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Effectiveness of Different Percentage of Bentonite in Soil Liner on Interface Shear Strength with Geosynthetic

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Abstract

Interface shear performance of various percentages of bentonite and fine soil were evaluated for landfill stability by conducting Direct Shear Test. The focus of this study is placed on interface shear strength of fine soil and soil with different percentage of bentonite. Bentonite is currently placed for use as buffer and backfill materials in landfill because these materials create an impermeable zone where it reduced the potential of soil contamination from leachate. In this study, direct shear box with dimension of 60 mm x 60 mm was used to determine the interface shear strength of soil with different percentage of bentonite at optimum moisture content. Normal stresses used were between 100 kPa to 300 kPa to represent the depth of 20 m metres of solid waste. Results showed that the most suitable percentage of bentonite was 5% due to the highest interface shear strength of the mixture with non-woven geosynthetic. Moreover, even the presence of bentonite in the sample is proved to give higher interface shear strength to the tested soil, additional bentonite tends to decreased it shear strength.

Keywords: Soil liner; bentonite; geosynthectics clay liner

INTRODUCTION

Landfills have been the most common methods of organized waste disposal. In most cases, open dumping is being practiced and takes place at about 50% of the total landfills. In addition, many landfills have opted to close rather than meet new while the quantity of waste generated yearly is much faster than the natural degradation process [1].The greatest threat to ground water posed by modern landfills is leachate. Leachate is a high-strength wastewater formed as a result of percolation of rain-water and moisture through waste in landfills [2]. During the formation of leachate, organic and inorganic compounds are transferred from waste to the liquid medium and pose a hazard to the receiving water bodies [3].

Recently, geosynthetic clay liner (GCLs) provides an alternative to compacted clay liners. It has been used to replace and reduce the thickness of compacted clay liners (CCLs) required in composite liner or cover systems for waste containment [4]. Due to important of the interface shear strength between geotextile and residual soil mixed containing with adhesive bentonite, this study is conducted to determine the difference of interface shear strength between geotextile and clay with different percentage of bentonite.

This study is laboratory based research which involved with fine soil which is carried out with several laboratory testing. The basic laboratory tests that have been performed are Particle Density Test and Atterberg Limit which includes Plastic Limit (*PL*) and Liquid Limid (*LL*) in order to determine the Plasticity Index (*PI*). In addition, specific gravity test, shrinkage limit test and pH test also included in this study. After all of the test have been conducted, soil sample is prepared and mixed together with the different percentage of bentonite and the optimum moisture content and maximum dry density are determine in compaction test. Then, direct shear direct test is performed for the determination of interface shear strength of the soil with different percentage of bentonite. Lastly, falling head test is performed to determine the correlation between hydraulic conductivity parameter and shear strength of the soil sample respectively.

MATERIALS AND METHODS

This study is laboratory based research which involved with fine soil which is carried out with several laboratory testing. All the standard tests are conducted based on British Standard as references. The basic laboratory tests that have been performed are Particle Size Distribution, Particle Density Test and Atterberg Limit which includes Plastic Limit (*PL*) and Liquid Limid (*LL*) in order to determine the Plasticity Index (*PI*). In addition, specific gravity test, shrinkage limit test and pH test also included in this study. All of the basic properties tests excluding Particle Size Distribution are performed repeatedly with different percentage of bentonite. After all of the test have been conducted, soil samples are prepared and mixed together with the different percentage of bentonite and the optimum moisture content and maximum dry density are determined in compaction test. The value is used for the preparation of remoulded samples for direct shear test. Then, direct shear direct test (60 mm x 60 mm) is performed for the determination of interface shear strength of the soil with different percentage of bentonite. Lastly, falling head test is performed to determine the correlation between hydraulic conductivity parameter and shear strength of the soil sample respectively.

RESULTS AND DISCUSSION

This study is laboratory based research which involved with fine soil which is carried out with several laboratory testing. All the standard tests are conducted based on British Standard as references.

A. Basic Properties Test

As a result the soil tested in Kampung Kundang, Banting, Selangor can be classified as a Well Graded Sandy SILT according to the Bristish Standard of Soil Classification. Table 1 shows the summary of the parameters in this study.

TABLE I. SUMMARY OF THE PARAMETERS IN THIS STUDY.

Sample	***SG (Mg/m3)***	***LL (%)***	***PL(%)***	***PI (%)***	***PH***	***SL (mm)***
SL-B	2.4	44.26	37.59	7	3.96	1.23
SL-2.5B	2.25	64.24	42.31	22	4.22	3.13
SL-5B	2.42	66.03	43.99	22	4.63	5.73
SL-7.5B	2.47	68.16	46.88	21	4.83	7.33
SL-10B	2.49	72.35	48.64	24	5.4	7.93

The results show that the increasing of bentonite gave higher plasticity of the soil. This was expected since the existence of bentonite giving the chance for more water to retain at the condition of suction. It was proved by Osinubi and Amadi [5] where in their previous studies shows that liquid limit is increased in increasing of bentonite. The mixture of the soil with bentonite displays a clayey nature at relatively high water contents. The influence of the bentonite content is more significant on liquid limit than on plastic limit. Moreover, the presence of bentonite caused the water to absorb and thus resulting the increasing of average elongation of the soil. Bentonite which contains swelling clay minerals such as montmorillonite is inferred to expand and fill the voids in the buffer and backfill materials [6]. In addition, it is proved that the presence of bentonite reduced the acidity of the natural soil and proven by Zanzinger *et. al* [7], where bentonite have typically value of pH 9 or more.

B. Compaction Test

The results of all samples for the compaction test in Figure 1, it is observed that the percentage of optimum water content is increased relatively with the increased of percentage of bentonite. The optimum moisture content for SL-B sample likely was the lowest which was 27.54% while the highest value obtained by SL-10B which also has the highest percentage of bentonite. As can be seen in the value, for all samples, the optimum moisture content only showed a slightly difference of optimum moisture content which increased for about 2% to 8%. Different from the Optimum Moisture Content (OMC), Maximum Dry Density (MDD) is decreased slightly with the increased of percentage of bentonite. SL-10B shows the lowest value of MDD while SL-2.5-D shows the maximum value which was 1.398 Mg/m3. In other hand, when the percentage of bentonite is increased, it gave a vice versa result for the value of the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC)

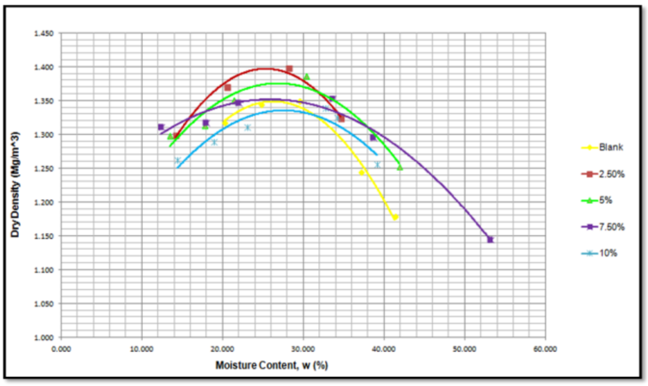

Figure 1: Combination of compaction curve

The maximum dry unit weights corresponding optimum water contents for all samples shown in Figure 2. From the combination graph, the increasing of bentonite caused the increasing of optimum moisture content and reducing the maximum dry density of the soil.

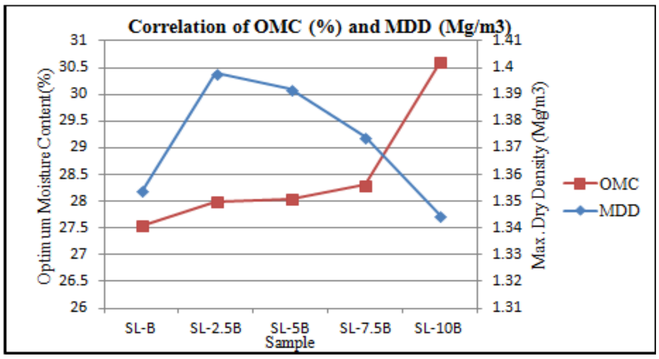

Figure 2: Correlation of OMC (%) and MDD (Mg/m^2)

When fine content (bentonite) is mixed with the soil, more water is required in compaction in order to achieve maximum dry density. When water is added to the mixture, the water acts like lubricant that allows soil particle to move closer to each other, air void is minimized, and higher unit weight can be achieved. When the bentonite was added, the dry unit weight decreased slightly at higher bentonite contents. The bentonite tends to swell further when additional water was added. At this stage, the water and swelled bentonite occupied more space in the compaction mould resulting in decreasing of maximum dry density of the mixtures.

C. Direct Shear Test

Direct shear Test was performed with applied normal stress of 100 kPa, 200 kPa and 300 kPa. Five (5) types of samples are tested giving the results as shown in Table 2. Figures 3,5,7,9,11 are the graph of Relationship Shear Stress and Horizontal Displacement for SL-B, SL-2.5B, SL-5B, SL-7.5B and SL-10B. Figures 4,6,8,10,12 are the graph of cohesion and internal angle.

TABLE II. COHESION AND FRICTION VALUE

Sample	*° (degrees)*	*c (kPa)*
SL-B	35.16	10.85
SL-2.5B	35.45	12.45
SL-5B	37.24	13.29
SL-7.5B	36.80	12.54
SL-10B	36.60	12.00

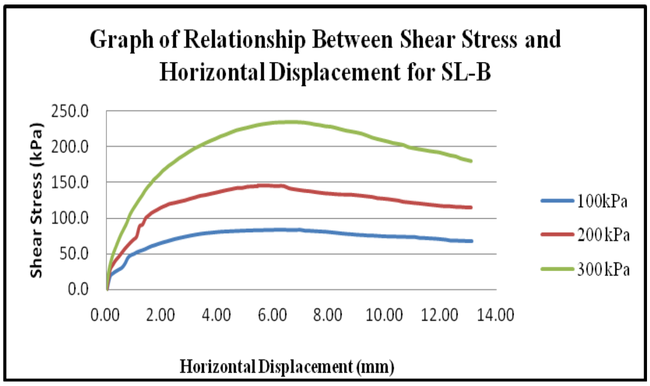

Figure 3: Graph of interface shear strength for SL-B

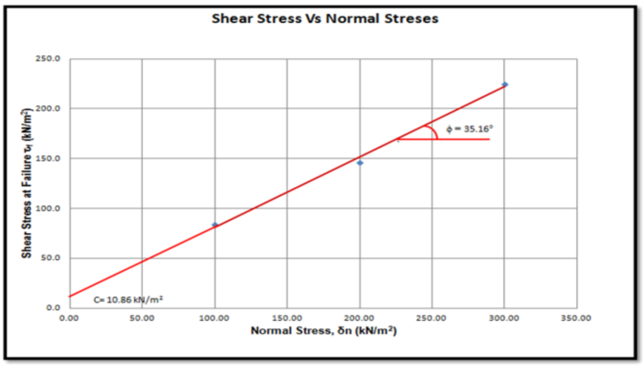

Figure 4: Graph of maximum shear stress vs normal stress for SL-B

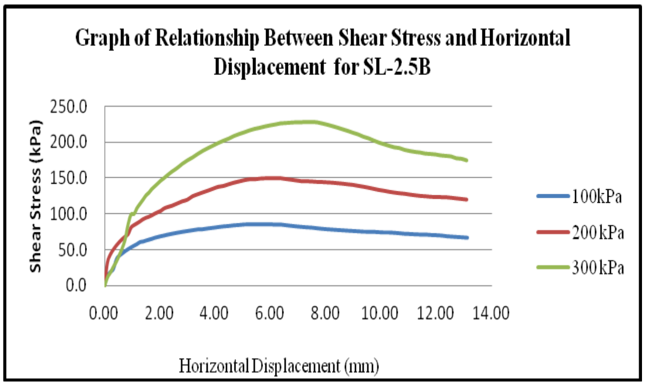

Figure 5: Graph of interface shear strength for SL-2.5B

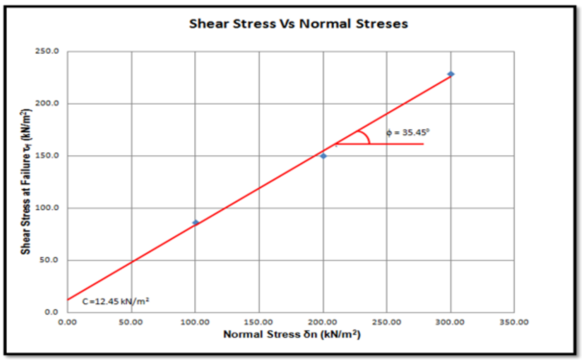

Figure 6: Graph of maximum shear stress vs normal stress for SL-2.5B

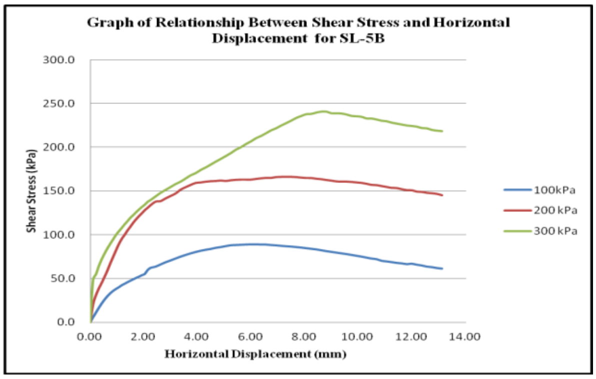

Figure 7: Graph of interface shear strength for SL-5B

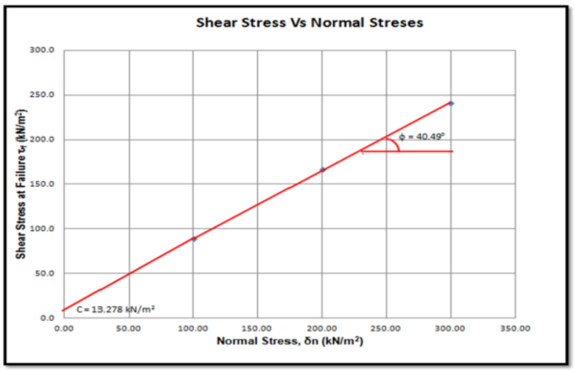

Figure 8: Graph of maximum shear stress vs normal stress for SL-5B

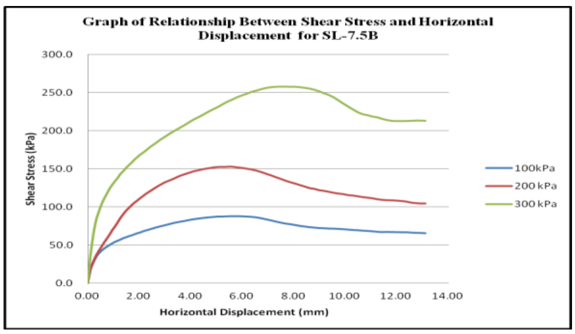

Figure 9: Graph of interface shear strength for SL-7.5B

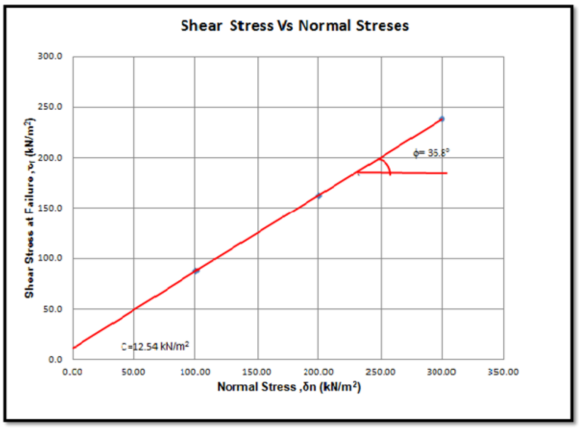

Figure 10: Graph of maximum shear stress vs normal stress for SL-7.5B

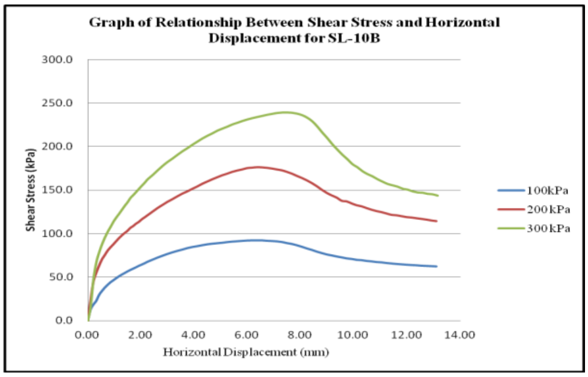

Figure 11: Graph of interface shear strength for SL-10B

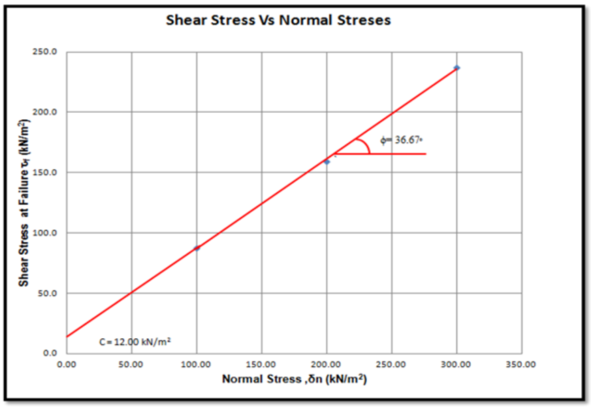

Figure 12: Graph of maximum shear stress vs normal stress for SL-10B

The summary of cohesion and friction angle of the soil is tabulated in Table 3. From the result, the presence of bentonite in the soil did not give a serious impact on the cohesion value and the angle of interface friction between samples and the geotextile. The angle of interface friction was shown to give a minimum value in SL-B which was 35.16° for friction angle and 10.85 kPa for cohesion value. The increased in the percentage of bentonite can help in increasing of cohesion and friction angle for the tested samples of SL-2.5B and SL-5B up to 37.24° for friction angle and 13.29 kPa. The correlation of friction angle (ϕ) and cohesion (C) is visualized in Figure 9.

TABLE III. **COHESION AND FRICTION VALUE**

Sample	*° (degrees)*	*c (kPa)*
SL-B	35.16	10.85
SL-2.5B	35.45	12.45
SL-5B	37.24	13.29
SL-7.5B	36.80	12.54
SL-10B	36.60	12.00

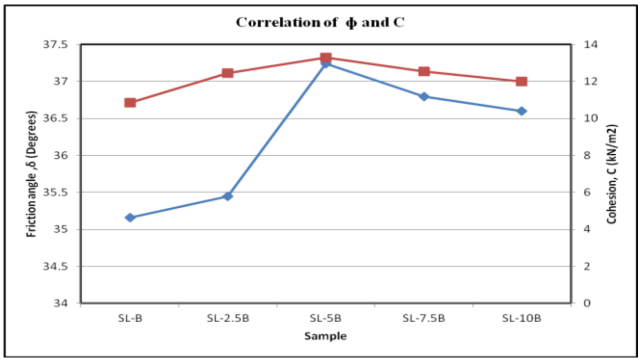

Figure 13: Correlation of friction angle and cohesion

The correlation of the graph in Figure 13 shows that the increasing of bentonite showed the increment until the additional of 5% of the additive. However, there is a limitation for bentonite content beyond which the parameters is dropped due to the increase of moisture content after 7.5% of the bentonite content. From the parameters, the shearing resistance of the soil is calculated for applied normal stress of 100kPa, 200kPa and 300kPa. Shearing resistance at failure for the tested samples shows in Table 4

TABLE IV. **SHEARING RESISTANCE OF SOIL AT FAILURE**

Normal Stress (kN)	*Shear Strength (kPa)*				
	SL-B	*SL-2.5B*	*SL-5B*	*SL-7.5B*	*SL-10B*
100	81.29	83.64	89.3	87.35	86.27
200	151.73	154.85	165.32	162.16	148.53
300	222.16	226.04	241.33	236.97	234.8

D. Direct Shear Test

Two (2) tests were conducted and the average coefficient of permeability is observed. From the result shows that the average coefficient of permeability for natural soil was 4.87365x10-7 cm/sec and for SL-5B was 2.05484 x 10-7 cm/sec. As for comparison, total reduction in permeability was 58 %. It has been observed that permeability decreases significantly with increase of bentonite. According to Nitish and Deepak [8] has found that for bentonite-silt mixtures the permeability varies due to the presence of bentonite which gave the higher total reduction in permeability. It is due to the characteristic of bentonite that tends to fill the void between the soil particles and reduce the permeability of water to flow through it.

CONCLUSION

The increasing of the percentage of bentonite tends to increase the liquidity of the soil resulting in the increasing of Liquid Limit and Plastic Limit. The specific and pH also increased in increasing of the bentonite in the natural soil sample. Moreover, the percentage of optimum water content is increased relatively with the increased of percentage of bentonite. In other hand, when the percentage of bentonite is increased, it gave a vice versa result for the value of the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC). In Direct Shear Test, it shows that even the presence of bentonite in the sample is proved to give higher interface shear strength to the tested soil, however additional bentonite tends to decrease it shear strength. It may happen due to the presence bentonite where its characteristic shows that it absorb higher water in its particle. The bonding between the soil particles might weaken due to the higher presence of water in the soil. In addition, the presence of bentonite reduced the permeability of the natural soil. It shows that the material is suitable to use as a barrier in landfill.

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