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Fines migration from soil daily covers in Hong Kong landfills

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ABSTRACT

Laboratory tests using 240 mm diameter columns were conducted to study fines migration in conditions that simulate daily soil covers in Hong Kong municipal solid waste landfills. Five factors suspected to affect fines migration were examined: moisture content at soil compaction, overburden pressure, pumping rate, cover thickness, and soil-waste interface condition. The results show that moisture content at compaction, cover thickness, and soil-waste interface are the most influential parameters on fines migration in completely decomposed granite daily covers. The measured equivalent sizes of migratory fines from the soil covers were in the range of 4–140 μm. The majority of migratory fines migrated during first permeations, representing 64–86% of the total by mass. Larger particles tended to migrate from the soil mass during the saturation process. In a typical run, about 0.0018% of the total cover soil (by dry weight) was washed out during a typical 1 h rainfall event. The results of the laboratory studies point to important engineering implications on the operation of local MSW landfills regarding the use of sandy daily covers.

1. Introduction

In spite of many waste processing and recovery techniques, such as composting and incineration that have been proposed in the last few decades, disposal of remaining solid wastes to land is inevitable. A leachate collection system (LCS) is one of the key engineered components of modern municipal solid waste (MSW) landfills to control excessive leachate mounding on top of the liner. A LCS is said to have clogged, and therefore reached the end of its service life, when it fails to maintain leachate levels below the allowable design leachate head. The long term performances of LCS and liner system are vital to the underneath groundwater quality.

Soils are the traditional materials for MSW landfill daily covers, but their use is controversial, particularly in consumption of valuable landfill space (Aivaliotis et al., 1995, 2004; Greedy, 1995; Haughey, 2001; Panagiotakopoulos and Dokas, 2001), contribution to waste mass instability and hydraulic heterogeneity (Hancook et al., 1999; Jang, 2000; Dixon and Jones, 2005), and reduction in drainage efficiency in the drainage layer due to fines migration and clog formation (Wiles and Hare, 1997; Fleming et al., 1999; Manning and Robinson, 1999; Bennett et al., 2000). In this paper, fines migration from typical Hong Kong soil daily covers by means of water permeation was investigated and quantified using column experiments. The primary objective of this study is to assess the extent of fines migration from soil covers under local geological, climatic and operational conditions. The results presented here are part of an on-going research program that aims to assess and broaden the roles of daily covers on the mechanical, operational and environmental performance of modern MSW landfills. This paper, however, only focuses on fines migration observed from local soil in laboratory column studies that simulate MSW landfill conditions in Hong Kong.

2. Background

The clogging of LCS has not been well understood until recently. In the last decade, LCS clogging was investigated extensively using field and laboratory column studies due to its practical significance (Fleming et al., 1999; Bennett et al., 2000; Rowe et al., 2000a,b, 2002; Cooke et al., 2001; Bouchez et al., 2003; Fleming and Rowe, 2004; VanGulck and Rowe, 2004a,b). In a previous field study conducted by Fleming et al. (1999), a 4-year-old landfill drainage blanket was exhumed and a considerable amount of void space was found occupied by the clog materials. The clog samples collected contained a significant amount of fine inorganic particles that were not present in the original gravel drainage layer. The accumulation of mineral clog deposits, biodegradation products and biofilm may result in partial or complete clogging of the LCS. The composition and effects of suspended solids on clogging were reported by others (Brune et al., 1991; VanGulck and Rowe, 2004a).

Manning and Robinson (1999) found that suspended solids in the leachate include a variety of minerals that likely originate from the daily cover or the MSW itself. By comparing the bulk mineral-

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ogy of the soil cover soils and clog matter collected in a landfill site, Bennett et al. (2000) showed that a considerable portion of the clog material in LCS originated from soil daily covers. The significance of suspended solids on clog formation was highlighted by Rowe et al. (2002). They conducted laboratory column tests with synthetic leachate (which contained negligible suspended organic and inorganic particles) and real leachate (which naturally contained considerable amount of these solids) to study possible clogging mechanisms of LCS. They found that columns with real leachate experienced a more rapid decline in drainable porosity, despite the fact that the synthetic leachate had a higher mass loading of organic acids. In their study, drainable porosity referred to the pore spaces that drain fluid freely in a gravitational field under atmospheric pressure. Rowe et al. (2002) concluded that the physical clogging of suspended solids played a significant role in the clogging process, as the suspended solids provided abundant nucleation sites for further growth.

Silicate materials are commonly present in sandy soils, such as those often used as daily covers. Compositional analyses of the clog material collected from landfills in Germany and Canada have confirmed that silica is one of the key constituents, representing about 16–21% of the clog by mass (Brune et al., 1991; Fleming et al., 1999). Despite many valuable works reported in literature on clog formation, the possible contribution of soil daily covers to LCS clogging has not been addressed adequately. There is a lack of laboratory evidence concerning the effects of sandy soils used as daily covers on the clogging of LCS.

The use of soil daily covers to cover freshly compacted waste is a standard practice in the industry (Bolton, 1995; McBean et al., 1995; Qian et al., 2002). The primary function of a daily cover is to control infiltration, disease vectors, fires, odors, blowing litter and scavenging (McBean et al., 1995; Qian et al., 2002). Most regulatory agencies around the world require that at least 150 mm of cover materials be spread across the work area of an active landfill cell at the end of each working day. For example, starting in 1993, all the owners and operators of the MSW landfills in the United States are required to cover the disposed waste with 150–300 mm of soil material on a daily basis, as stated in Title 40, Part 258 of the Code of Federal Regulations, Solid Waste Disposal Facility Criteria (commonly referred to as Subtitle D).

Landfill cover soil is usually excavated from the site, or a nearby borrow area, to minimize operation cost. The soil covers in Hong Kong landfills are comprised mainly of completely decomposed granite (CDG), one of the most abundant soil types in Hong Kong. Local laws and regulations require that landfill operators cover the compacted waste with at least 150 mm of soil if the tipping area is left unattended for more than 24 h. However, in order to achieve the minimum 150 mm soil cover, more than 150 mm must be applied due to the highly uneven, sloped surface of freshly compacted waste. A thicker layer of soil is required to smooth the surface and provide a stable pathway for vehicular access. The actual thickness of soil daily covers used in UK landfills is about 300 mm (Greedy, 1995). This finding is also consistent with North America experience; for example, in a large US municipal landfill, the depth of a daily soil cover varied from 127 to 1067 mm (Bolton, 1995). Since published data on daily cover thickness in local landfills is unavailable, these overseas data are reported as reference.

Effective use of landfill space is very important in sustainable waste disposal practice. However, it has been reported that the total landfill space lost due to the placement of soil daily covers alone can be as high as 25% of the total capacity of a typical MSW landfill (Greedy, 1995; Wiles and Hare, 1997). In other words, the soil from daily covers constitutes a substantial share of modern MSW landfill space, and may contribute an enormous amount of migratory fines for nucleation of clog material in LCS.

Since landfilling is usually the ultimate step in any solid waste management system, knowledge on better utilization of the technology is unquestionably valuable. Technical challenges associated with deep landfills such as fines migration and clog formation in the LCS arising from the use of soil covers are thus becoming more important than ever.

3. Objectives and definition

The presence of fines in leachate can enhance the rate of clogging in the LCS by providing additional sites for heterogeneous nucleation (Fleming et al., 1999; Bennett et al., 2000). Given the fact that a soil cover can occupy about a quarter of total landfill space (Greedy, 1995; Wiles and Hare, 1997) as well as the field and experimental evidences of fines migration from soil covers (Fleming et al., 1999; Manning and Robinson, 1999; Bennett et al., 2000), the objectives of the present study are (i) to examine the factors affecting fines migration of CDG daily covers, (ii) to quantify fines migration from CDG daily covers under local climatic and operating conditions in Hong Kong and (iii) to make practical recommendations for landfill operators regarding the use of CDG daily covers. The results presented here are intended to provide the necessary laboratory data for understanding the LCS clogging mechanisms in Hong Kong. In this paper, the terms "fines" and "migratory fines" are defined as any small particles or discrete solids indigenously present in CDG soils, which can be mobilized by the means of water permeation, with equivalent sizes varying from 0.4 to 200 μm.

4. Materials and methodology

4.1. CDG soils

Due to the abundance of the material, CDG is generally used as cover material in Hong Kong landfills. CDG is commonly described as sand or silty sand with some fine gravel (Junaideen et al., 2004). The CDG used in this study was excavated from a hillside slope in Shatin, Hong Kong at depths of 2.0–4.0 m. Fig. 1 shows the average particle size distribution curve from mechanical sieving (for particle diameter larger than 63 μm) and hydrometer analyses (for the remaining fraction) for three samples taken from the same site. The samples taken from the site are very consistent, as shown. In terms of gradation, the CDG is well-graded, with a coefficient of uniformity of 9.1 and a coefficient of gradation of 1.5. The soil consists of approximately 85% sand, 2.4% silt and 0.5% clay and was classified as well-graded sand (SW) under the unified soil classification

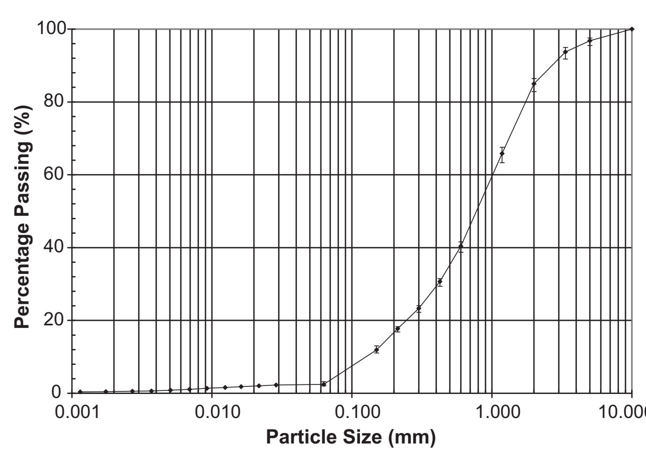

Fig. 1. Particle size distribution curve for the CDG samples.