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Laboratory Analysis of Geocomposites for Use in Drainage Systems in CCP Landfills

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ABSTRACT

Geocomposite leachate collection systems are increasingly being considered as a replacement for conventional graded sand filters in coal combustion products (CCP) landfills. The geocomposites liners are attractive because they are not as thick as the graded sand filters still largely in use. To be a satisfactory substitute for filters constructed of natural materials, the geocomposite must not restrict the flow of leachate to the collection system while, at the same time, prevent the migration of the material to be retained through the filter and into the leachate collection system.

An experimental program designed to test the suitability of a specific geocomposite system in a CCP landfill was performed. In a modified triaxial chamber, the hydraulic conductivity of the geocomposite was measured alone and with four different materials. The effluent was collected at several times during the test and the amount of particulate material in the water as a function of the volume of liquid passing through the CCP was determined. Three of these materials were CCPs commonly placed in utility landfills: fly ash, stabilized FGD (calcium sulfite), and FGD gypsum. The fourth material was uniformly graded sand used as a control.

The permeability measured for geocomposite was greater than the value recorded for any of the retained materials; indicating system permeability would not be controlled by the hydraulic conductivity of the geocomposite although system (material plus geocomposite) permeability was lower than the value measured for the material alone. In three of the four materials tested the amount of particulate matter in the leachate decreased to very low steady-state levels. The amount of fly ash in the leachate increased throughout the test to the point where testing had to be terminated when drainage lines from the triaxial chamber became clogged with fly ash.

In general, the experimental program conducted on landfilled CCPs demonstrated the suitability of geocomposites as filters in a leachate collection system. The results of tests conducted on the fly ash/geocomposite system showed that additional testing is

necessary since some CCPs may not be adequately retained using currently recommended filter materials.

INTRODUCTION

In the design of landfills to contain CCPs, the leachate collection system is typically overlain by a graded sand filter. If the sand filter can be replaced with a geocomposite, substantial savings in placement costs as well as increased landfill capacity could be realized. An experimental program consisting of tests to measure the hydraulic conductivity of compacted CCP layers placed in direct contact with a geocomposite was performed. The geocomposite used in the experiments consisted of a 270 mil geonet bonded on top and bottom to an eight ounce woven geotextile layer (Figure 1). The expressed goal of the experimental program was to evaluate the effectiveness of this specific geocomposite as the primary drainage system for a CCP landfill. Figure 1 includes a schematic of the testing system and photograph of the disassembled geocomposite used in the testing program.

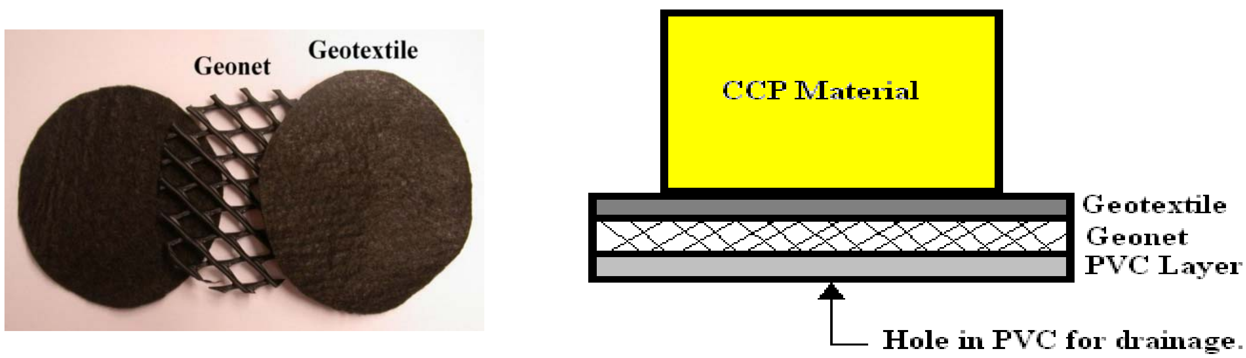

Figure 1 – Geocomposite Test System

EXPERIMENTAL PROGRAM

Several laboratory test programs have been conducted in recent years (Koerner and Koerner, 1995, Xiao and Reddi, 2000, Reddi, et al. 2000, Reddi, et al. 2005, Siriwardene, et al. 2007) to identify the behavior of natural soils and geocomposites when either is used as a liner and/or filter for a landfill. In these programs, specimen tests provided experimental evidence that clogging is a problem. The possibility that clogging can occur along with the consequent reduction in the ability of the filter to carry leachate away from the landfill without an unacceptable increase in the water level within the landfill, must be considered in any leachate system design.

Permeability Tests on Backfill Material: Conventional falling head permeability tests (ASTM D5804) were conducted to determine the hydraulic conductivity of the compacted CCPs (Class F fly ash, stabilized FGD, and FGD gypsum). A constant head permeability test (ASTM D5856) was performed to measure the hydraulic conductivity of the control sand. The measured lab permeability of each of these materials is plotted in Figure 2 as a function of the volume of water passing through the sample (one pore volume is equal to the amount of water required to completely fill the sample void space).

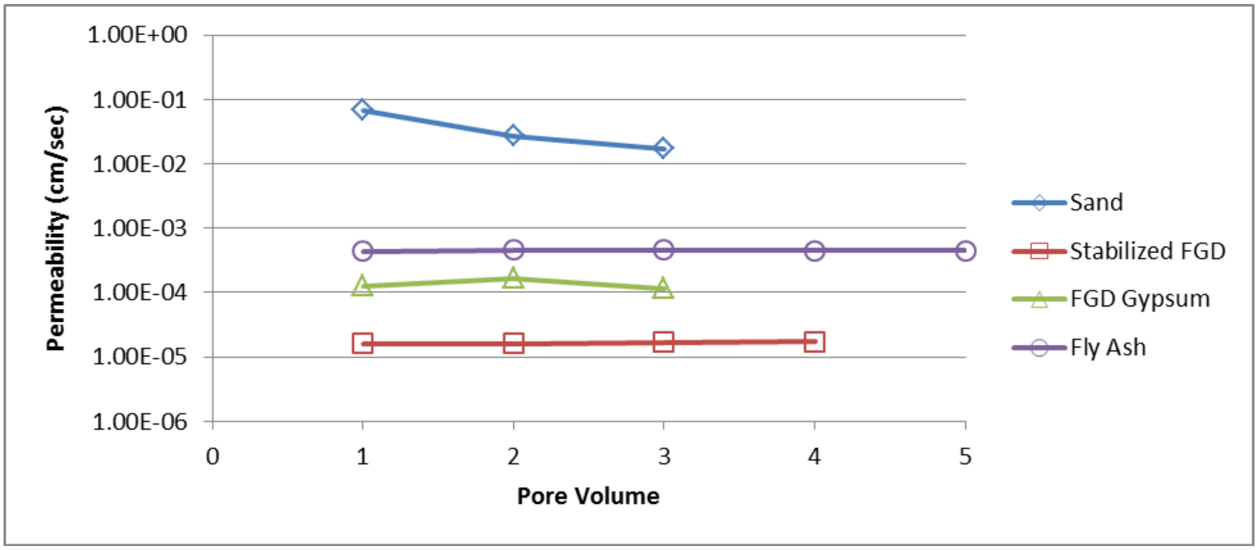

Figure 2 - Permeability of Tested Materials

<u>Permeability Tests on Geocomposite</u>: Initial tests to determine the hydraulic conductivity of the geocomposite alone were conducted in a modified triaxial test chamber. The modification consisted of removing the base plate and porous stone and replacing them with the geocomposite. A thick layer of gravel with a large permeability coefficient was placed in the chamber directly on the geocomposite. The effective permeability of the geotextile layer was measured to be 1.27×10^{-3} cm/sec.

<u>Backfill and Geocomposite System Permeability Tests</u>: In a series of falling head permeability tests, the three CCP materials were compacted in a modified triaxial chamber in which the geocomposite base layer replaced the porous stone. Shown in Figure 3 is the effect on the measured permeability of including the geocomposite layer. From Figure 3 it is apparent that the system permeabilities are lower than the permeabilities measured for the CCP and sand materials alone. However, it is also clear that the differences are relatively small compared to the differences in permeability from one material to another material.

The permeability of the fly ash samples are shown in Figure 4. In the tests with the compacted fly ash placed directly on the geocomposite severe clogging was observed after less than one pore volume. Additional laboratory tests supported this finding when drainage lines consistently became clogged with fly ash.

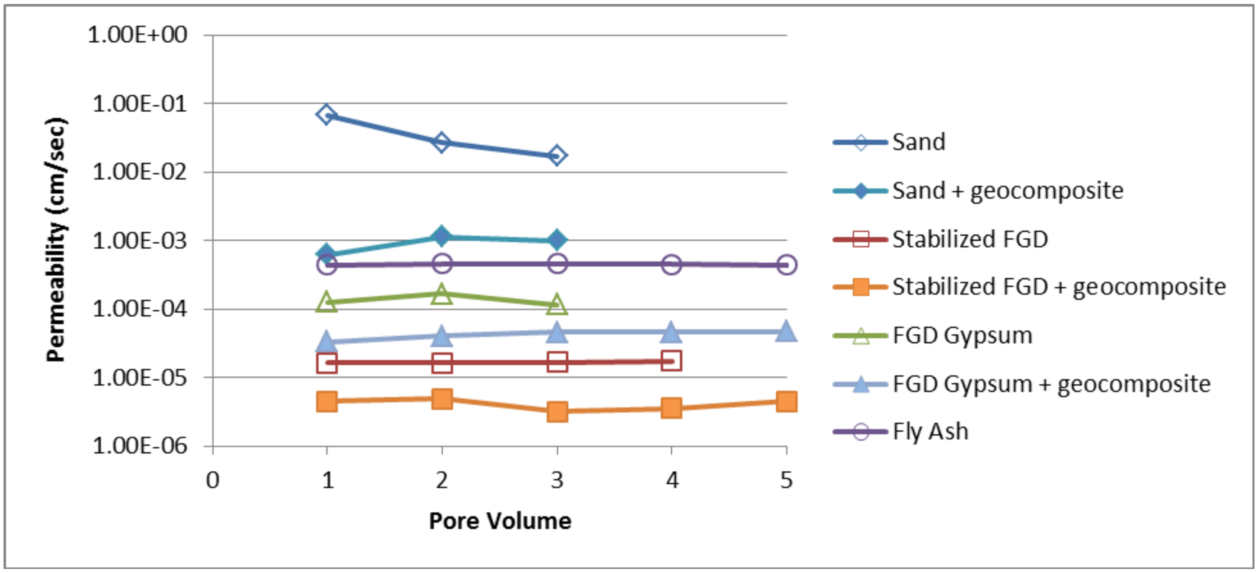

Figure 3 - Permeability Results for Geocomposite plus Retained Material

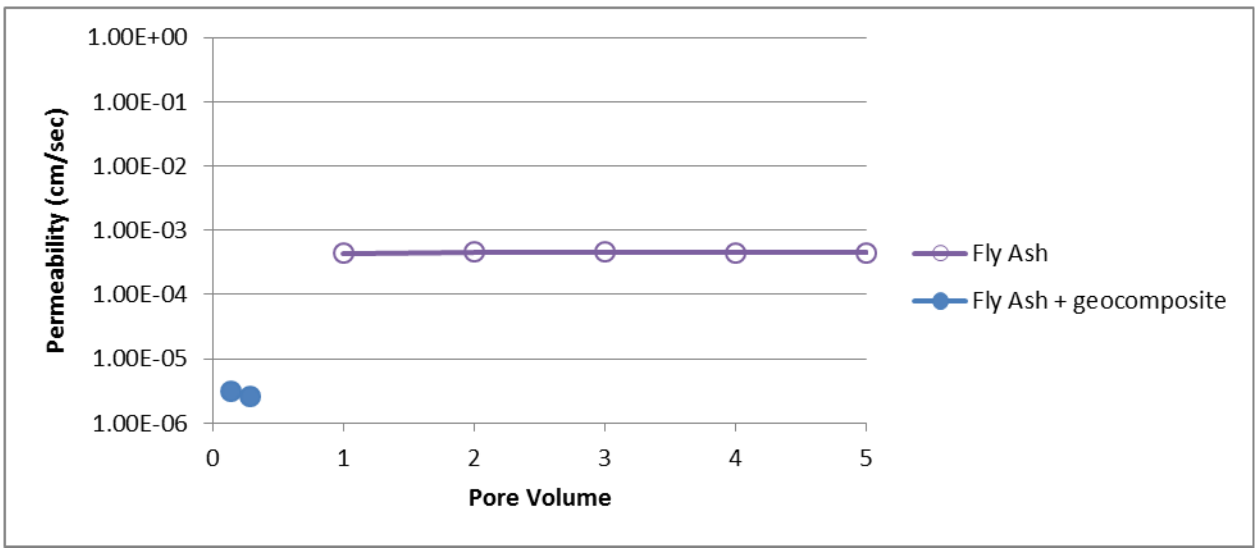

Figure 4 - Permeability Results for Compacted Fly Ash Samples

Leachate test results: Since long term stability of a constructed CCP fill will depend not just on the strength of the retained material but also on material solubility, during the permeability tests on the CCPs, the amount of CCP in the leachate was measured by collecting samples of the leachate at several intervals throughout the duration of each test. Figure 5 shows the amount of material collected in the leachate as a function of the amount of water passing through the sample. The tests show that the amount of FGD gypsum and stabilized FGD going into the leachate solution is small (<0.4%) by weight after an initial flush. In contrast, the amount of compacted fly ash captured in the leachate collection system increased until the system clogged effectively ending the permeability tests on that material.

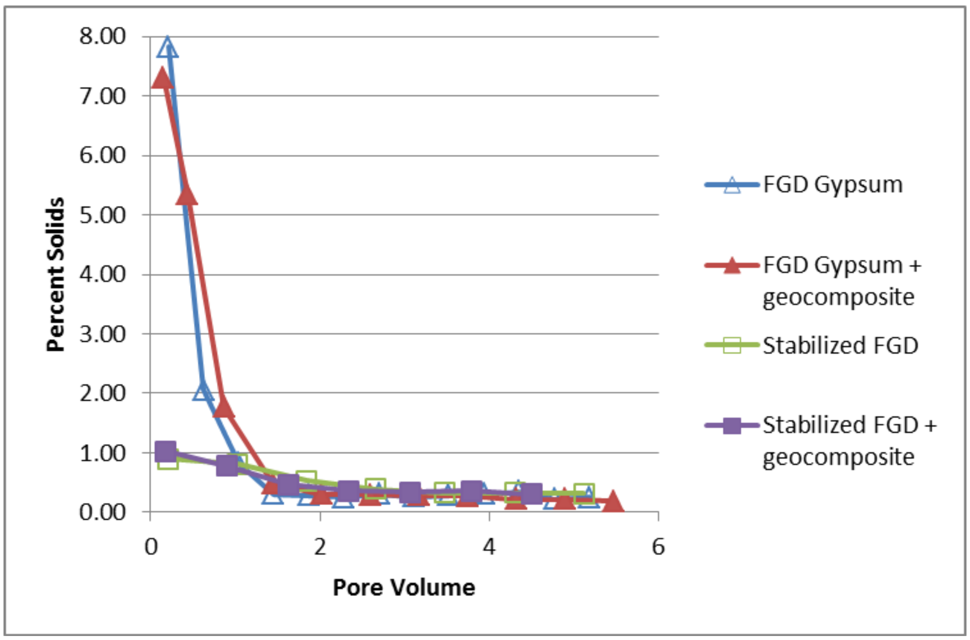

Figure 5 - Amount of CCPs Recovered in Leachate as a Function of Leachate Volume

CONCLUSIONS

Permeability criteria for geotextiles typically require that the permeability of the geotextile be at least five times the permeability of the surrounding soil. Although laminar flow would not have been maintained in the geocomposite during the test program (US Army, 1995) using the modified test apparatus, we report the flow rates measured as a permeability because “the values obtained are considered useful as a relative measure of the permeabilities”.

Because the permeability of some geotextiles decreases under load, the geotextile/gypsum system was tested at two different confining pressures typical of values expected during construction and operation of a CCP landfill. We observed that there was a decrease in permeability of as much as a factor of 5. Baker and Brendel

(2007) showed that the hydraulic conductivity of FGD gypsum is unaffected by changes in confining stress so it is assumed this measured change in the gypsum/geocomposite is primarily the result of changes in permeability of the geocomposite in response to increased confining pressure.

Measured permeabilities of the CCPs tested ranged from a high value of slightly less than 1x10-4 cm/sec (equivalent to a silt) for the gypsum and Class F fly ash samples to 7x10-6 cm/sec (silt or clay) for the stabilized FGD. When these materials were placed in a test chamber modified to simulate the fill/drainage layer/ impermeable membrane system more closely than a conventional permeameter, the effective permeabilities decreased, typically by a factor of 5. In contrast, the effective permeability of the sand/geocomposite was reduced by more than an order of magnitude over the permeability of the sand alone. The quantity of the fill material recovered in the leachate was found to be a small amount that decreased to a very small value after only one or two pore volumes for the FGD gypsum and the stabilized FGD. On the other hand, the amount of fly ash recovered in the leachate collection system increased during the test until it was more than the system could accommodate and the testing had to be terminated. The test program described showed that stabilized FGD and FGD gypsum behave similarly when the conventional graded sand drainage layer is replaced by a geocomposite layer. Although the measured permeabilities of the two materials differ by more than an order of magnitude, both are affected similarly by the geocomposite and after the first flush of water passes through the fill material, both release similar, small amounts of material into the leachate collection system. Fly ash appears to not be adequately retained by the geocomposite. In spite of the fact that the initial permeabilities of the fly ash and the FGD gypsum were very similar, the fly ash particles went into the leachate at a much higher rate and the amount increased rather than decreased as was documented for the FGD gypsum, until the laboratory experiments on the fly ash/geocomposite samples were terminated.

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