CHAPTER 5

BARRIER DESIGN AND PERFORMANCE EVALUATION

5.1 Introduction

From the previous chapter it is quite evident that the landfill interstitial water in Sabak Bernam is heavily polluted with heavy metals. The toxicity risk potentials associated with some of these heavy metals have also been mentioned.

Fig. 5.1 Landfill site at Sabak Bernam. Interstitial water contains high heavy metal content.

It is on the basis of this contamination of interstitial water that it is thought worthwhile to add a single chapter on the method of designing and evaluating the performance of a lined waste containment system to prevent contamination of groundwater.

The design of urban solid waste disposal needs the solution for many geotechnical problems. If any impervious natural layers do not exist on the site, artificial fluid barriers must be made to prevent pollution of surrounding areas (Favaretti, et al., 1992). To make the bottom and sides of the dumping area impermeable to any kinds of fluid, economical materials which have the properties of lasting for several decades should be used. Such impervious liners can comprise geosynthetic clays, geomembranes, clay-sand mixtures and compacted clays.

The effectiveness of the clay lining in preventing movement of leachate depends on its ability to maintain a very low permeability while in contact with contaminated fluids. Permeant passing through fluid barriers can cause unexpected increase in linear permeability leading to unexpected increase of leachate seeping through the clay liner. According to Tan (1998), Yong et al., (1992), Rowe et al., (1995), DOE (1995) and CIRIA (1996), the use of clay liners is attributed to the low hydraulic conductivity and high adsorption capacity of clay soils.

5.2 Types of lining system

There are several types of linings. The four lining system is as shown in Figure 5.2 (a) to (d). The figure also shows the structure of the leakage detection system underneath the various lining systems. It is achieved by a 4 mm thick geonet with transmissivity 10^{-4} m^2/s under 200 kPa lateral compression pressure.

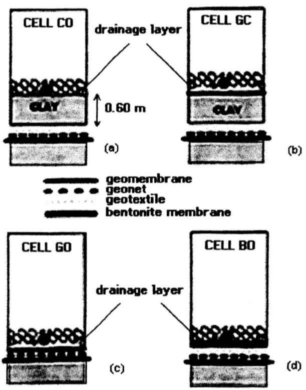

Fig 5.2 (a) to (d). The four lining system

This system is only in use at the bottom of the cells up to an intermediate trench 1.5 m from the bottom. The leakage can be collected in a sump located at the lowest point of each cell.

Regardless of the nature of the structure or its contents, the purpose of the lining system is containment of leachate. With leachate that would have deleterious effects on the surrounding environment, double lining and four lining systems have been developed. These multiple linings can intercept leakage which occurs through the top liner and control the driving forces to the lower liners so that leakage through the bottom liner can be minimised.

Regardless of the configuration of the lining system, the primary concern in the design is the magnitude of leakage through the top liner of a multiple-lined system. In evaluating the performance of the system the leakage ratio is the more practical and verifiable parameter. The leakage ratio is defined as the ratio of the leachate quantity to the leakage quantity and is given (Akgun, 1997) by

$$LR = Q_{LC} / Q_{LK}$$

where LR is the leakage ratio, Q_{LC} is the quantity of leachate (m^3/s) and Q_{LK} is the quantity of leakage (m^3/s). For a good lining system, it is expected that LR be very high, so that leakage quantity, Q_{LK} will be small. This means that the leakage flow rate through the top liner is indeed very small and the leachate quantity that can be collected is large.

5.3 Calculation of leachate quantity

The leachate flow Q_{LC} represents the quantity of leachate that will seep through a soil drain or flow through a geosynthetic drain situated above the top liner in a multiply-lined system. It is given by

$$Q_{LC} = TiB$$

where *i* is the liner slope of the liner (no dimension) B is the width of the flow path (m) and T is the transmissivity of the leachate collection layer (m^2/s). The higher the transmissivity, the greater the quantity of leachate that can be removed from above the liner. The factor I and B are best kept at value greater than 1 m each for Q_{LC} to be high. However, the value of Q_{LC} is much more dependent on T rather than i and B.

5.4 The transmissivity of the leachate collection layer

The transmissivity of the leachate collection layer, T is given by

$$T=kt$$

where T is the transmissivity of the leachate collection layer (m^2 /s), k is the hydraulic conductivity of the leachate collection layer (m/s) and t is the leachate collection layer thickness (m). Figure 5.3 depicts leachate flowing in a sub-surface drainage.

Figure 5.3 Leachate flow in a sub-surface drainage.

5.5 The hydraulic conductivity, k

According to Tan 1998 the hydraulic conductivity and coefficient of permeability of the soil is the same. The coefficient of permeability can be calculated from

$$k = A/FT$$

where A is the area of bore hole and F is a constant normally taken as 2.5 for clay (BS1377) and T is time before ground pressure occurs in a falling head experiment (Geotechnical Manual for Slopes, Geotechnical Control Office Engineering Development Department, Hong Kong 1984).

5.6 An example

From the equations described above and using values obtained from several literature, let us calculate a value for LR. We already know that,

$$LR = \frac{Q_{LC}}{Q_{LK}}$$

$$= \frac{TiB}{Q_{LK}}$$

$$= \frac{k \times t \times i \times B}{Q_{LK}}$$

$$= \frac{0.0001 \times 1 \times 60 \times 1}{4.2 \times 10^{-7}}$$

$$= 1.4 \times 10^{4}$$

which is in reasonable agreement with some of the results presented by Akgun (1997). In this calculation, the values of $k = 10^{-4}$ m/s, t and B are taken from Akgun (1997) and their value is equal to 1 m and i = 60 from Tan (1998). The value $Q_{LK} = 4.2 \times 10^{-7}$ m^3/s was taken from Berhnard et al., (1992).

Hence to construct a landfill lining system with the aim of preventing pollution to the surrounding area, one can use a collecting layer with transmissivity of 10^{-4} m^2/s. The thickness of leachate collecting layer is 1 m and its flow path width is 1 m. The leachate collecting layer should allow the leachate to leak at a maximum leakage rate of 4.2×10^{-7} m^3/s. Figure 5.4 presents an existing retention pond at Sabak Bernam Landfill.

Fig.5.4 An existing retention pond at Sabak Bernam Landfill.