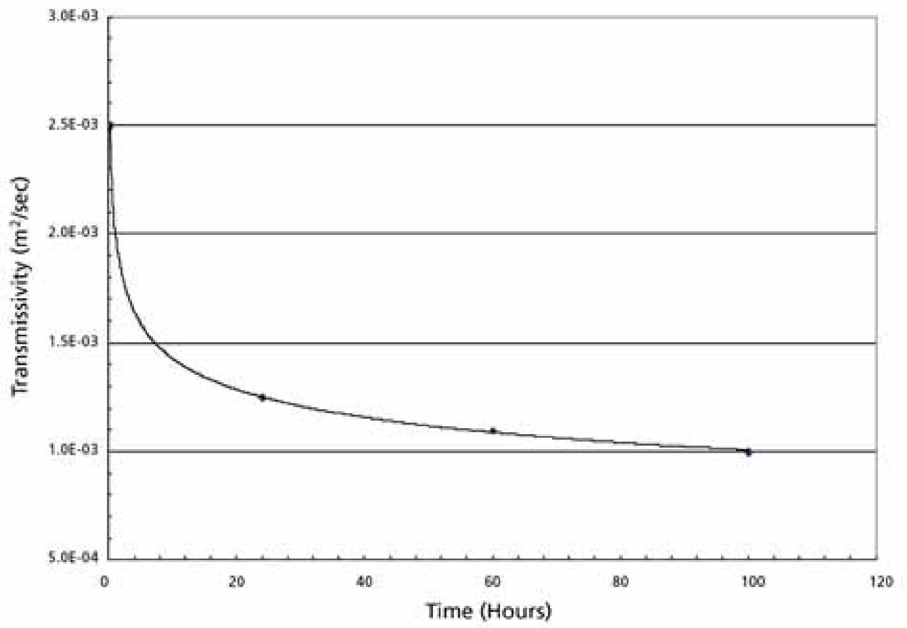

Figure 2. Typical transmissivity behavior of synthetic drainage products with time. From Narejo and Richardson (2003).

The subject of the overall factor of safety is perhaps even more open to discussion. Koerner (2002) states that design parameters associated with flow rates and permeability have the highest statistical variation of all design categories, with even greater variation than estimates of the reduction factors. Out of 49 design examples covering a range of design goals, those dealing with filtration and drainage had the highest average factor of safety. Furthermore, even with those relatively high factors of safety, the filtration/drainage design examples still had the greatest probability of failure (averaging about 1 in 20) compared to other types of design issues. The accepted norm in the industry is currently to use a global factor of safety of 2–3 when designing with geocomposites. As stated by Cedergren (1977): "Most experienced seepage, and drainage engineers regard seepage theory as a means of predicting the general order of magnitude of problems." In this regard, each design situation requires careful attention to all its elements when selecting an appropriate global factor of safety. These considerations must start with the estimate of flow coming into the system, the various reduction factors, redundancy and the consequences of catastrophic failure.

It is important to realize that RF values are actual reductions that represent true field conditions, and that they contain no FS value. A designer still needs to decide on an FS where

FS = (test value/RFs) / (required design value)

A value of FS = 2 for transmissivity may not be adequate for leachate systems in recirculation landfills, or for final covers where root penetration may pose a problem. (This is related to vegetative potential—high rain, long growth season, etc.) For years the industry has used FS = 2 for a no-recirculation leachate collection and removal system (LCRS). This is because LCRSs dry with time; they appear to be working well today. Also, FS = 2 has been used commonly for the final cover designed with the unit-gradient method since the system is accessible for repair, and because the unit-gradient method seems to be conservative. It may be appropriate on final covers to increase the FS above 2 for steeper and longer slopes. A probabilistic approach may be useful here, since cover system stability is very sensitive to small changes in normal forces and pore pressures. Changes in properties on a flat top don't significantly influence the FS; where as, only minor changes on a 4H:1V or 3H:1V slope can be dramatic.

The remaining articles in the current design series are intended to expand the range of applications for which geocomposites can be designed in landfills (Part 2); provide more design guidance regarding the timing of estimated flows into the geocomposite versus its loading history in the bottom of a landfill (Part 3); and provide the latest insight into the requirements for internal shear strength of geocomposites in terms of the peel test (Part 4).

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