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GEOTECHNICAL PROPERTIES OF MUNICIPAL SOLID WASTES AND THEIR USE IN LANDFILL DESIGN

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INTRODUCTION

Modern landfills are complex structures that require careful design to ensure adequate long-term performance, so that human health and the environment are not exposed to undue risks. The main containment features of modern landfills are comprised of the liner system, the final cover system, and the surface water management system; the main operational features are the leachate collection and removal system, and the gas management system.

The design and permitting of landfills requires performing comprehensive geotechnical analyses to demonstrate that all the landfill systems have been designed to be consistent with long term performance requirements. Correct selection of geotechnical properties of waste materials for use in these analyses is of paramount importance, as the safety and cost of landfills are sensitive to variations in these properties. Unfortunately, the geotechnical properties of waste materials can vary within broad ranges, change significantly with time, and are not easily amenable to direct measurement, due to heterogeneity and hard inclusions. Furthermore, published data is limited and the conditions under which the properties were measured or back-calculated are often unclear.

In addition to their impact on the assessment of landfill performance, the unit weight and compressibility of waste materials have an important influence on the economic evaluation of landfill projects, since the waste stream is generally measured as gate weight whereas landfill capacity is measured by volume (in-place, compacted, including covers). Therefore, selection of these geotechnical properties impacts issues such as financing, tipping fee, cell life, and construction scheduling.

This paper is based on a research project recently completed at Purdue University (Fassett, 1993). A general discussion of the geotechnical properties required for the analysis for the design of landfills is presented first, followed by the results of an extensive compilation of the geotechnical properties of municipal solid waste (MSW). Emphasis is placed on unit weight, static and dynamic shear strength, compressibility, shear modulus and damping coefficient. Although the review was comprehensive and provides useful guidelines, it was found that major gaps exist in the characterization of these properties on the basis of past records; moreover, much of the available data is not applicable to landfills constructed according to modern practice. Accordingly, needed research to fill these gaps is identified, with emphasis on features that are most urgently needed.

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The majority of the reported values above 0.1 are from a site discussed by Druschel & Wardwell (1991). The authors realized that their findings differed from those obtained by others, but were unable to find an explanation. For typical landfills the lower limit of C_α is generally around 0.01 to 0.03. This compares to 0.005 to 0.02 for common clays (Holtz & Kovacs, 1981). The typical upper limit of C_α appears to be approximately 0.1.

Using the data from Table IV, an attempt has been made to examine what effect various parameters (including unit weight, waste thickness, and compaction effort) have on C_α (Fassett, 1993). The findings of this endeavor include the following:

- little correlation was evident between C_α and unit weight;
- a rough correlation was found to exist between waste thickness and C_α; and
- the available data showed no relationship between compactive effort and C_α.

Discussion of Compressibility Parameters

C_α would be expected to decrease with increasing unit weight, provided the higher unit weights were achieved by compaction. The fact that little correlation was obtained between C_α and unit weight suggests that settlements also contributed to increases in unit weights.

According to Yen & Scalon (1975), the settlement rate of waste increases with depth, hence larger values of C_α should be associated with thicker fills. Yen & Scalon's observations indicated that this effect leveled off at about 90 ft. It was suggested that below this depth conditions within the landfill limited the biological activity to anaerobic decomposition, which is much slower than the aerobic decomposition believed to occur in shallower fills. However, evidence suggests that anaerobic decomposition may be the dominant reaction even at shallow depths.

Long-term compressibility of MSW would be expected to decrease with increasing compaction effort. However, as mentioned above, no such trend is evident with the available data. This is due to the limited number of data points available and the unclear relationship between reported values of C_α and the actual settlement rate.

Two references in Table IV show the effects of aerating MSW within landfills (Merz & Stone, 1962; Stone, 1975). In both cases, the aerated landfill cells had C_α values over four times greater than comparable standard cells. The marked increase in C_α with aeration is attributable to both the increase in the rate of decomposition as well as to the increase in temperature resulting from the decomposition process.

Values of C_α and $C_{\alpha\epsilon}$, like C_c and $C_{c\epsilon}$, are dependent on the values used for e_o or H_o. $C_{\alpha\epsilon}$ is also dependent on stress level, time, and on how the origin of time is selected. The filling period of landfills is often long and should be taken into consideration for settlement rate analyses (Yen & Scalon, 1975). Watts & Charles (1990) show time settlement curves developed for two sites using different criteria for selection of the zero time (Figure 4). The zero time selection is seen to have a large impact on C_α particularly during the earlier times.