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RATIONAL DESIGN APPROACH FOR LANDFILL LINER PROTECTIVE SOIL COVER

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ABSTRACT

This paper presents a rational approach for designing protective soil cover for landfill geomembrane liners in order to prevent damage to the liners. The present practice involves using a combination of geotextile and soil layer as protective cover. The geotextile is placed directly over the geomembrane and then a protective soil is placed on the geotextile. The protective soil layer generally consists of a free-draining granular soil which also serves as a drainage layer for the leachate collection and removal system. The degree of protection offered to the geomembrane depends on the type of geotextile, and the composition and thickness of the protective soil used.

INTRODUCTION

The performance of a landfill liner system can primarily be predicted by the properties of the barrier system. However, the actual performance will depend on strategic and accurate design of the drainage collection and removal system. With the use of geomembranes as a barrier in modern landfills, the leachate collection system now is required to also be a protective layer. To simply specify a thickness of 12 inches and a permeability requirement of 1×10^{-2} cm/sec will not necessarily provide all aspects of a proper drainage and

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protective cover system. This paper presents a logical approach to the design, selection. and installation of a drainage system which will also protect the geosynthetic components of the landfill liner system.

There is a wide variety of natural and manmade products being utilized as drainage and protective cover material for the landfills. The products vary as widely as the geology of the nation, the creative use of byproducts and the ingenuity of the industry to produce a new product. This paper is limited to the characterization of natural granular materials. Natural sands and gravels have been used extensively in landfills and other engineered drainage/filtering/support systems. This success makes them an obvious selection for further research to provide a design process specific to landfills.

Five granular soils were obtained from active landfills for physical property testing Reddy et al. (1995). All of these landfills have used the selected soils for more than five years in conjunction with geomembranes. Operational monitoring has shown them to function as designed for this period. A summary of characteristics of the five granular soils is provided in Table 1. Obviously, if a source is identified which has the characteristics of the tested soils, a design can expect the material to perform adequately. However, a systematic design approach will increase this assurance.

DESIGN APPROACH

The first step in the design of the protective cover is to identify foundation conditions and physical properties of the geomembrane/geosynthetics in the liner system. With these conditions identified, the design can proceed to design a protective cover system to match these limitations.

The second step is to determine the availability of various drainage materials in the vicinity of the landfill. In some locations, the design is only presented with one choice of natural granular material. In others, a variety of materials may be available such as fine-grained sand, river stone, glacial gravel deposits and crushed stone or rock. The cost of each of these materials should be obtained so as a cost benefit of each system can be evaluated. At this time, it is also appropriate to determine if a byproduct or geosynthetic drainage medium is more cost effective. Assuming natural materials are more cost effective, the design process proceeds.

The third step is material physical property screening. At minimum, the following properties should be determined:

- Grain size distribution
- Permeability
- Soundness

Table 1- Summary of Characteristics of Protective Cover Soils Tested

Property	**Soil G1**	**Soil G2**	**Soil G3**	**Soil G4**	**Soil S1**
Particle shape characteristics	Subangular Coarse Gravel	Angular Crushed Gravel	Subrounded Fine Gravel	Subrounded Pea Gravel	Medium to Fine Sand
Major mineralogy	Quartz, Pyroxene and Olivine	Feldspar, Calcite, Pyroxene, Olivine	Quartz, Feldspar, Olivine, Pyroxene	Quartz, Feldspar Mica(trace)	Quartz, Feldspar, Clay, Pyroxene Olivine
% Finer than No. 200 Sieve	0.25	3.46	0.67	1.17	3.47
%gravel, %sand Cu, Cc USCS class.	100, 0 1.33, 1.22 GP	84, 16 4.00, 1.33 GP	95, 5 2.15, 1.33 GP	45,55 2.00, 1.10 GP	0, 100 3.75, 0.75 SP
Dry max. density min. density (g/cc)	1.767 1.486	1.760 1.450	1.929 1.583	1.897 1.624	1.981 1.620
Av. hydraulic conductivity (cm/sec)	2.26	0.97	1.96	1.60	0.02
Triaxial Test c(kPa),ϕ(deg)	0, 43	0, 41	0 , 40	0, 38	0, 32
L.A. Abrasion % wear	18.44	37.20	30.75	21.10	NA

- Shear strength

If leachate properties are known, the design may determine chemical compatibility at this stage. However, research for filtering materials for sewage treatment plants has shown that most sound material can withstand chemical attack by solutions similar to domestic sewage. Testing with procedures such as those recommended by ASTM (e.g., an acid boiling to determine carbonate content) can be utilized to determine relative degree of reaction between possible sources. Material with lower reactivity can be expected to perform better.

The fourth step is to determine if waste has the possibility of migrating in to the granular material voids. The characteristics of the waste needs to be determined. Use of standard filtration, retention, clogging procedures can be utilized as detailed in Koerner (1994). Municipal waste could be modeled as a peat assuming long-term decomposition. However, if the design is for retention of daily cover soil, long-term waste retention can be expected. In conjunction with physical clogging, an assessment of biological clogging should be made. The strength of leachate and detention time in the material will impact growth potential. Logically, material with relatively large voids, small surface area and high permeability would limit growth.

The fifth step includes a dual analysis of constructibility and puncture resistance. Construction of thin, uniform layer over a geomembrane must be done in a manner that limits point pressure on the geomembrane, supports equipment, limits rutting and is not conducive to slippage. Unpaved road design can be utilized to estimate required thickness (Reddy et al., 1995). Typically, the best method to assure geomembrane survivability is to perform a field trial. Schmucker and Buffalini (1995) provided a description of a test with crushed glass. Field tests are scheduled at a landfill site to determine the effect of construction activities on the granular protective layer and the underlying geomembrane liner. As part of this field testing, several construction operations will be conducted and monitored. These include:

- dozer pushing piles of protective cover material and the dozer track spinning in-place,
- dozer locking one track and turning; causing a torsional strain,
- truck or wheel loader causing a rut (bearing failure type rotation of material).

Survivability of geomembrane can be evaluated using a multiaxial burst evaluation after a loading period using normal stresses of the landfill and actual construction material (Motan et al., 1993).

Material which demonstrates adequate trafficking capability under construction conditions may not provide adequate puncture resistance. Two choices are possible at this point in the design. First is to eliminate material in the first lift of waste that may have the potential to damage a geomembrane. However, this may not be practical considering compression may reduce the first lift of 8 to 10 feet to a thickness of 2 to 4 feet (Koerner, 1994), removal may not be adequate. Penetration testing on different soil types shows that unconfined material performs relative to friction angle. Saturated clay, sand, rounded stone and crushed stone were tested and the results are plotted as shown in Figure 1. These results show angular, high friction materials provide the highest resistance over depth. The design can provide a cost-benefit analysis at this point for example to determine if a greater thickness of sand is less costly than a standard gravel thickness.

In addition to puncture resistance the protective layer must adequately disperse dynamic loads. This is where the properties of the foundation material are incorporated. Unpaved road design can be utilized to determine rut potential (Reddy et al., 1995). Dispersion of loads to bearing capacity of the foundation by utilizing material thickness and shear strength can also be used.

The final step in the design is to evaluate sideslope stability of the protective cover material. Geomembrane to material friction can be used in an infinite slope stability analysis as a start.

$\tan \phi / \tan \alpha > 1.3$ (ϕ- interface friction angle, α-slope angle)
Since many geosynthetic interface strength tests result in apparent cohesion it is suggested that the actual interface shear strength can be utilized in the design (Koerner, 1994). If frictional resistance is not adequate, geosynthetic tensile reinforcement with geotextiles or geogrids can be incorporated.

Serviceability of the layer on the sideslope is important. If the layer erodes or slips due to seepage forces over time liner failure can occur. Seepage forces can be evaluated and should include the infiltration due to a design storm which can be expected during the exposure of the slope. Rainfall probability methods are available to determine probable risk of sideslope drainage.

SUMMARY

A protective soil cover serves two important functions: leachate collection and protection of geomembrane liner. In order to select the appropriate material and thickness, the potential borrow sources of natural material should be characterized for material properties and costs. The design of the protective cover should be based on long-term loads, construction methods, and exposure. Alternative materials should be considered and evaluated if natural materials are not viable. Further testing is needed to correlate construction loading to actual failure modes and provide methods to design for these stresses. Penetration resistance under confined conditions is also needed to determine long-term performance.

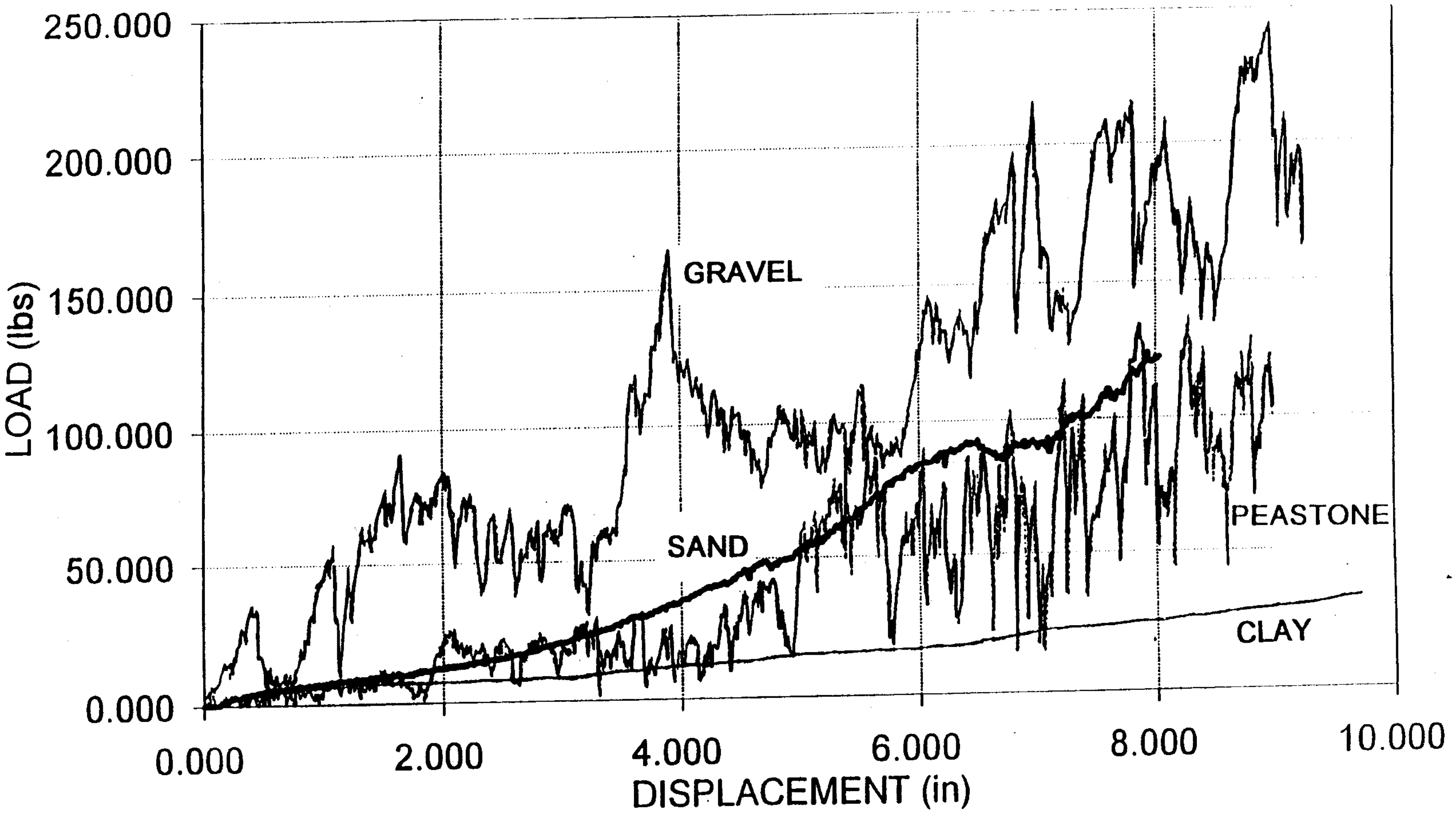

Figure 1- Penetration Testing on Different Soils

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