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FOREWORD

First and foremost, we would like to extend our sincere appreciation and utmost gratitude to Associate Professor Dr. Ngah Ramzi Hamzah, Rector of UiTM (Pulau Pinang), Dr. Mohd Mahadzir Mohammud@Mahmood, Deputy Rector of Academic Affairs and Dr. Mohd Subri Tahir, Deputy Rector of Research, Industry, Community & Alumni Network for their generous support towards the successful publication of this issue. Not to be forgotten also are the constructive and invaluable comments given by the eminent panels of external reviewers and language editors who have worked assiduously towards ensuring that all the articles published in this issue are of the highest quality. In addition, we would like to thank the authors who have submitted articles to EAJ, trusting Editor and Editorial Board and thus endorsing a new initiative and an innovative academic organ and, in doing so, encouraging many more authors to submit their manuscripts as well, knowing that they and their work will be in good hands and that their findings will be published on a short-term basis. Last but not least, a special acknowledgement is dedicated to those members of the Editorial Board who have contributed to the making of this issue and whose work has increased the quality of articles even more. Although there will always be cases in which manuscripts will be rejected, our work so far has shown that the board members' motivation has been, and will be, to make publications possible rather than to block them. By means of intensive communication with authors, academic quality is and will be guaranteed and promising research findings are and will be conveyed to the academia in a functional manner.

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EVALUATION OF SHEAR STRENGTH PARAMETERS USING SHEAR BOX TESTS FOR SLOPE FAILURES IN PENANG

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ABSTRACT

On 11th December 1993, Highland Tower near Hulu Kelang, Selangor toppled due to slope failure causing 48 residents to be killed. It became the worst nightmare to all Malaysians especially to the residents of the un-failed nearby tower as well as in the engineering lines. Since then, many more slope failures have occurred in Malaysia yearly during the rainy seasons. Hence, slope failure has been ranked as the worst natural disasters in Malaysia. Therefore, the studies on slope failures are becomes more important. Slope failure, also referred to as mass wasting, is the down slope movement of rock debris and soil in response to gravitational stresses. There are many factors affecting slope failures such as weaknesses in the composition or structure of the rock or soil; variation in conditions such as change in rainfall, unorganized drainage or surface stability (removal of vegetation). Among these factors, rainfall, earthquake and human activities are important starter factors that are causing slope failures to occur. This study is to determine the soil shear strength under saturated condition along Teluk Bahang-Balik Pulau road Penang. Saturated shear box tests were conducted to determine the shear strength for soil samples taken from slope failure locations.

Keywords: shear box test; strength of soil; landslides; slope stability.

1. INTRODUCTION

In Malaysia, slope failures occur every year especially during the monsoon seasons. Among the factors causing slope failures are soil types, absence of vegetation cover on slope surface, vibration, slope angle, slope height, drainage system on slope surface, saturation of soil slope due to intense and prolonged rainfall etc. This study is to determine the relationship between physical soil properties and soil shear strength under saturated and at bulk density conditions. Hydrometer and sieve analysis tests to determine the physical soil properties and saturated shear box tests were conducted to determine the shear strength for soil samples taken from slope failure locations. The slope failure locations selected were from slope failure tragedy sites in Balik Pulau, Penang.

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2. LITERATURE REVIEW

Residual soils can be found in many parts of the world. Residual soils are formed from rock or accumulation of organic material and they remain at the place where they are formed as mentioned by Harwant Singh and Huat (2004) which are caused by the rapid rate of rock weathering. The Public Works Institute Malaysia (1996) defines residual soils as a soil which has formed in situ by decomposition of parent material and which has not been transported over any significant distance.

Residual soils contain materials that originate from the in situ parent rocks by mechanical and chemical weathering. The properties of residual soils depend strongly on weathering conditions and features of the parent rocks. The unique formation history of residual soils potentially leads to different engineering properties compared to sedimentary soil which is also known as transported soil (Wang, Guan, & Xin, 2003) and it is not impossible to claim that some of the residual soils are having good engineering materials and some soils may also be problematic.

Some engineering term and interpretation must be understood before we can get the clear view on this residual soil specifically on the test that must be conducted, the indicator required to determine the strength of the residual soil, the stability of soil in term of factor of safety to be considered and so on. According to Schnaid and Huat (2012), in Malaysia, the chemical weathering of the rocks is intense since we are located in wet and hot climates, as in tropical and equatorial climates. Chemical weathering involves decomposition of the rock or in simple words is the breakdown of minerals in the rock by various chemical processes such as oxidation, hydrolysis, carbonation and so on. The products of the chemical weathering are new, secondary minerals such as clay minerals and iron oxides or hydroxides that then remain as part of soil constituents. As stated before, the parent material is one of the main geological factors that control the formation and properties of these tropical residual soils. So, the three major classes of rocks listed as igneous, sedimentary and metamorphic rocks will lead to the different properties of tropical residual soil formation. Besides, the original mineralogical composition of parent rock, its texture and the rock mass structure also affected the final product and depth of weathering. In addition, the geomorphic factors also will affect either the process of chemical weathering or its product. Top or upper portions of hills or slopes will generally contain thicker residual soil mantel compared to those at base or valleys. Well-drained soils produce kaolinite as the predominant clay mineral compared to montmorillonite in poorly drained soils (Schnaid & Huat, 2012).

Therefore, the distribution of tropical residual soils is closely related to the distribution of the various rock types in the country. Hence, Ooi (1982), had produced a geological map for Peninsular Malaysia as in Figure 1 which consists of the distribution of three major classes of tropical residual soils that correlated with the distribution of residual granite soil, residual sedimentary rock soil and coastal or river alluvium formation in nationwide.

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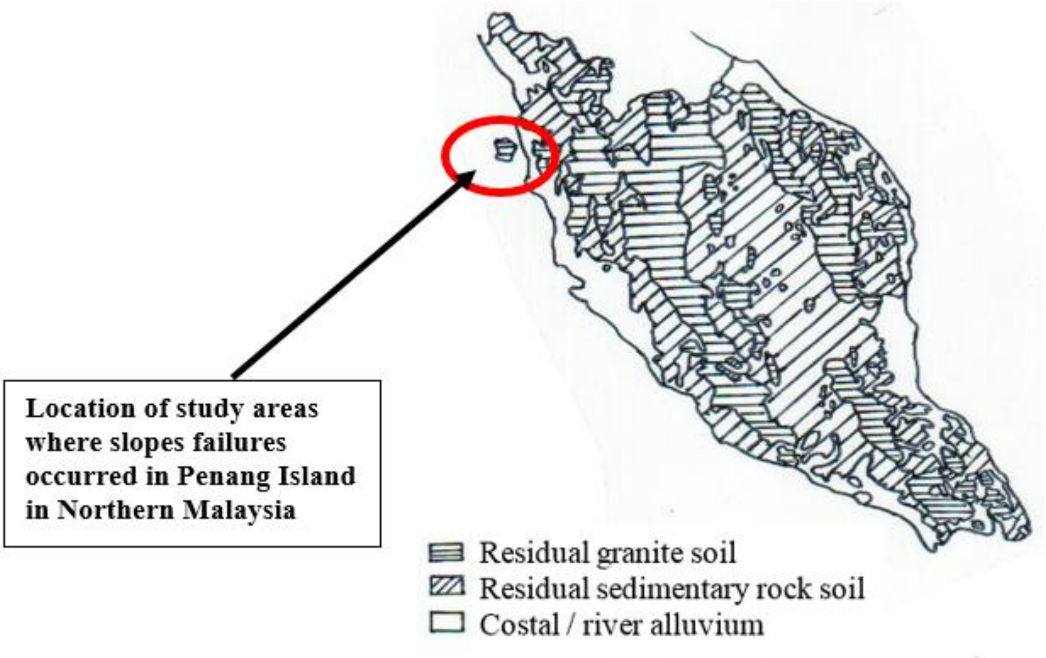

Figure 1: Distribution of tropical residual soils in Peninsular Malaysia (Ooi, 1982).

All locations chosen for this study were residual granitic soils type. Figure 2 shows the geology, notations and locations of the slope failures along Teluk Bahang-Balik Pulau road. The road passed through granitic residual soil as well as alluvium soils.

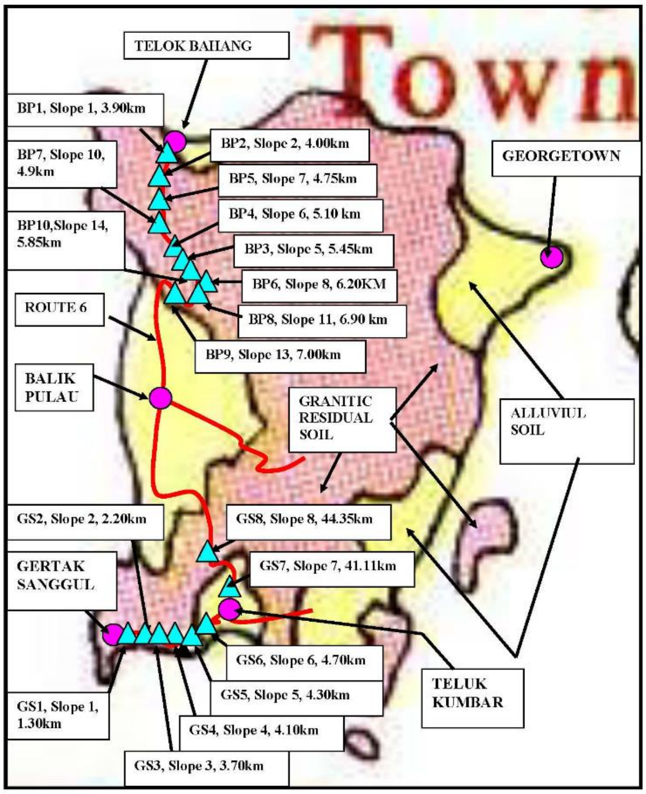

Figure 2: Detailed geology of the slope failure locations in Penang.

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In all slopes, there exists an inherent tendency to degrade to more stable form such as towards horizontal movement. The instability of slope is constructed as the tendency to move, and failure as an actual mass movement. The forces that cause instability of slope are mainly those associated with gravity and seepage, while resistance to failure is derived mainly from a combination of slope geometry and the shear strength of the rock or soil mass itself (Whitlow, 2004).

Slope failures are usually precipitated by variation in conditions, such as a change in rainfall, drainage, loading or surface stability. Such change may occur immediately after construction, or they may develop slowly over a number of years or they may be imposed suddenly at any time. There are three classes of slope failure that have been observed such as falls, slides and flows (Whitlow, 2004). Slopes stability is also necessary to consider whether slope failure is likely to occur along a newly created slip surface, or along a pre-existing one, since the difference between the peak and residual shear strength in some soil may be considerable (Whitlow, 2004).

3. FACTOR AFFECTING SLOPE STABILITY

Slope failure, landslides, slips, mudflows and slumps are some common terms used to describe downward and outward movement slope (Omar & Neoh, 1997). Basically a slope will fail if the shear stresses along a critical surface exceed the shear strength. Hence a stable slope can become unstable if the shear strength is reduced by:

i. Additional wetting of soil mass as a result of excessive infiltration by surface water runoff to a ground water.

ii. Loss of suction or decrease of strength as a result of saturation

iii. Gradual loss of strength due to loss of fines materials through seepage flow or weathering process.

iv. Vibration as result of nearby piling activity or blasting.

A force that causes instability is mainly associated with gravity and seepage. Failures occur as a result of a shear failure along internal surface or when there is a general decrease in affective stress between particles due to full or partial liquefaction (Whitlow, 2004).

A slope will also fail when the disturbing forces at critical surface exceed the shear strength. Then the slopes become unstable when the shear strength is reduced by the environments of the slope such as the new construction of new houses where piling or blasting activity will affect the slope stability. Another factor is the decrease of strength or loss of suction and excessive infiltration by surface runoff (Rubber Research Institute of Malaysia, 1990).

There are some factors that can precipitate slope failure:-

i. Effect of water or ice pressure.

ii. Increase in pore pressures that result in loss of shear strength.

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iii. Change in rainfall pattern and drainage systems.

iv. Change in loading and surface protection of slope.

v. Cutting into toe of slope.

In this research, the saturated condition was used in the experiment. This is because, the situation is assume to be the worst case scenario in slope design. The properties of the surface between the object and the slope (e.g. friction) and the physical properties of the sliding object itself all contribute to the potential for mass wasting. The object is more likely to move if friction between the object and the slope is reduced. In contrast, a slope will be less likely to fail if the cohesion between the grains in the material is increased. In contrast, by adding a little water, the cohesion between the sand grains (surface tension) increases dramatically. The addition of excess water to a slope may also be the precursor for a disaster. Not only does excess water saturate the material and reduce cohesion between grains but water saturated pore spaces will support the weight of overlying material thus reducing the effect of friction. Finally, the addition of water may promote instability by adding weight to a slope.

4. SLOW (DRAINED) TEST ON CLAYS AND SILT

Since shear box test is more applicable in determining shear strength parameter in terms of total stress, the effective stress of soil can also be apply by using shear box with very slow shearing rate which will not have an effect on the pore water pressure in soil samples. Slow means allowing full drainage or the dissipation of any excess pore water pressure set up during the shear process (Head, 1980). Usually tests for which drainage is allowed is performed with the soil specimen fully immersed in water in order to eliminate the effect of capillary moisture stresses (Head, 1980). So, under these conditions the effective stresses are equal to the applied stresses. This type of test is referred to as a consolidated-drained (CD) shear box test.

5. SOIL SHEAR STRENGTH

Shear strength of the soil is the major factor that affected the landslide occurrence. However in Malaysia, with an estimated 3000 mm of heavy rainfall per year, causing most of the hill slopes in Malaysia greatly exposed to failure and soil erosion (Zainal Abidin & Mukri, 2002). Saturation of soil slope will reduce the soil strength which will lead to numerous collapse and failures to the slopes. The definition of shear strength of a soil mass as stated by Braja (2005) is the internal resistance per unit area that the soil mass can offer to resist failure and sliding along any plane inside it. Strength is the measure of the maximum stress state that can be induced in a material without it failing; fundamentally it is the ability to sustain shear stress that provides strength (Whitlow, 2004). Essentially, shear strength within a soil mass is due to the development of frictional resistance between adjacent particles. Analytically speaking, the contribution of the soil characterization and its physical properties play the main role on determining the stability and the sustainable of slopes.

6. SHEAR STRENGTH PARAMETERS

In this study, the method that was used in determining the shear strength parameter is direct shear test which is uses the shear box tests apparatus. For long term shear strength such as

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slope failure, consolidated-drained (CD) shear test was conducted. In this test, the normal stresses, σ and corresponding values of peak shear strength, τ_f, obtained from the number of tests are plotted on a graph, from which the shear strength parameters are determined (Braja, 2005). The concept of determining shear strength parameter has been adopted from Mohr-Coulomb Failure Criteria. The shear strength of soil is given as equation 1 while the shear strength parameters of soil are the values of c' and ϕ'.

$$\tau_f = c' + \sigma' \tan \phi' \tag{1}$$

Where, τ_f = shear strength of soil

c' = Effective cohesion

ϕ' = Drained shearing angle of internal friction

σ' = Effective normal stress on the potential failure surface

These two parameters are important in predicting the ability of soil mass to sustained loading or pressure that acting on it. The typical value of drained shearing of internal friction is shown in Table 1.

Table 1: Typical values of drained shearing angle of friction for sands and silts (after Whitlow (2004)).

Soil types	ϕ' (deg)
Sand: Rounded grains	
Loose	27-30
Medium	30-35
Dense	35-38
Sand: Angular grains	
Loose	30-35
Medium	35-40
Dense	40-45
Gravel with some sand	34-48
Silts	26-35

7. RESEARCH METHODOLOGY

The summary of overall research methodology are as follows:

i. Disturbed soil samples from failed slopes along Teluk Bahang - Balik Pulau road in Penang and along Balik Pulau - Teluk Kumbar – Gertak Sanggul road also in Penang were taken. For each failed slope, 4 samples were taken from failed zone and 3 samples were taken from un-failed slope section. For each soil sample location, bulk density tests were also conducted.

ii. Test the soil samples using shear box test under saturated and bulk density conditions.

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iii. Find the relationship between the soil shear strength under saturated and bulk density conditions for both roads.

8. COLLECTION OF SOIL SAMPLES

At each slope failure location, seven soil samples were taken. Three soil sample points were taken from un-failed zone while another three soil samples were taken from the failure mass zone and another one sample was taken from failure scar zone. All soil samples were taken in locations of about 100 mm below the existing ground level. Also at each sample point, field bulk density was taken using bulk sampler with a cylinder mould of about diameter 50 mm × 230 mm long. At each sample point, about 200 g of soil was taken for moisture content test and also at each sample point, about 1500 g of soil was taken for conducting hydrometer and sieves analysis tests as well as shear box test.

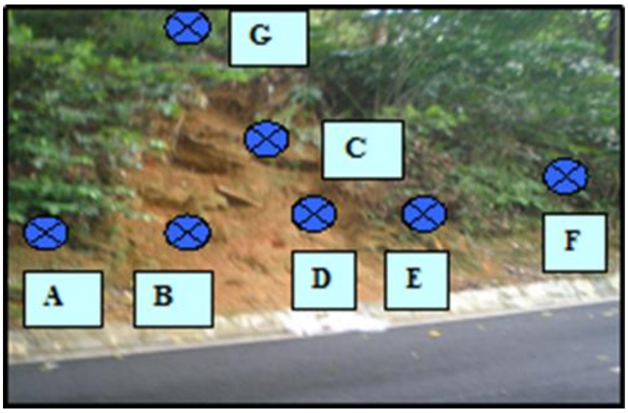

Figure 3: Typical soil sample points (Disturbed Soil).

9. RESULTS AND DISCUSSION

Table 2 shows the summary results of saturated peak shear box tests and particle size distribution tests in this study.

Table 2: Results of saturated peak shear box and particle size distribution tests.

Item	Soil types	Range of cohesion	Range of angle of shearing resistance	Frequency
1	Silt	0.1 – 33.4	22.9 – 47.1	34
2	Very Silty Sand	0.6 – 8.3	30.7 – 62.4	7
3	Sandy Silt	0.0 – 27	18.6 – 52.9	4
4	Very Silty Gravel	0.8 – 37.5	24.5 – 57.2	12
5	Gravelly Silt	0.0 – 40.8	18.1 – 65.8	29

From Table 2 above, soil types commonly found in this study area are silt, very slity sand, sandy silt, very silty gravel and gravelly silt. Silt is the most commonly found soil type in this

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study. Gravelly silt has the largest range of angle of shearing resistance while silt has the smallest range of angle of shearing resistance. Gravelly silt has the largest range of cohesion while very silty sand has the smallest range of cohesion.

Table 3 shows the example results of particle size distribution tests in this study. The result shows that sample mass from unfailed slope consist more gravel particle compare to sample mass from slope failure.

Table 3: Results of soil classification and particle size distribution tests (BS 5930, 1990).

ITEM	SLOPE NO	Km	SOIL SAMPLE LABEL	SLOPE CONDITION	% GRAVEL	% SAND	% SILT	% CLAY	SOIL CLASSIFICATION
1	SLOPE 1 BP1	3.90	A	UNFAILED	64.88	18.08	17.04	0.00	Very Silty GRAVEL
			B	FAILURE MASS	37.92	20.67	41.25	0.16	Gravelly SILT
			C	FAILURE SCAR	36.26	30.16	33.53	0.05	Gravelly SILT
			D	FAILURE MASS	36.88	24.21	38.67	0.24	Gravelly SILT
			E	FAILURE MASS	26.19	36.88	36.85	0.08	Gravelly SILT
			F	UNFAILED	76.93	7.45	15.50	0.12	Very Silty GRAVEL

From Table 4, it can be seen that failure mass with soil type of gravelly silt is the most commonly found. Slope condition of failure mass with soil type of gravelly silt has the largest range of cohesion while unfailure mass with very silty sand has the smallest range of cohesion. Slope condition of failure mass with soil type of gravelly silt has the largest range of angle of shearing resistance while failure scar with very silty gravel has the smallest range of angle of shearing resistance.

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Table 4: Slope condition, soil type, cohesion and angle of shearing resistance.

Slope condition	Soil type	No.	C		Ø	
			low	high	low	high
Failure scar	Sandy SILT	11	0.1	7.5	27.8	49.3
Failure scar	V silty gravel	2	4.2	11.1	31.1	38.8
Failure scar	Gravelly Silt	5	0.9	25.4	18.1	50.0
Failure scar	V Silty sand	0	-	-	-	-
Slope crest	Silt	5	-	-	-	-
Slope crest	Sandy Silt	3	-	-	-	-
Slope crest	V Silty sand	2	-	-	-	-
Unfailed	Silt	10	0.1	10.0	24.3	47.1
Unfailed	Sandy silt	14	0.1	27	24.3	45.1
Unfailed	V Silty sand	3	0.6	8.3	30.7	62.4
Unfailed	V silty gravel	6	0.8	37.5	24.5	48.4
Unfailed	Gravelly silt	8	0	23.4	25.1	48.1
Failure mass	Silt	13	0.4	29.1	22.9	41.9
Failure mass	Gravelly silt	23	0	14.2	18	49
Failure mass	V silty sand	2	11.6		31.4	
Failure mass	Gravelly silt	17	0.6	40.8	21.1	65.8
Failure mass	V silty gravel	4	3.1	12.0	40.2	57.2
Failure scar	Silt	6	0.2	12.1	27.7	38.7

10. CONCLUSION

The soil types commonly found in this study area are silt, very silty sand, sandy silt, very silty gravel and gravelly silt of which silt is the most common. Gravelly silt has the largest range of angle of shearing resistance while silt has the smallest range of angle of shearing resistance. Gravelly silt has the largest range of cohesion while very silty sand has the smallest range of cohesion. It can be seen that failure mass with soil type of gravelly silt is the most commonly found. Slope condition of failure mass with soil type of gravelly silt has the largest range of cohesion while unfailure with very silty sand has the smallest range of cohesion. Slope condition of failure mass with soil type of gravelly silt has the largest range of angle of shearing resistance while failure scar with very silty gravel has the smallest range of angle of shearing resistance.

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