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INTERFACE SHEAR STRENGTH AND THE SOIL SOFTENING EFFECT ON THE SOIL-GEOCOMPOSITE DRAINAGE LAYER SYSTEM STABILITY

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Abstract

Geosynthetics are commonly used to support solid waste landfill facilities as a liner system due to their low permeability. The application of Geocomposite drain (GD) is increasingly in civil engineering specifically on geotechnical and geoenvironmental system. GD consists of a high flow capacity drainage core with a non-woven geotextiles filters/separator cover. In the landfill capping system, GD has been used as a drainage layer. The soil-geosynthetics or geosynthetic-geosynthetic interfaces play a major role in the landfill cover system's performance. This research work discussed the finding on the field work measurement of the landfill cover system. The trial site of landfill was carried out to investigate the effect of soil water content on the soil-GD interface shear strength of landfill cover/capping. The performance of landfill cover soil panels using different types of geosynthetic drains was studied. The finding suggests that the softening soil layer at the interface of soil-geosynthetic drainage reduces the shear strength as a result of the water accumulated behavior, and this issue has to be addressed in design specifications and construction control for landfill cover system.

Keywords: Capillary break, Geocomposite drain, Interface shear strength, Landfill cover system.

1. Introduction

In construction technology of geotechnical and geo-environmental application particularly on municipal solid waste landfill, the multilayer barrier system composed by soil and geosynthetics are commonly applied. Landfill covers structures consisting of several layers' including soil and different types of geosynthetics. These layers consist of interaction in between interfaces that control the stability of the system. The mechanical parameters of the interfaces that form between the various layers of the landfill cover system are important factors that contributed to the performance of the system. As GD gives a drainage function which can replace the conventional solution by adopting the gravel layer in the application of landfill cover hence the stability will be controlled by the interaction of shear strength between the GD and the adjacent soil layer [1, 2].

The stability assessment on the landfill application guidelines and design framework was established by [3]. Despite design methodology to determine the stability of landfill are widely known [4], failure cases found to be high and can affect the environment [5, 6]. All the potential failure mechanisms need to be studied and monitored based on field or laboratory work using real construction projects or to simulate field circumstances [7-11].

In the previous investigation, the influences of moisture content on the mechanical properties of soil and geosynthetics interfaces have been studied [1, 12-18]. The effects of water accumulation at the position of interface soil-GD in the landfill cover soil induced the capillary break was observed to be a reason for landfill cover failure [19] and other applications [20-22]. The slope failure of Kettleman Hills landfill is confirmed caused by an increment of water at the soil-geosynthetic interface [23] and some failure in the UK site [24]. A capillary break seems to have the consequence of causing water accumulated in the cover soil resulting side slopes failure was observed by [25]. The soil softening layer effects at the interface have a large potential on the cause of slope failure. These water accumulations might be attributed to many factors related as the occurrence of capillary break behaviour occurs at the soil-GD interface [19, 25-28] or related to the increment of water pressure at the position from toe of the panel up to the landfill cover drain [2, 29]. Most of laboratory work and numerical analysis on the capillary behavior have been confirmed by [1, 12, 13]. Heavy rainfall events have also been attributed to the overflow of drainage outlets [1, 29].

The performance of landfill cover/capping was investigated, and data was collected using a field work test designed by the landfill capping panel and carried out in 2014 at Bletchley landfill in the UK.

2. Field works at Bletchley, UK landfill site

The landfill cover/capping system was constructed in autumn 2011 as a field experimental capping system at Bletchley landfill, Milton Keynes, UK (Fig. 1) by [30]. Figure 2 shows the field trial of landfill cover at landfill site. In this research, the field measurement works are measured on the same field site panel. Currently, the Bletchley landfill site is actively operational, but the study was conducted on the new trial capping system on the closed landfill cell.

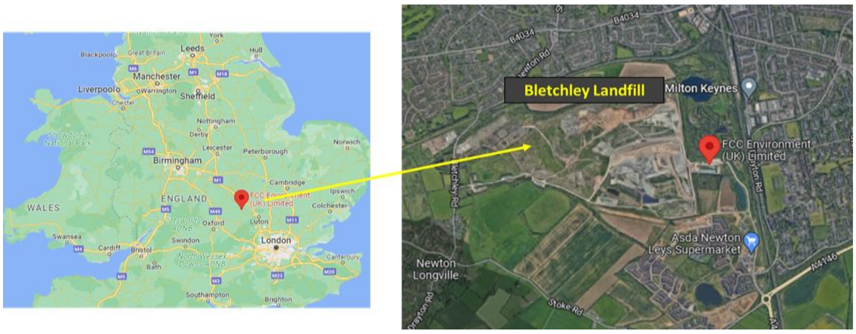

Fig. 1. Bletchley landfill, Milton Keynes, UK trial site [30].

Fig. 2. Bletchley landfill trial site [30].

The primary objective of the fieldwork is to examine the landfill cover system stability using different forms of geosynthetic drains. The field work stages are shown in Fig. 3. The fieldwork is to examine the effects of soil water/moisture content on the interface shear strength of soil-GD layer.

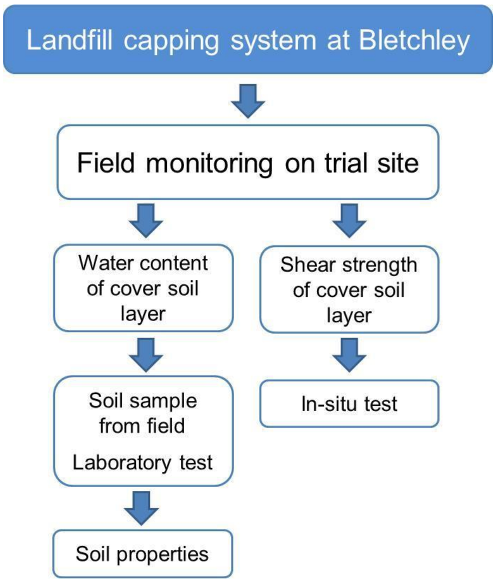

Fig. 3. The primary phases of field work at Bletchley landfill cover trial site.

The capability of four different types of GD is being tested on the field. In this field site, Panel 1 was installed with the geocomposite drain with cuspated core, while Panel 2 is a panel with no geosynthetic drain i.e. control panel, Panel 3 was layered with a non-woven needle punched geotextile sandwiched GD and lastly, Panel 4 was installed using the GD with band drains. Furthermore, Panel 4 features two separate GD sides, one of which had a band drain and the other without any band drain. Figure 4 shows the different types of GD installed. The size of the trial landfill cover panel was 40 x 6 m (length and wide) with a slope inclination of 7.2^o (1v:8h) on average.

Fig. 4. (a) Panel 1- cuspated core GD, (b) Panel 2 (Control panel) - without any geosynthetic drain, (c) Panel 3- non-woven needle punched geotextile GD and (d) Panel 4- GD with band drains and with no band drain side.

In this field work, the trial set were built using compacted clay layer with low permeability. The average thickness of the landfill capping layer is 1 m. This is to replicate a similar landfill cover system in a real construction and to allow any penetration of root from vegetation [8, 9]. The topsoil of cover system is laid over each panel (average of 400 m). Most of the landfills site is using the nearby borrow area or the same site soil as a topsoil layer/restoration soil. This can reduce the operational and material costs.

The effects of water content on the shear strength of soil-GD interface and stability of landfill cover application

The relationship between soil moisture content and the shear strength of soil-GD layer interface influences the stability performance of landfill cover application. The sampling are samples at two different heights including at the position of mid height of the cover soil (0.2 m from the interface) and immediate above interface (0.025 m from the interface) as shown in Fig. 5. In total of 32 samplings of soil were obtained from the trial cover site. The testing on the amount of water in the cover soil above each geosynthetic drain installed was carried out in the laboratory using the soil sampling from the trial set.

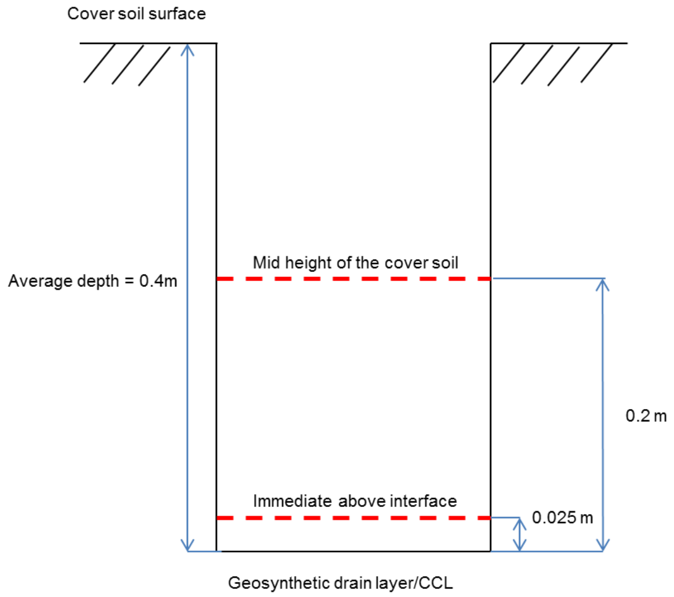

Fig. 5. The soil sampling location on the cover soil layer above geosynthetic drains/CCL panel.

In this field measurement, a mobile type of shear vane apparatus has been applied to assess the in-situ shear strength of the landfill cover soil. The measurement was taken using horizontal and vertical orientation of vane as shown in Fig. 6.

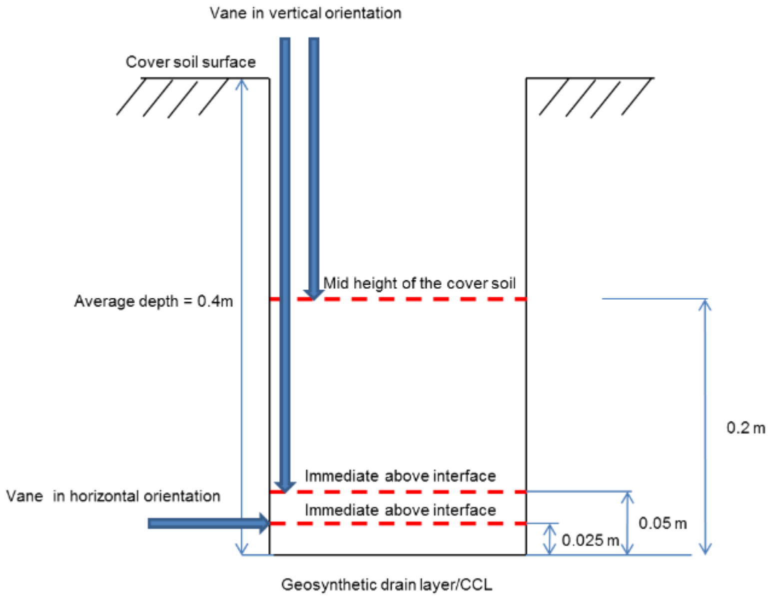

Fig. 6. The measurement of in-situ shear strength on the landfill cover soil layer above geosynthetic drains/CCL position, in both orientations (vertical and horizontal).

3. Results and discussion

The application of different types of geosynthetic drains was examined in this field work measurement. The geosynthetic drain provides a drainage function which can replace conventional solutions of adopting a gravel layer in landfill cover system.

The soil properties of soil samples collected at Bletchley landfill cover site were investigated in the soil laboratory. Based on the Casagrande plasticity chart [31], the specimens resulted to be plasticity clay (CI). The index properties are Liquid Limit (LL) = 50% and Plastic Limit (PL) = 21%. The measured value of landfill cover soil water content is reported in Fig. 7. The highest value was measured at the toe of the panel (0 m from toe) where the soil layer at the immediate above interface. These values were consistent at all panels. In average, Panel 2 consists of higher water content at both positions compared to other panels with an average of 38%. The percentage of water content at the control panel also shows higher compared with panel with drain at Panel 4. Furthermore, water content at the interface of soil-geosynthetics shows an increment along the panel. The water content tends to increase to 30% which exceeds the value of Plastic Limit (21%) of the soil. The results are consistent in all panels. These conditions also agreed by [26, 27].

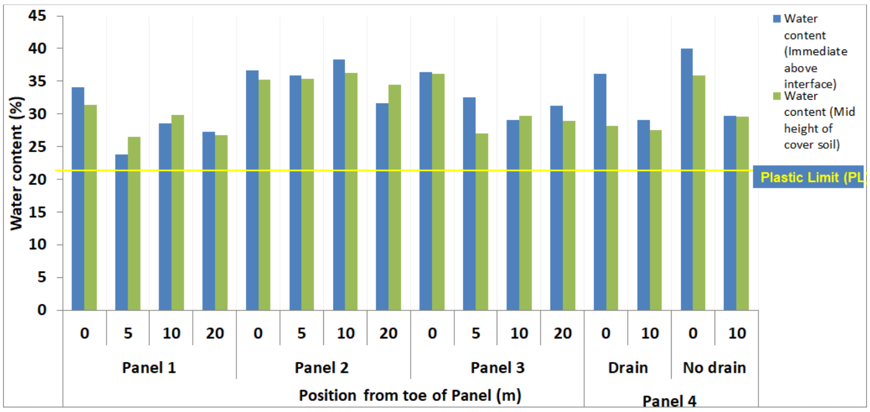

Fig. 7. Soil water content measurements above geosynthetic drain at different position from toe of the panel for Panel 1, 2, 3 and 4 at Bletchley landfill trial site.

3.1. In-situ shear strength of soil-GD layer

Figure 8 shows the observed result of in-situ shear strength on the landfill cover soil at the different position of above the layer of geosynthetic drains/CCL. The results show that the majority of the lowest shear strength consistently shows at the immediate above interface of soil-geosynthetics with horizontal direction of testing with average of 8.6 kPa. The highest undrained shear strength measured mostly around area mid-height of cover soil, further higher of interface with an average of 18 kPa using vertical direction of measurement. The measurement obtained near the toe position is always low compared to the further higher position from toe for all panels. The shear strength of cover soil shows to decrease around 50% especially at Panel 1 and this may have related to water accumulation in a cover soil at the same panel. In average, Panel 1 holds the lowest shear strength.

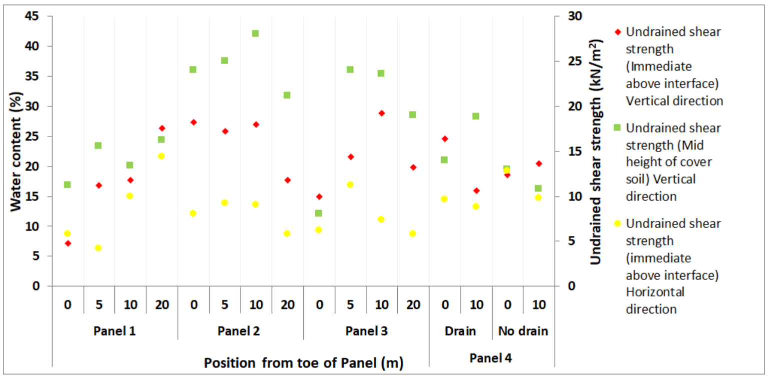

Fig. 8. Undrained shear strength measurements at different position using vertical direction and horizontal direction above geosynthetic drain for Panel 1, 2, 3 and 4 at Bletchley trial panel.

The interaction of interface shear strength that developed between various layers presents the overall performance of the landfill cover application in terms of their stability. As GD functions as a drainage layer in the application of landfill capping system, the interaction between soil-geosynthetic and geosynthetic-geosynthetic interface controlled the stability performance of the system.

3.2. The present of capillary break event at the interface of soil-GD layer

The presence of capillary break behavior caused an increase of water in a cover soil. Water flow in a landfill cover soil tends to pond at the soil-GD interface and starts to accumulate [1, 19, 28, 32-35]. According to GD design, water will flow from the surface of landfill cover into GD through a filter layer directly to the drain core. As non-woven geotextile filters are in contact with cover soil, the interaction between soil particles and water in soil pore at the interface restricts the water from flowing through the GD core [6, 34]. In this situation, the restriction of water is due to capillary break events. This behavior or drying-wetting cycle [36] tends to soften the interface layer due to water accumulation. As a result, the soil-GD layer's shear strength is weakened, and gives a high potential of failure to occur. [32, 33] concluded that the percentage of water in the landfill soil cover beyond GD interface by more than 100% and the shear strength of the softened soil layer reduced to less than 10 kPa.

4. Conclusions

The interaction on the interface of shear strength between soil and geosynthetic layer in landfill cover application is a critical issue related to design. The designer of the landfill cover system stability had consistently ignored the issue related to the soil softening occurring at the soil-GD interface, which contributed to the failure. Key findings and analyses of a fieldwork on the application of landfill cover sites in the UK are described in this paper. The finding discovered that the decrease of shear strength value on the soil softening layer at the interface of soil-GD can be related to capillary break event hence restricting the flow of water. In the design of landfill cover system, the lowest value of interface shear strength is recommended. Currently, the stability and integrity design related to a landfill lining system is highlighted in [14]. But the element on the soil softening at the interface of soil-GD found in this study is not mentioned.

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