Factors affecting the hydraulic conductivity of waste

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Introduction

Landfill has been the primary means of solid waste disposal in many countries for the past hundred years or more. Sites containing both old and new wastes will often require active pumping of leachate for level control or treatment purposes, and/or to achieve long-term stabilisation through biodegradation and flushing. For these reasons, knowledge of the hydraulic conductivity of domestic wastes and an understanding of the factors that control it are essential. The presentation will discuss the effects of waste treatment involving particle size reduction, degradation and burial on the hydraulic conductivity of domestic wastes, with reference to the results of a series of tests carried out in the Pitsea compression cell.

Apparatus and experimental procedures

The tests in the Pitsea compression cell (Fig. 1) were carried out as part of a continuing programme of research into the compression and flow characteristics of wastes. The Pitsea cell is a purpose-built apparatus that accommodates a sample of waste 2 m in diameter and up to 2.5 m high – a size necessary to obtain representative results from samples of generally highly heterogeneous wastes. Overburden pressures are simulated by applying a vertical stress via hydraulic rams acting on a platen on top of the waste. Typically, the applied stress is increased in five or six stages to a maximum of 600 kPa, representing landfill depths of up to 60 m. At the end of each compression stage, the bulk density, drainable porosity and saturated hydraulic conductivity of the waste are determined.

Detailed descriptions of the compression cell, including a correction to the applied stress to account for side friction are given by Powrie & Beaven (1999) and Beaven (2000), but the general testing procedure may be summarized as follows. A waste sample is loaded into the cylinder, and its as-placed weight determined by means of the load cells on which the apparatus is mounted. The waste composition and as-placed water content are determined by sorting and oven drying sub-samples typically totalling ~2 tonnes. When compression in response to the application of a vertical stress has substantially ceased (i.e. compression is increasing at a rate of less than 1% of the sample thickness in 24 hours), the waste is saturated by allowing water to flow into the sample through the lower platen. After the refuse has been saturated it is allowed to drain under gravity to field capacity (defined as the water content of the waste in conditions of free downward gravity drainage), and the drainable porosity is calculated from the volume of leachate drained, per unit total volume. The bulk density can be calculated from the known mass and volume of the waste at any stage.

Fig.1. Pitsea compression cell

The hydraulic conductivity of the refuse at each vertical load is measured in a constant head flow test. Water from the header tanks is allowed to flow upward through the refuse. The hydraulic gradient is determined by means of piezometers inserted through ports in the side of the column. Piezometers at the same horizon indicating the same hydraulic head confirm that flow is vertical and approximately uniform. The flow rate is measured using electromagnetic flowmeters, except at low flow rates when direct measurement of the (small) fall in water level in the header tanks with time has been found to be more reliable. The refuse is then drained, the applied stress increased and the cycle of operation and measurement repeated.

Tests were carried out on four different samples of domestic waste (DM3, PV1, DN1 and AG1) to investigate the effects of particle size reduction, degradation and compression on the bulk vertical hydraulic conductivity. DM3 was fresh, unprocessed waste; PV1 was fresh waste that had been pulverized and passed through a 150 mm screen and heavy fines (including some putrescibles) removed; DN1 was fresh waste that had been partly sorted and tumbled in a drum using the Dano system ; and AG1 which was a 25 year old partly degraded waste containing a mixture of soil, crude waste and pulverised waste that had been recovered from a depth of less than 5 metres from a landfill site. Further tests were carried out on sample DN1 to investigate the effects of partial saturation and gassing. Full characterization analyses are given by Powrie & Beaven (1999) for sample DM3, by Hudson *et al* (2001) for waste DN1, and by Beaven (2000) for wastes PV1 and AG1.

Results

Raw data of hydraulic conductivity, drainable porosity and density at various vertical effective stresses are given for samples DM3, PV1 and AG1 by Beaven (2000), and for sample DN1 in high and low gas accumulation conditions and with high and low pore water pressures by Hudson *et al* (2001). Figure 2 shows the permeability in notionally saturated conditions for all four wastes plotted as functions of (a) vertical effective stress; (b) density and (c) porosity.

Figure 3 shows the effect on hydraulic conductivity of gas accumulation in the Dano processed sample DN1, with the sample free to vent to atmosphere.

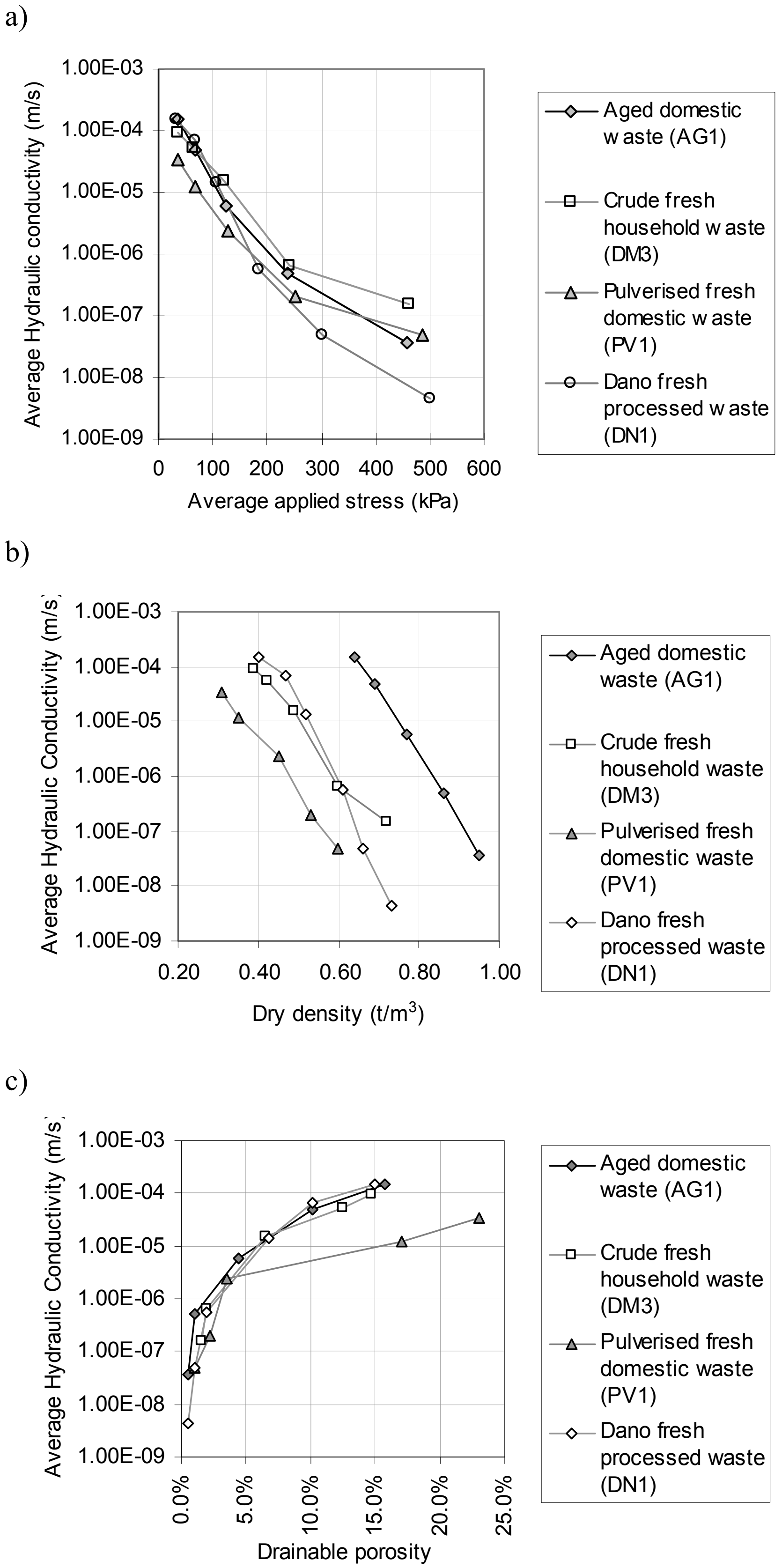

Fig. 2. Vertical hydraulic conductivity against (a) the logarithm of the vertical effective stress in first loading; (b) the drainable porosity; and (c) density, for wastes DM3, PV1, AG1and DN1 (data from Beaven, 2000 and Hudson et al*, 2001)*

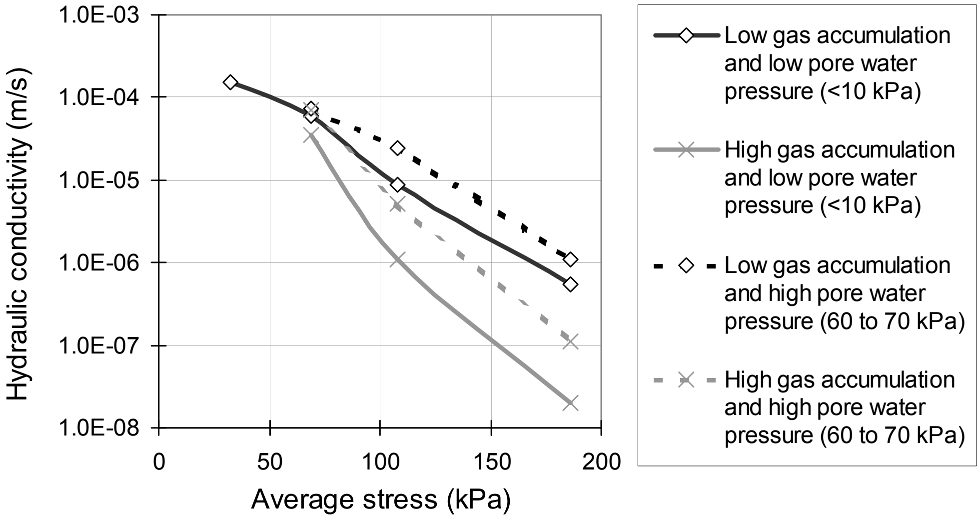

Fig. 3. Vertical hydraulic conductivity against vertical effective stress for sample DN1, showing the effect of gas accumulation (data from Hudson et al*, 2001)*

Conclusions and comments

1. There is a single correlation for all samples between vertical hydraulic conductivity and vertical effective stress in first loading. Differences in hydraulic conductivity resulting from particle size reduction and waste degradation are essentially second order, but appear to become more significant at higher vertical effective stresses (with a spread of just over one order of magnitude in hydraulic conductivity at a vertical effective stress of 500 kPa).
2. There are individual correlations between vertical hydraulic conductivity and density for each waste type, with an essentially linear relationship between the logarithm of the vertical hydraulic conductivity and the dry density.
3. There is a single correlation between the vertical hydraulic conductivity and the drainable porosity of the waste. This is not surprising, as the drainable porosity represents a measure of the size and degree of connectivity of the voids, both of which will have a major influence on the bulk hydraulic conductivity. However, unlike the vertical effective stress, the drainable porosity is a difficult parameter to estimate *a priori* for design purposes, so the correlation between vertical hydraulic permeability and vertical effective stress is of more practical use.
4. Gas accumulation could reduce the hydraulic conductivity by between one and two orders of magnitude; at elevated pore water pressures, compression of the trapped gas will reduce its impact.

References

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