DEPTH VARIATIONS IN HYDRAULIC CONDUCTIVITY WITHIN A SINGLE LIFT OF COMPACTED CLAY*

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Abstract. Compacted clay liners are commonly used as components of the lower portion of composite double liner systems for hazardous waste containment. Because the overlying leachate collection and removal systems and the FMLs are not perfect leachate still comes into contact with the lower liner and thus makes it critical that the clay liner component be constructed to achieve the lowest possible hydraulic conductivity. This research was conducted to evaluate the effects of clod size on the hydraulic conductivity of compacted soils and the uniformity of conductivity with depth within a lift of compacted soil. Two subsoils, one from the Beaumont series (smectitic) and one from the Kosse series (kaolinitic), were evaluated in the laboratory and then compacted in large fixed wall permeameters using maximum clod sizes of <2.5, <5.0, and <7.5 cm to a compacted lift thickness of 23 cm. Measurements were made of the hydraulic conductivity of the entire lift, the lower two thirds of the lift, and the lower one third of the lift. The results show that the conductivity of the lower one third of the lift can be as great as 8.7 times that measured for the entire lift and indicates that liners need to be constructed using thin lifts to achieve more uniform low conductivity throughout the liner. The data also indicated that under the carefully controlled conditions of this study and with the clod sizes used, the clod size did not have a significant effect on the hydraulic conductivity of the soils tested. Soil bulk density was poorly correlated with hydraulic conductivity and indicates that measuring the bulk density of a compacted soil is an inadequate method for assuring low hydraulic conductivity. Measurements of the time to the first appearance of leachate indicated that 8 to 17 d are required for water to penetrate a 23 cm thick compacted liner with an average conductivity of $1 \times 10^{-7}$ cm s$^{-1}$.

1. Introduction

Although compacted clays were formerly used as the sole liner for landfills and impoundments, current regulations require double liners with associated leachate collection and removal systems (EPA, 1989). Clay liners are still used, however, typically as the bottom component of the lower composite liner of many double lined facilities. Although no waste or waste components should reach the clay liner, the overlying flexible membrane liners (FMLs) and leachate detection, collection, and removal systems (LDCRS) are not perfect and do allow waste constituents to reach the clay liner. Mechanisms by which the waste constituents pass the overlying FMLs include punctures, seam failures and diffusion (Gunkel, 1981; Brown and Thomas, 1988; Bass et al., 1985; Laine and Miklas, 1989; Haxo and Lahey, 1988). Therefore, it is critical that the clay liner component be constructed to achieve

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the lowest possible hydraulic conductivity.

Current criteria for selecting an appropriate soil material include: (1) the hydraulic conductivity is equal to or less than \(1 \times 10^{-7}\) cm s\(^{-1}\), (2) the soil should have at least 20% fines, (3) the plasticity index (PI) should be greater than 10%, (4) the soil should have 10% or less gravel-size particles, and (5) the soil should not contain any soil particles or chunks of rock larger than 2.5 to 5 cm in diameter (EPA, 1989).

In the field, the soils are wetted to between 0 to 5% above the optimum moisture content and then compacted in lifts ranging from 15 to 25 cm in thickness with sheep’s foot or pad foot compactors to within 95% of proctor density or 90% of modified proctor density. Quality assurance checks normally performed in field installations include using nuclear surface density meters to measure both the moisture content and the soil density. It is then assumed that soils compacted at the proper moisture content and within the specified density range will have hydraulic conductivities similar to those measured in the laboratory tests. Field studies, however, indicate that field conductivities may be as great as 1000 times greater than laboratory values (Daniel, 1984; Daniel and Brown, 1987; Elsbury et al., 1988). In addition, some studies (Anderson et al., 1985; Brown et al., 1986; Elsbury et al., 1988) indicate the presence of areas of high permeability at lift interfaces. It is possible that the compaction procedure may not result in lifts of uniformly low hydraulic conductivities. Another possible cause for the discrepancy between laboratory and field conductivities may be the difference in clod sizes used. Benson and Daniel (1991) report that the conductivity measured in the laboratory using 4.6 mm diameter clods may be \(1 \times 10^6\) times smaller than that of samples prepared with 19 mm diameter clods. Therefore, this study was conducted to evaluate the uniformity of hydraulic conductivity with depth in a lift of compacted clay, and the effect of initial clod size on the final hydraulic conductivity of the compacted clay.

2. Materials and Methods

Two subsoils, one from the Beaumont and one from the Kosse series, were collected for use in this study. The Beaumont soil (a fine, montmorillonitic, thermic, Entic Pelludert) is frequently used for constructing clay liners in the Gulf Coast area. The Kosse soil (a fine-loamy, mixed, thermic, Fluvaquentic Haplaquoll) is primarily kaolinitic and is mined for industrial uses. Each soil was characterized through a series of laboratory studies and then used in tests involving large 60 cm diameter fixed wall permeameters.

2.1. Laboratory Characterization Studies

Representative samples of each soil were characterized through a series of laboratory tests including: texture, mineralogy, Atterberg limits, optimum moisture content, swelling, and water retention. Soil texture was measured by the pipette technique.