Interface Shear Strength of Geosynthetic Clay Liner (GCL) and Residual Soil

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Abstract— **In this study, direct shear box with dimension of 100 mm x 100 mm was used to determine interface shear strength of a GCL and compacted residual soil at optimum moisture content. The tests were carried out using dry GCL sample at shearing rate of 0.5 mm/min. Normal stresses used were between 100 kPa to 300 kPa to represent the depth of 20 meters of solid waste (15 kN/m^3). The needle-punched GCL was tested for both sides, woven and non-woven. Results showed that the residual soil, classified as CL according to the Unified Soil Classification System (USCS) with a hydraulic conductivity of 7.05 to 5.54 x 10^{-9} m/s, was suitable to be used as compacted clay liner (CCL). Test results on the interface shear strength of woven and non-woven GCL with residual soil in terms of internal friction angle were 33° and 37°, respectively.**

Keywords— **Interface shear strength; geosynthetic clay liner (GCL); residual soil.**

I. INTRODUCTION

Malaysia is a tropical country. More than 75 % of the land in Peninsular Malaysia consists of residual soil. This soil has a low hydraulic permeability (10^{-7} m/s) and is suitable for use as compacted clay liner (CCL) for construction of landfill.

Geosynthetic clay liner (GCL) is usually used as a hydraulic barrier (i) at the base of landfill to prevent the flow of leachate into the surrounding soil and (ii) at the top of landfill as cover to reduce infiltration of rainwater into the waste deposit [1] [2]. GCL is used as an alternative to CCL because it has a very low hydraulic conductivity of water (k_w $<10^{-11}$ m/s) and the cost of installation can be considered cheap [3]. It is also used in combination with CCL to provide double protection for municipal solid waste (MSW). For hazardous landfills, GCL and CCL are used in combination with geotextile and geomembrane.

In a construction of landfills, slopes can not be avoided. The interface friction of GCL and soil must be high enough to sustain the load generated during the life of the facility [3]. The value of friction is important because a combination of soil adjacent to the geosynthetics or geosynthetics adjacent to geosynthetics can produce weak surface at which failure or sliding may occur [4].

Due to the importance of interface friction between GCL and soil on slope, a study on the interface shear strength was conducted. Results in terms of residual soil properties and interface shear strength of GCL and residual soil are presented in this paper.

II. METHODOLOGY

To determine the properties of residual soil, several tests were carried out such as (i) particle size distribution, (ii) Atterberg limit, (iii) specific gravity, (iv) compaction, (v) permeability, and (vi) direct shear strength. Table 1 shows the specifications of GCL used in this study according to the supplier.

TABLE I
GCL PROPERTIES

Material Properties	Test Method	Value
Bentonite swell index	ASTM D 5890	24mL/2g. min.
Bentonite fluid loss	ASTM D 5891	18 mL max.
Bentonite mass/sq. area	ASTM D 5993	4 kg/m^2
Grab strength	ASTM D 4632	400 N
Peel strength	ASTM D 4632	65 N
Index flux	ASTM D 5887	1 x 10^{-8} m^3 / m^2 / c
Permeability	ASTM D 5887	5 x 10^{-9} cm/s
Hydrated internal shear strength	ASTM D 5321	24 kPa (typical)

Residual soil was compacted at optimum moisture content (OMC) of 13.9 % and maximum dry density of 1875 kg/m^3. Compaction was done using CBR mould having a diameter of 151.5 mm and height of 127.5 mm. The soil was compacted in three layers with a hammer height of 300 mm and 55 blows per layer to achieve maximum dry density. The soil was cut to the required sizes of 100 mm x 100 mm.

Direct shear test was conducted with the maximum horizontal displacement of 15 mm and a constant shearing rate of 0.5 mm/min. Dimension of the upper and lower shear box was 100 mm x 100 mm. Normal stresses, 100 kPa, 200 kPa and 300 kPa used in this study were to simulate the stresses due to 20 m height of landfill based on the assumption that the density of the wet waste was approximately 15 kN/m^3 [2]. This test was conducted according to ASTM D6243-98 procedures [5].

After the test, shear stress versus displacement was plotted to determine the shear strength at failure for each value of normal stress. The value of shear strength at failure was plotted against the normal stress to obtain the values of friction angle and adhesion.

III. RESULTS AND DISCUSSION

Fig. 1 shows the results of particle size distribution, while Table 2 shows the properties of the sedimentary residual soil. Fig. 2 shows a graph of shear strength based on the relationship between shear stress and normal stress. From the graph, it is estimated that the values of internal friction angle and cohesion of the residual soil are 36.1° and 55.2 kN/m2, respectively.
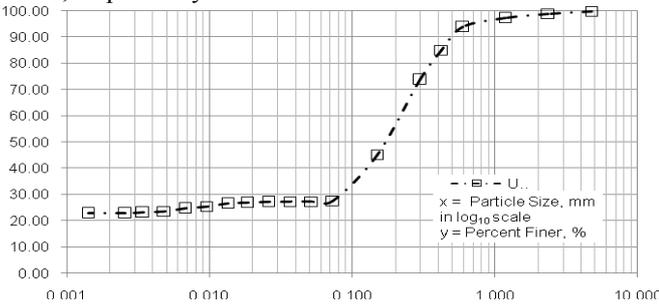

Fig. 1 Particle size distribution of residual soil

TABLE II
PROPERTIES OF RESIDUAL SOIL

Liquid limit, %	35.92
Plasticity index	19.12
Optimum moisture content, %	13.89
Maximum dry density, kg/m^3	1875.18
Specific gravity, Sg	2.57
Hydraulic conductivity, m/s	7.05 - 5.54 x 10^{-09}

Fig. 3 and 4 show the relationship between shear stress and displacement for the woven GCL and non-woven GCL when they are in contact with the compacted residual soil while Fig. 5 shows the comparison between the woven GCL and non-woven GCL in terms of interface shear strength at the time of the failure for certain normal stress value. In this analysis, the shear strength at failure is based on the peak shear strength.
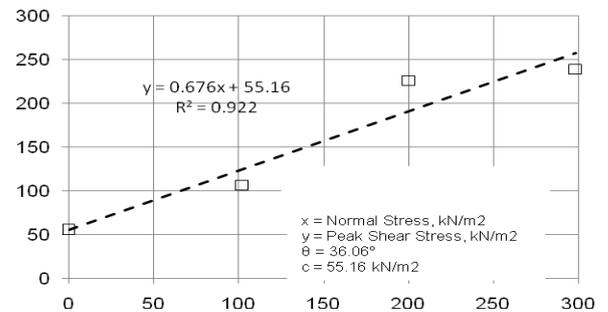

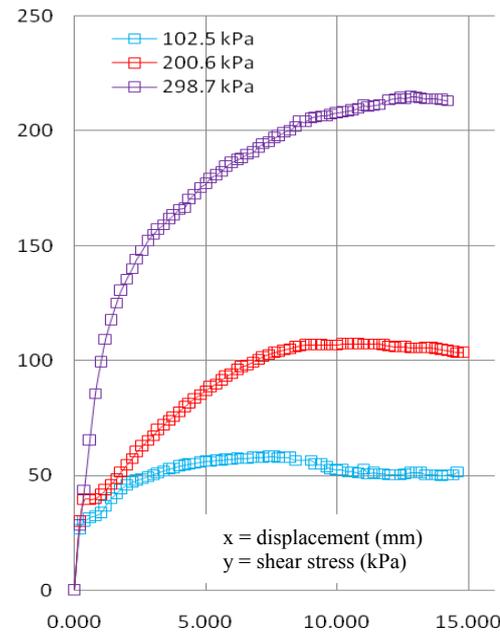Fig. 2 Shear strength of residual soil

Fig. 3 Interface shear strength of woven GCL and residual soil
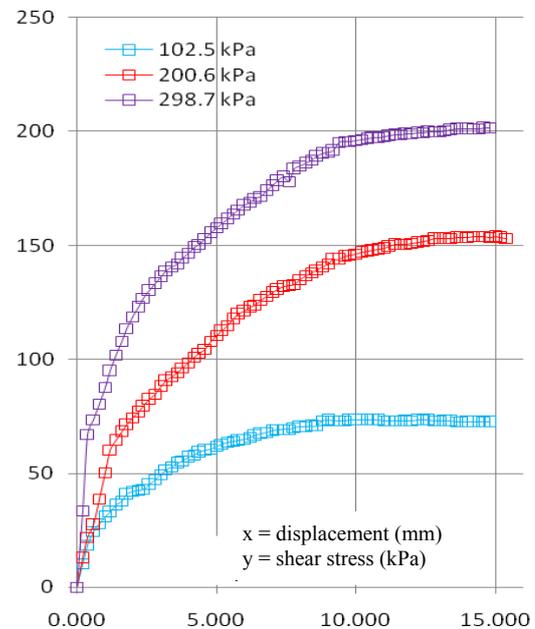

Fig. 4 Interface shear strength of non-woven GCL and residual soil

Hydraulic conductivity for the residual soil sample is in the range of 7.05 to 5.54 x 10-9 m/s. To ensure that functions as a liner, the hydraulic conductivity of the CCL

should be ≤ 1 x 10-9 m/s [6]. Thus, it can be said that the residual soil is suitable for use as CCL in landfills.

The interface friction angle of woven GCL is higher (37°) than that of non-woven GCL (33°) although the difference is small (4°). In terms of adhesion, it is not significant for woven GCL (0 kN/m2) while for non-woven GCL it is significant (12.3 kN/m2). Based on these observations, it can be said that the different textures of geosynthetics provide different interface shear strength values.
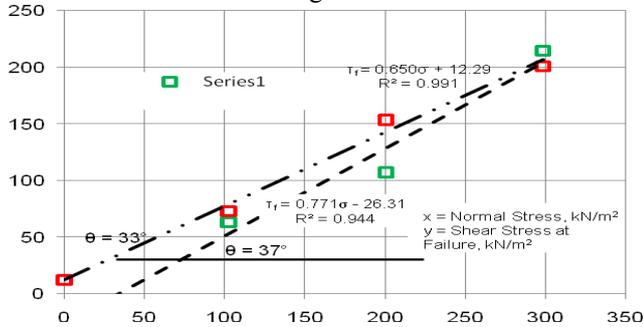

Fig. 5 Shear stresses vs. normal stresses

IV. CONCLUSIONS

In summary, some observations were made after testing the basic properties of residual soil and interface shear strength of woven GCL and non-woven GCL with residual soil using 100 mm x 100 mm shear box. It was found that (i) residual soil could be used as CCL for the construction of landfills because of the low hydraulic conductivity (k = 7.05 to 5.54 x 10^{-9} m/s) and (ii) woven GCL has higher interface friction angle than the non-woven GCL.

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