LANDSLIDE ASSESSMENT ON UTP CUT SLOPE

by

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CERTIFICATION OF APPROVAL

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project. The original work of this project is my own except as specified in the acknowledgements and references, and that the original work contained herein have not been undertaken or done by unspecified persons.

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NUR AMIRA BINTI ABDUL RASHID

ABSTRACT

This project aims to study the causes and design the slope failure at Block 14, Universiti Teknologi PETRONAS (UTP). The causes of the slope failure need to be investigated and it can prevent the slope failure occur again. Preliminary observation, site survey, soil investigation, soil laboratory testing and design the stability of cut slope are the methodology for this project. This project started with preliminary observation which performs the observation on the cut slope current condition, drainage system, type of vegetation and the surrounding of the cut slope. Site survey consists of topography survey as to identify the current geometry of the cut slope. In this project, there are two methods for soil investigation, which are open pit sampling and rotary wash boring. Water stand pipe and an inclinometer have been installed to monitor the ground water table and measure the movement of the cut slope respectively. Soil laboratory testing is used to determine the soil parameters of the cut slope and the list of tests are moisture content, atterberg limit, sieve and hydrometer analysis and triaxial test. GeoStudio software utilized to design the stability of cut slope by using slope/w application. The slope failure has caused by the poor maintenance at the drainage channels and modified slope has been designed using rock filling.

ACKNOWLEDGEMENT

First and foremost, I would like to extend all praises and thanks to Allah SWT, the Lord of the World for giving us the blessings and opportunities to undergo this Final Year Project. My deepest appreciation goes to my supervisor, AP Ir Dr Hisham Bin Mohamad for his guidance and supports in completing this project. I'm also would like to thank to Ir Shukri Ahmad as willing to help and keep explaining about my job scope. Not to forget to my beloved parents, friends and lab technicians for their support during my study. Special appreciation goes to contractor who helped me to obtain the soil investigation and site survey data in order to do analysis and design the slope failure. Lastly, many thanks are presented to all parties that are directly and indirectly involved in this project.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Slope failure is always happening in Malaysia, especially in rainy season. The general term of slope failure is defined as mass wasting which includes the downslope movement of material under the influence of gravity. The soil condition also plays an important role in solidifying the slope conditions without failure. Slope failure will give an impact hazard to the public and facilities if it is not recoverable immediately. Slope consisting of two types are man-made and natural slope. Rupke et al. (2007) defined the man-made slope should be designed based on the natural physical, hydrological and rock and soil mechanical conditions while for the natural slope is at the hilly areas used for the construction of roads and other infrastructures.

In this project, the cut slope which is man-made slope is located near to Block 14 and 13 as shown in *Figure 1-1* consists of three-level berms covered with vegetation of ferns and trees. *Figure 1-2* shows the slope failure at Block 14 is occurred at the second berm of the cut slope. It is categories as localised slope failure as the area affected is about 1.5 m depth and the extended of the slip is relatively shallow. Robert W.D. (1996) mentioned, superficial slope failure could be destructed the landscaping, irrigation, and drainage lines of the slope. The signs of the slope instability can be observed to the tension crack at the crest, tilting trees and bulging of soils near the lower berm.

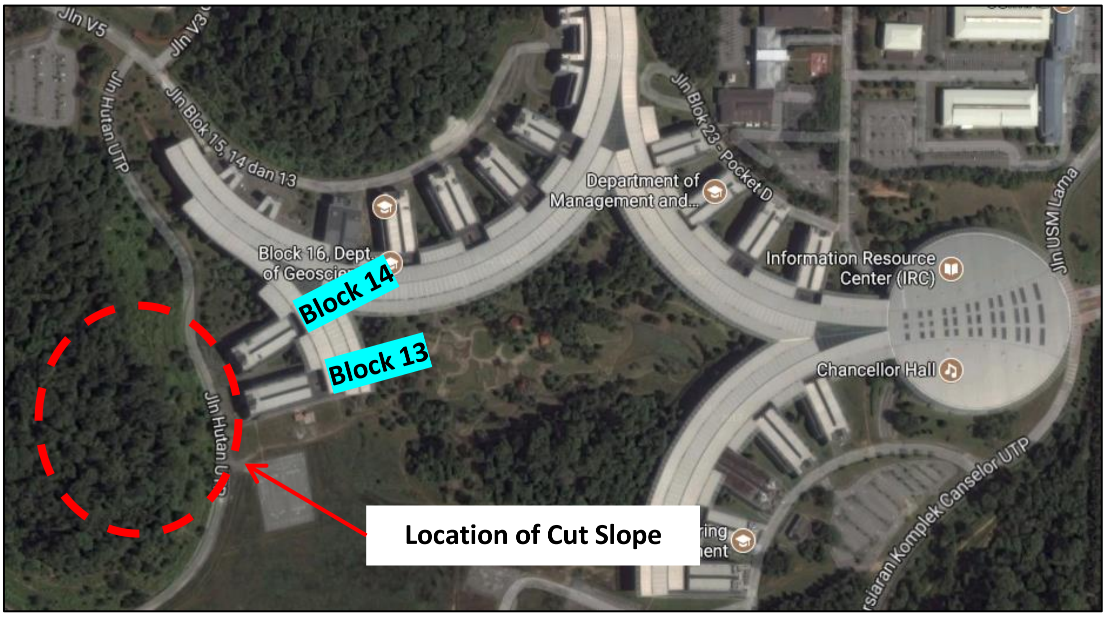

Figure 1-1: Location of Cut Slope *(Source: Google Earth)*

Figure 1-2: Slope Failure View from Block 14 *(Source: Author)*

1.2 PROBLEM STATEMENT

Localised slope failure incident at Block 14, UTP was identified at the second berm of the cut slope which consists of three-level berms and it has been happening on February 2017. The soil condition, drainage system, high ground water level and the type of vegetation in the cut slope area might be the causes of the slope failure. Due to that, further investigation on the slope failure is required to do and the next step should be taken in order to ensure the condition of slope failure does not cause destruction to public.

1.3 OBJECTIVES

The purpose of the "Landslide Assessment on UTP Cut Slope" project is to achieve these following goals;

i. To investigate the root cause of the slope failure mechanism.
ii. To study the geotechnical details of the slope failure and re-design the slope.

1.4 SCOPE OF STUDY

This project focuses on identify the causes of the slope failure and re-design the slope. Project started with preliminary observation of the current site condition and including the site survey. Besides, soil investigation will be carried out, followed by laboratory tests to obtain the soil parameters that will be used in designing.

CHAPTER 2

LITERATURE REVIEW

2.1 TYPES OF SLOPE FAILURES

According to Vardon P.J et al. (2017), five types of slope failures have been identified which are rotational slides, translational slides, superficial slides, earthflows, and spread. Each type of the slope failure has its own characteristic and *Figure 2-1* shows the example of slope failures. The rotational slides, little slumps that deformed are slides along a surface of rupture which the curve of failure is concavely award. Translational slides occur when the mass wasting is moving down from the surface and has a little rotary movement. It will always happen if the surface on the slope is at rest and inclined while the shear resistance is lower than driving force. The difference between rotational and translational slides is the planning control measures (Varnes D.J, 2005).

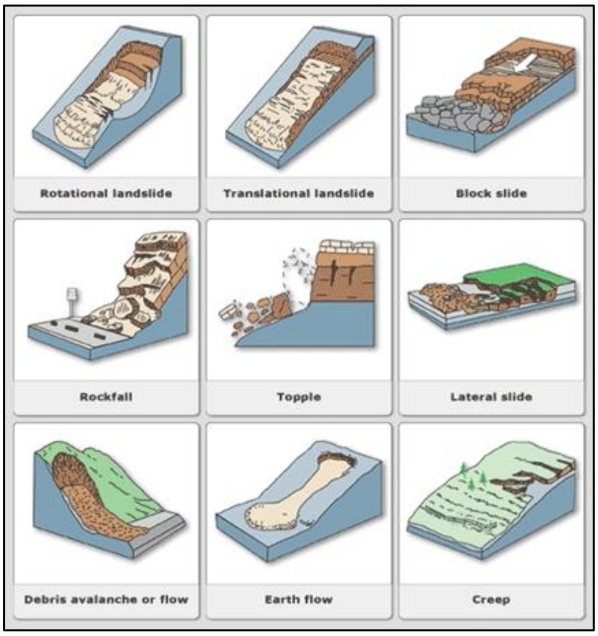

Figure 2-1: Example of Types of Slope Failures ***(Source: Google Image)***

Day, R.W. (1996) reported that slides are types of shallow slope failures that are parallel to the slope face and it can accidentally happen without any warning of the potential slope failure. Earthflow is a downslope viscous flow when the volume of water containing in the coarse and fine-grained is high. Spread slope failure is defined as the fracturing that involving movement of the extension cohesive soil.

2.2 GEOTECHNICAL INSTRUMENTATION

Geotechnical instrumentation is important in terms of acquiring information and data as a project requirement. Durham Geo Slope Indicator (2004) stated, before selecting the instruments to be used in this project, engineers must identify the parameter needed to measure. For this project, water standpipe, inclinometer and rotary wash boring used for data gathering. Robert, W.D. (1996) mentioned in his research paper that the result recorded by inclinometer does not show all the movement at specific depth but it consist of progressive deformation.

Water standpipe is required to measure the ground water level and pore water pressure in soil. The reason of monitoring the pore water pressure is to determine the safe rates of fill, predict the slope stability, design and build for lateral earth pressures and monitor the effectiveness of drainage schemes. Sew, G.S. and Chin, T.Y. (2000) highlighted, subsurface exploration generally used rotary wash boring to obtain all the data of subsurface condition such as depth of soft soil, hard stratum, and depth of bedrock.

2.3 SLOPE STABILITY

The repairing of slope failure is very significant in every slope failure cases which involving many methods after obtained the soil parameters from the soil investigation work. According to Robert, W.D. (1996), surficial slope failures commonly occur in Southern California and the repair method including the rebuild failure area, geogrid repair, soil-cement repair and also pipe piles and wood lagging. Rebuild failure area method's is not effective because the shear strength of soil remain the same as the soil in the affected area is re-used to bury the failed area. Geogrid repair is acting as reinforcement and depending on the shear strength of import fill, slope inclination, and the thickness of the potential failure mass. The import fill is compacted to fill about 90% of the modified proctor maximum dry density while for soil-cement repair method's there is slightly difference where the import fill is mixed with 6% cement. The last method of repair slope failure in the Southern California is pipe pile and wood lagging. This method used hollow galvanized steel pipe and wood lagging which is placed behind the steel pipe as a retainer with compacted fill. However, the deprival of this method is the steel pipe piles have low capacity of flexural strength and the system not designed properly that causes of fail.

The study of stability of man-made slope should be started with identify the existing natural hazards (Rupke, J et al, 2007). Based on JKR Guidelines for Slope Design (2010), after designing all the geotechnical works, Independent Geotechnical Checker (IGC) must check the design and approved by Project Director (PD). The slope stability analysis is including the design criteria and performing calculation data should be based on detailed site plans, detailed field descriptions and laboratory test data which may have to identify the weakest potential of failure surface.

CHAPTER 3

METHODOLOGY

This chapter describes the process flow of this project in order to ensure this project successful. Preliminary observation, site survey, soil investigation, soil testing and slope failure design are the methodology in this report and providing the description.

3.1 FLOW CHART

Flowchart in *Figure 3-1* shows the procedure of this project execution as the following;

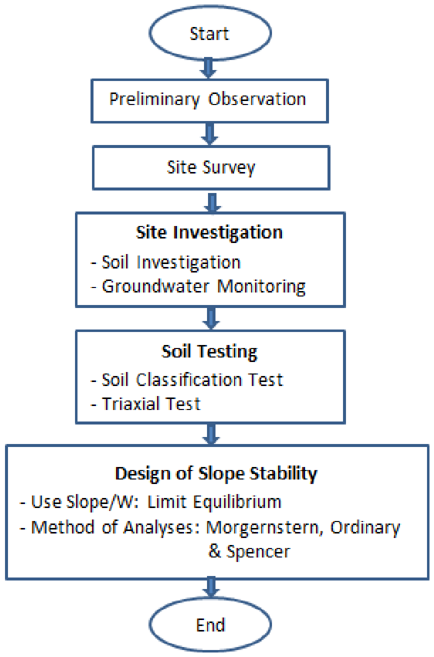

Figure 3-1: Flow Chart of the Project Execution

3.1.1 PRELIMINARY OBSERVATION

"Landslide Assessment on UTP Cut Slope" project will start with preliminary observations of slope failure area such as identify the vegetation types, drainage system, soil conditions and current conditions in the failure area.

3.1.2 SITE SURVEY

Site survey is included in this project to identify the geometric measurement of the slope area and produce a topographic map as to know the geomorphology features (Sew G.S. and Chin T.Y, 2000). Total station and prism pole as shown in *Figures 3-2 and 3-3* are the basic instruments that are very important to measure the exact coordinates of the location.

Figure 3-2: Collecting the Coordinates using a Total Station (*Source: Author*)

Figure 3- 3: Holding Prism Pole for Data Collection *(Source: Author)*

3.1.3 SITE INVESTIGATION

The purpose of the soil investigation is to provide technical information and analysis from field and laboratory testing to enable designer to decide and design the slope mechanism system of the proposed project. In this project, soil sample from rotary wash boring and open pit sampling were taken as the points of each method of sampling is different. The points of the open pit and rotary wash boring sampling are shown in *Figures 3-4 and 3*-5 respectively. Each method of sampling has two points which points for open pit sampling are in failure area while points for rotary wash boring are in the upslope area.

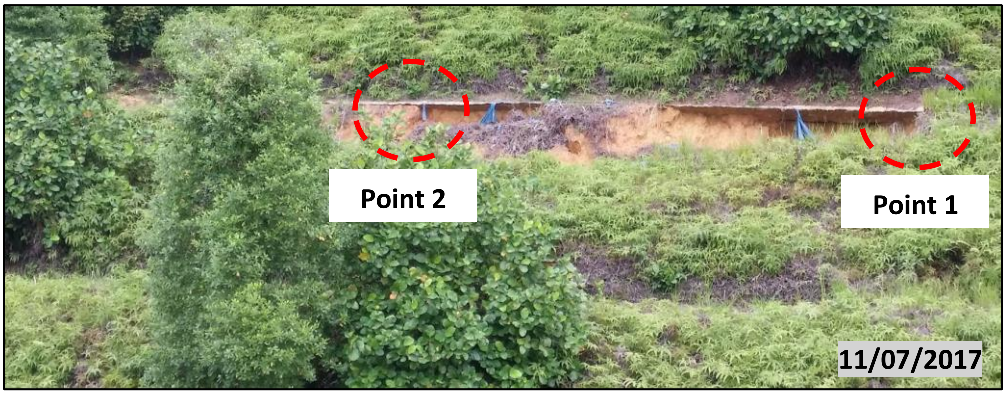

Figure 3-4: Points for Open Pit Sampling (*Source: Author*)

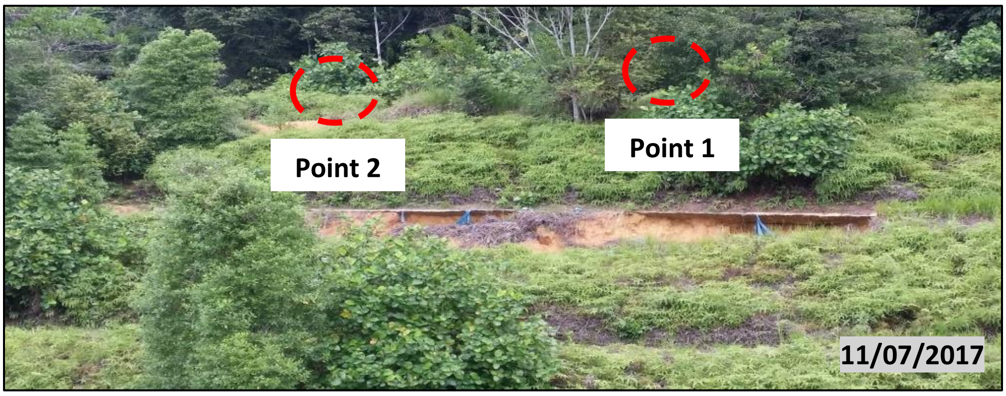

Figure 3- 5: Points for Rotary Wash Boring (*Source: Author*)

Rotary wash boring named Toho D2K as shown in *Figure 3-6* is used to drive a rotary tool tipped with core tube in NW and HW size casing to the specified depths. The soil samples which are disturbed and undisturbed samples were taken at specified depths. The specific depth is reached according to the Standard Penetration Test (SPT). The two points of borehole for rotary wash boring are used to installed inclinometer and water standpipe. Inclinometer was installed to record the movement of the slope while water standpipe is used to measure the water table. The water level of the location is extremely important input in designing as it may identify the soil conditions, and water level is the influencer to the stability of rock, waste rock, and soil or fills slopes. (Durham Slope Indicator, 2004).

Figure 3-6: Rotary Wash Boring (Toho D2K) (*Source: Author*)

3.1.4 SOIL TESTING

Soil laboratory testing could be started after the soil samples are obtained. The function of the soil laboratory testing is to determine the soil parameters that will be used in designing such as unit weight, cohesion, friction angle, and soil classification. The author only performed the laboratory testing for open pit sampling while for the rotary wash boring performed by contractor due to the amount of soil samples collected is not sufficient. The following are the several laboratory tests conducted in this project;

a) Soil Classification Test

i. Moisture Content

Moisture content is a test to measure the water content in soil. In this experiment, four containers for the soil samples as shown in *Figures 3-7 and 3-8* are used in order to obtain the moisture content where the calculation is using Equation 3-1.

$$\boldsymbol{w = \frac{M_2 - M_3}{M_3 - M_1} \, x \, 100\%} \qquad \text{(Equation 3.1)}$$

where;

w is the moisture content (in %)

M_1 is the mass of the container (in g)

M_2 is the mass of the container and wet soil (in g)

M_3 is the mass of the container and dry soil (in g)

Figure 3-7: Moisture Content for Point 1 (*Source: Author*)

Figure 3-8: Moisture Content for Point 2 (*Source: Author*)

ii. Atterberg Limit Determinations

Atterberg Limit consists of two tests which are plastic limit and liquid limit. Plastic limit is defined as the percentage of the moisture content when the soil rolled into threads of 3.2 mm in diameter. *Figure 3-9* shows the shape of the soils after has been rolled.

Figure 3-9: Rolled soil sample (*Source: Author*)

The fall cone method has been used in this experiment to determine the liquid limit. Basically, liquid limit is the moisture content where the apex angle of the cone is 30° and weight of 0.78 N (Das B.M. and Sobhan K, 2014). After the point of the cone has been positioned on the surface of the soil as shown in *Figure 3-10*, it will be penetrated into the soil in 5 seconds.

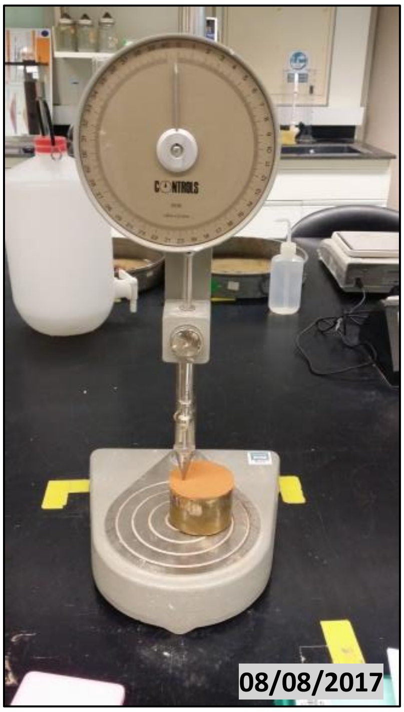

Figure 3-10: Cone's Point at the Surface of Soil (*Source: Author*)

Subsequently, plasticity index require to be calculated to determine the difference between liquid limit and plastic limit. Below is the equation of the plasticity index;

$$PI = LL - PL \qquad \text{(Equation 3.2)}$$

where;

PI is the plasticity index. (in %)

LL is the liquid limit. (in %)

PL is the plastic limit. (in %)

iii. Particle Size Distribution

The particle size distribution test consists of two methods which are wet and dry sieving. Wet sieving as shown in *Figure 3-11* is applicable for cohesion less soil while dry sieving for soil containing insignificant quantities of silt and clay. In wet sieving procedure, hydrometer test is utilized by measuring the density of soil suspension at various intervals until 24 hours as shown in *Figure 3-12*. The combinations of the two methods are the continuous particle size distribution curve of soil to be plotted from the coarsest particle down to the clay size.

Figure 3-11: Preparation for hydrometer test by wet sieving (*Source: Author*)

Figure 3- 12: Hydrometer Test (*Source: Author*)

b) Triaxial Test

Triaxial test is used to measure the mechanical properties of the soil such as angle of shearing resistance and apparent cohesion. There are three standard types of triaxial test which are consolidated-drained test (CD), consolidated-undrained test (CU) and unconsolidated undrained test (UU). In this project, CU test is conducted and the saturated soil specimen is first consolidated by an all-around chamber fluid pressure that results in drainage. Mohr's

Circle obtained from this type of triaxial test which in sand and normally consolidated clay.

3.1.5 DESIGN OF SLOPE STABILITY

In designing the stability of the cut slope failure area, Geoslope Studio Software has been used by using slope/w application. The soil parameters such as unit weight, cohesion and friction angle are important as an input in the software in order to find the factor of safety. There are three types of analysis chosen to design the slope stability which are Morgenstern Price, Ordinary Method and Spencer Method. Morgenstern Price is the best-fit in regression solutions which have direction of the interslices force. In ordinary method, is the simplest analysis among the other analyses types that the interslices force can be neglected because parallel to the base of each slice. The last analyses type is Spencer Method that has constant relationship between the magnitude of the interslice shear and normal forces.

The slip surface is a failure closely follows the arc of a circle that usually toes to the bank. Entry and Exit and Grid and Radius are the slip surface option utilized in this project. The number of critical slip surface is about 30 because the more reading taken, the more accurate the result. The factor of safety of the stability cut slope must be in the range of 2.0 to 3.0 to avoid the failure occurring.

3.2 KEY MILESTONE

Figure 3-13 shows the key milestone for this project;

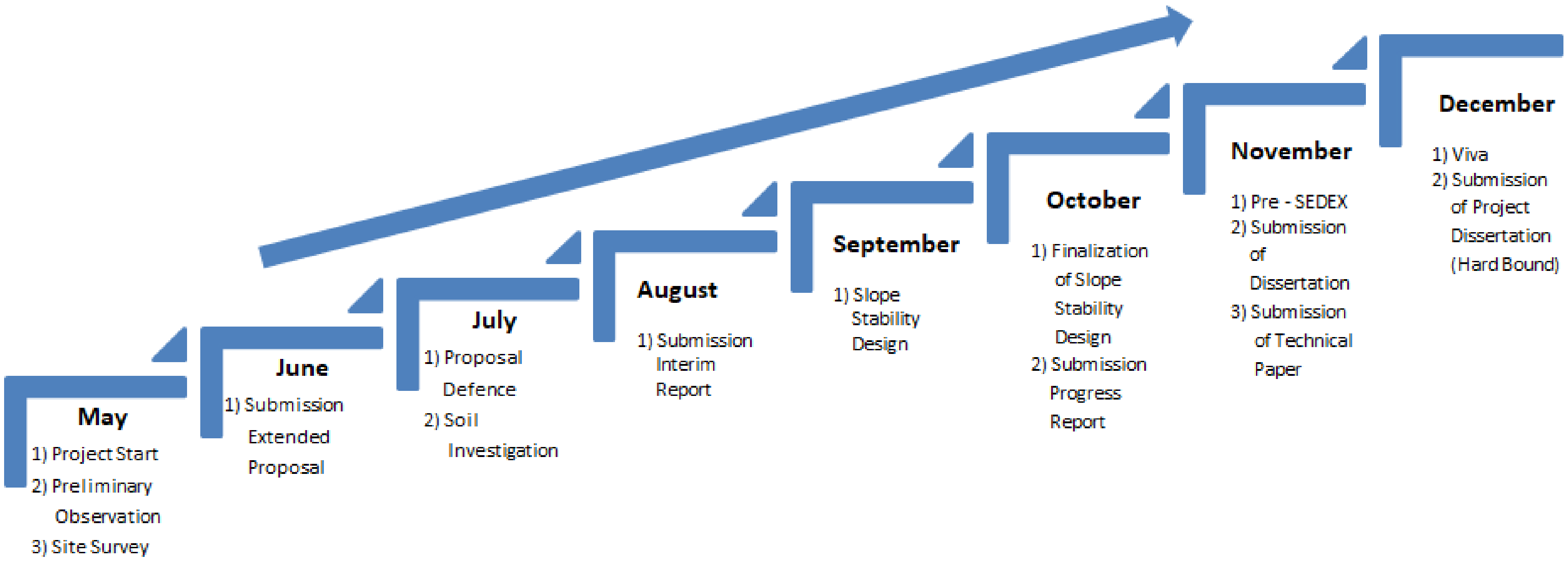

Figure 3-13: Key Milestone for FYP 1 & 2 (*Source: Author*)

3.3 GANTT CHART

Table 3-1: Gantt Chart for FYP 1

NO	ACTIVITIES	MAY			JUNE				JULY				AUGUST		
		W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
1	Selection of Project Topic														
2	Brief Explanation of Project Topic														
3	Topographical Survey														
4	**Extended Proposal:** Chapter 1: Introduction														
	Chapter 2: Literature Review														
	Chapter 3: Methodology														
5	**Interim Report** Chapter 1: Introduction														
	Chapter 2: Literature Review														
	Chapter 3: Methodology														
6	Submission of Extended Proposal														
7	Raya Holiday														
8	Proposal Defence														
9	Site Investigation														
10	Soil Sampling														
11	Laboratory Test														
12	SI Report														
13	**Interim Report** Chapter 4: Result & Discussion														
	Chapter 5: Conclusion & Recommendation														
14	Submission of Interim Draft Report														
15	Submission of Interim Report														

Table 3-2: Gantt Chart for FYP 2

NO	ACTIVITIES	SEPTEMBER			OCTOBER				NOVEMBER					DECEMBER	
		W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
1	Slope Stability Design														
5	Finalization of Slope Stability Design														
6	Preparation of Reports and Presentations														
7	Submission of Progress Report														
8	Pre-SEDEX														
9	Submission of Draft Final Report														
10	Submission of Dissertation (soft bound)														
11	Submission of Technical Paper														
12	Viva														
13	Submission of Project Dissertation (Hard Bound)														

CHAPTER 4

RESULTS & DISCUSSIONS

4.1 DETAILED OBSERVATIONS

Based on the site survey to the slope failure area, the author found that the drainage system at a certain placement is damaged either not functioning. *Figure 4-1* shows the drainage at the third berm of slope and the red line shows the drain that has been covered by soil and dried leaves. This problem has caused the drain clogged and water does not have a correct flow line. Besides, the clogged drains also cause stagnant water as in *Figure 4-2* and indirectly become mosquito breeding place.

Figure 4-1: Clogged Drain (*Source: Author*)

Figure 4-2: Stagnant Water in the Drain *(Source: Author)*

Figure 4-3 shows the drain’s position has moved from the original position. The movement of the drain might be caused by the movement of the soil towards water flow. Sew, G.S. and Yun, W.S. (2010) mentioned that infiltration and erosion that causes by heavy rain can be reduced by maintaining the quality of the drainage system. High infiltration from heavy rain and catchment areas has also caused the slope failed. The soil strength reduced because having high water content and *Figure 4-4* shows the cracked drain due to the damaged discharge line.

Figure 4-3: Misaligned Drainage (*Source: Author*)

Figure 4-4: Cracked Drain *(Source: Author)*

4.3 EXISTING SLOPE SURVEY

The site survey has been carried out on 20th May 2017 by the certified experience surveyor which covers the approximate 50m (L) x 12m (W) x 15m (H) and the specified area of landslide of 76.5m^2. The survey works details includes of taking EGL of each berm height, road level, drainage and specified the localised slope failure. The slope failure extends from second berm drain to first berm drain which covers at approximate 20 m length as shown in *Figure 4-5*. *Figure 4-6* shows the cross section of the slope zone with specifies the horizontal distance of each berm.

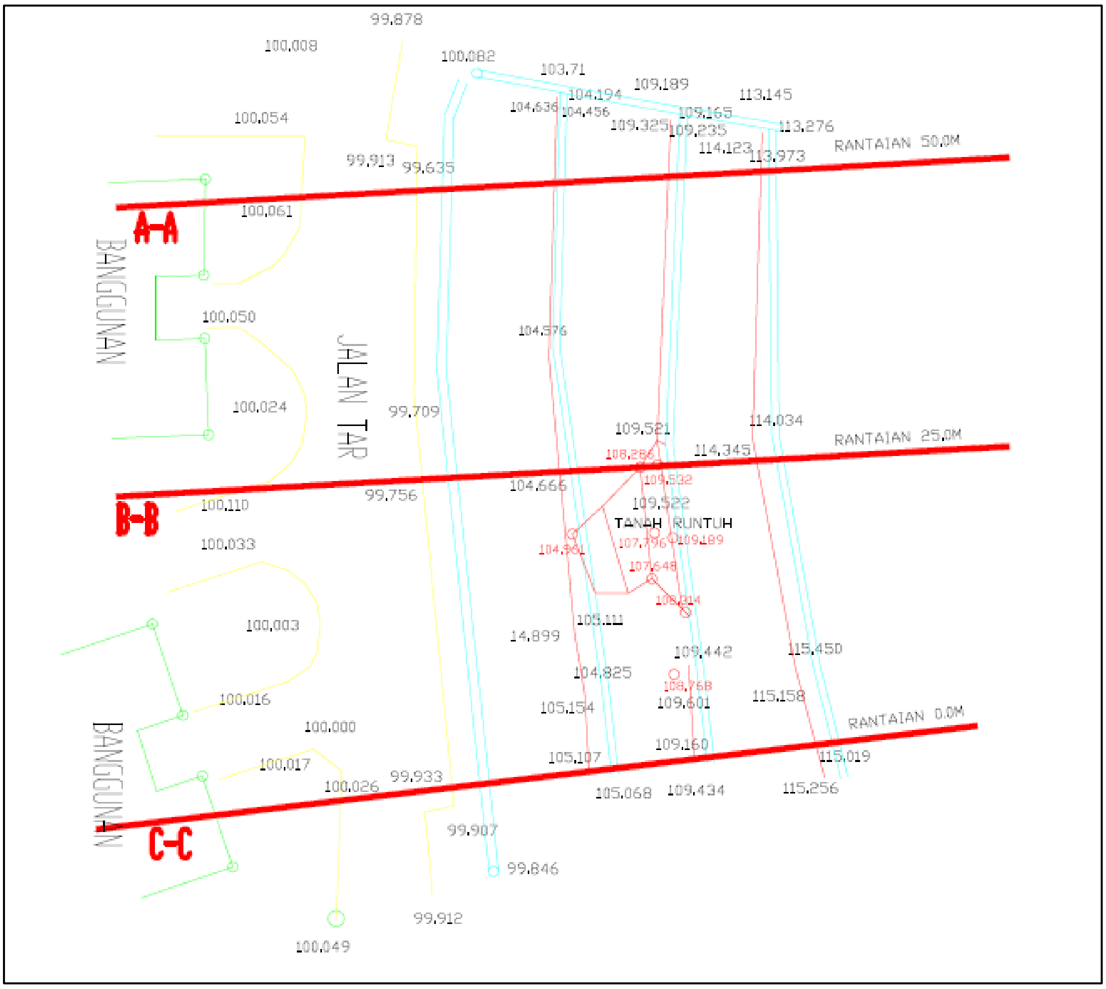

Figure 4-5: Survey Plan View of the Block 14 Slope Failure

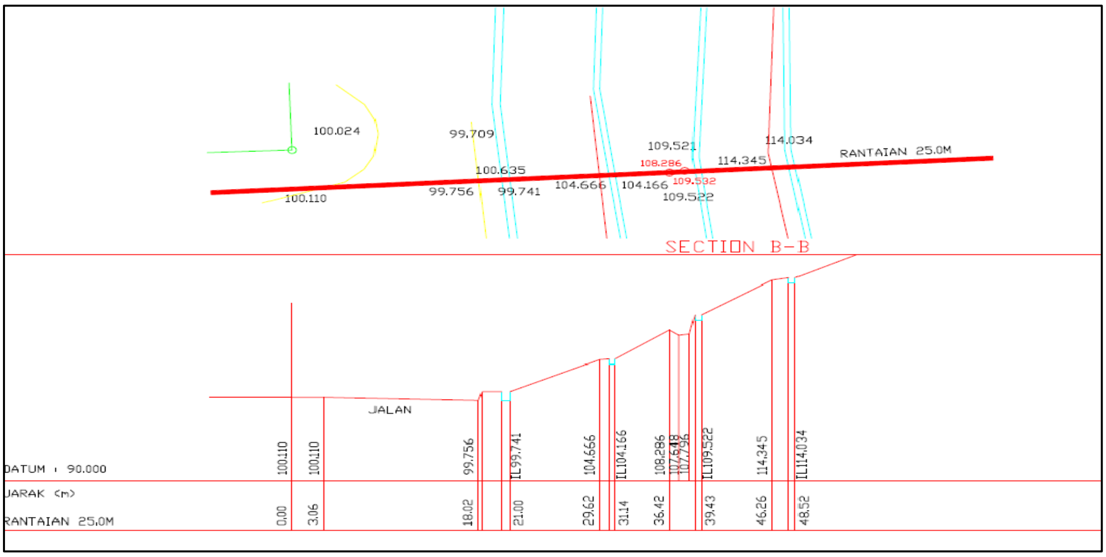

Figure 4-6: Cross Section of Slope Failure

4.3 SUB-SURFACE SOIL AND GROUNDWATER LEVEL

The soil investigation is carried out using Rotary Wash Boring (Toho D2K) and two boreholes have been made which used for setting up standpipe and inclinometer. The distance between two boreholes is 20 m and the location is at the top of the slope as shown in *Figure 4-7.*

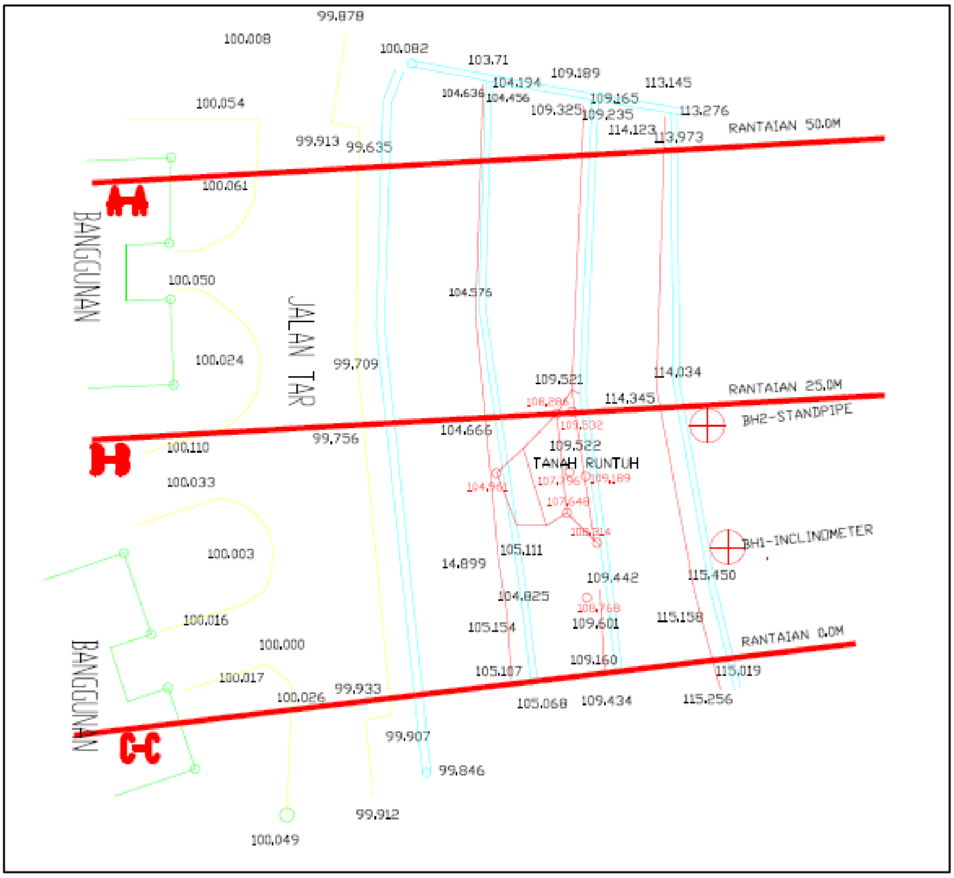

Figure 4-7: Location of Boreholes

The result of the drilling at points 1 and 2 are stated in *Table 4-1*and the bore log result may refer to APPENDIX. In *Table 4-1*, the SPT values for points 1 and 2 which the number of blow counts were carried out at intervals of 1.5 m. The disturbed samples were taken at depth of 3.0 m and 6.0 m for point 1 while for point 2 at depth of 1.5 m and 4.5 m with thin-wall tube sampler. Subsequent to the penetration these samples, both ends of the samples coated with a non-shrinking wax to ensure an airtight seal and the void at the top and bottom of the tube was then filled.

Table 4-1: SPT Value for Points 1 and 2

Point 1		Point 2	
Depth (m)	**SPT Value**	**Depth (m)**	**SPT Value**
0	0	0	0
1.5	5	1.5	UD 1
3.0	UD 1	3	7
4.5	11	4.5	UD 2
6.0	UD 2	6.0	13
7.5	2	7.5	12
9.0	4	9.0	12
10.5	8	10.5	9
12	9	12.0	9
13.5	23	13.5	23
15	24	15.0	24
16.5	17	16.5	17
18	50	18.0	50
19.5	46	19.5	46
20.0	End of borehole	20.0	End of borehole

From the site investigation boreholes data, *Figure 4-* 8 shows the SPT blow count for each depth of boreholes and the SPT value at depth of 6 m to 15 m is slightly different. For borehole 1, the depth of boring at 7 m has the same depth of the failure occur with the SPT value of 2 which means the soil bearing capacity is weak. The SPT blow counts are not consistent increasing until the depth of 2 m such at the depth of 16.5 m, the SPT value decrease from 24 to 16. The soil type at the cut slope is not residual soil but it’s originally soil formed. Basically, after the depth of boring achieved 19.5 m, no bedrocks were found and the boring was ended at 20 m depth.

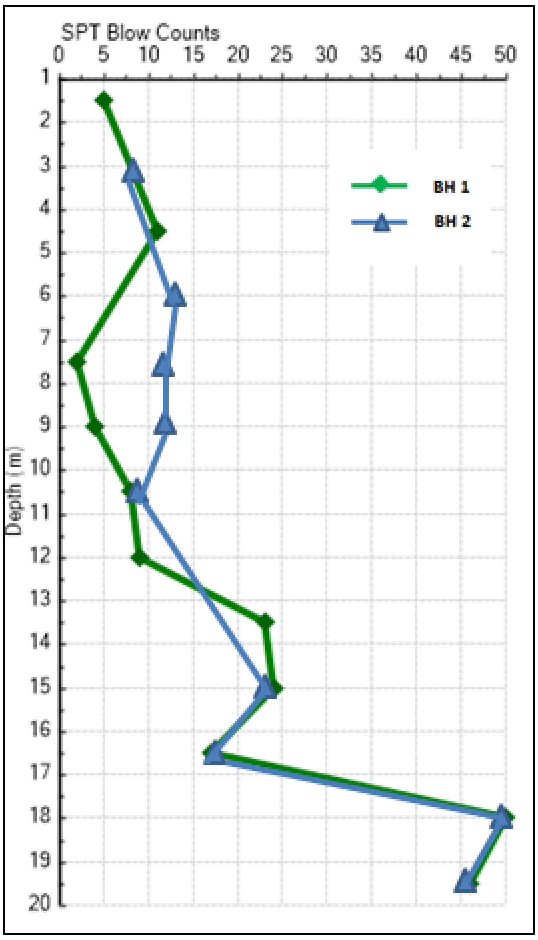

Figure 4- 8: Graph of Depth against SPT Blow Counts

The measurement of the water table in the water standpipe was executed using measuring tape. The recordings were taken at the end depth of borehole and repeated twice a week. The casing top was capped overnight to prevent entry of rainwater. The groundwater table was detected at depth of 3.6 m below surface level during the soil exploring. After that, the monitoring work proceeded twice a week and Figure *4-9* shows the result of groundwater table. From the result, the depth of water table increase to 4 m from the ground surface level. The range of the result is from 5.9 to 6.5 m and it can be said that the ground water table is not the cause of the slope failure.

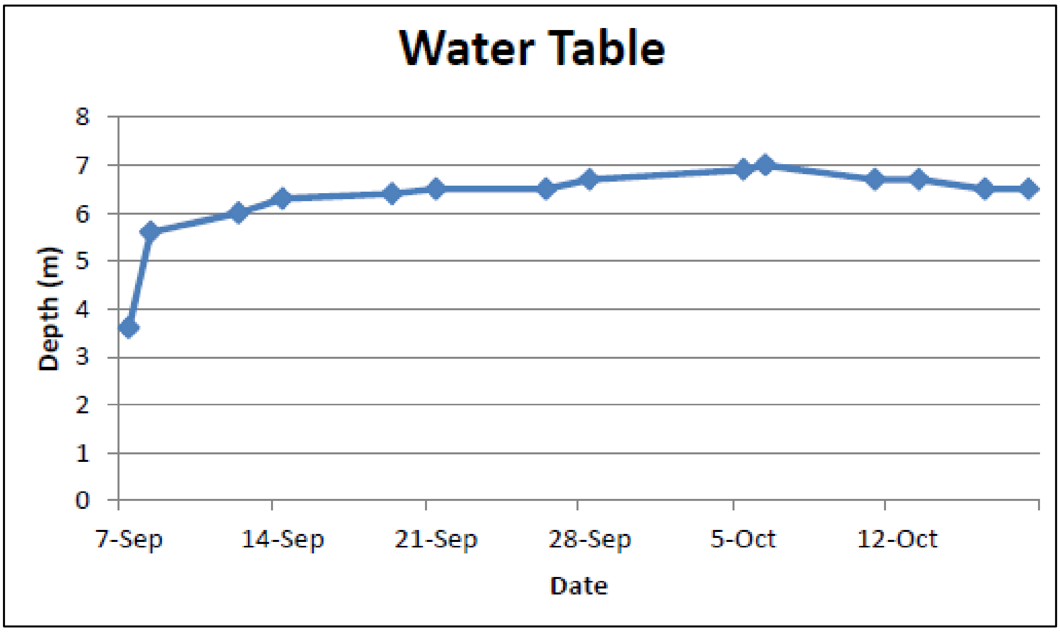

Figure 4-9: Graph of Water Table against Date

4.4 LABORATORY TESTING RESULT

In this section, the soil parameters obtained from soil laboratory testing. The properties of the soil are to investigate the conditions of the subsurface and materials which can evaluate the stability of the cut slope.

4.4.1 Open Pit Sampling

Table 4-2: Summary of Test Results for Open Pit Sampling

Point	Moisture Content (%)	Atterberg Limit			Sieve & Hydrometer Analysis			
		Plastic Limit (%)	Liquid Limit (%)	Plasticiy Index (%)	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
1	23.29	27.74	50	22.26	45	14	31	10
2	23.26	37.70	56	18.3	45	14	30	11

Table 4-2 shows the summary of test results which consists of moisture content, atterberg limit and sieve and hydrometer analysis. The overall result for points 1 and 2 is just slightly different and it is shows that the soil parameters between points 1 and 2 are similar. The moisture content value for

point 1 is 0.03 increases than point 2. The plastic and liquid limit for the both points, point 2 is higher that point 1. Besides, for sieve and hydrometer analysis, the percentage of clay and silt for both points is 45% and 14% respectively. The percentage of sand for point 1 is higher than point 2 while the percentage of gravel is vice versa.

By referring to the Unified Soil Classification System (USCS) and American Association of State Highway and Transportation Officials (AASHTO), the types of soil can be classified. There are two categories of soil which are coarse-grained soil and fine-grained soil. Coarse-grained soil is gravelly and sandy in nature with less than 50% passing through the No. 200 sieve while fine-grained soil is 50% or more passing through No. 200 sieve. Thus, the type of soil for points 1 and 2 is well graded sand with clay (sandy fat clay).

4.4.2 Rotary Wash Boring Sampling

Table 4-3: Summary of Test Results for BH 1

Specimen	Depth (m)	Moisture Content (%)	Atterberg Limit			Sieve & Hydrometer Analysis			
			Plastic Limit (%)	Liquid Limit (%)	Plasticity Index (%)	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
D2	1.5	23	22	38	16	40	22	38	0
UD1	3.0	31	21	36	15	39	28	25	8
D3	4.5	45	22	45	23	54	36	10	0
D5	9.0	45	22	43	21	49	39	12	0
D9	15.0	31	22	48	26	52	35	11	2
D11	18.0	25	21	43	22	51	37	11	1

Table 4-3 shows the summary of test results which consists of moisture content, atterberg limit and sieve and hydrometer analysis for borehole 1. There are several results for disturbed samples and one result for undisturbed sample at 3.0 m depth. As the depth of the specimen increasing, the value of

moisture content and atterberg limit are fluctuated. Sieve and hydrometer analysis result shows that the percentage of clay is the highest among the other type of soil which are silt, sand and gravel. By referring to the Unified Soil Classification System (USCS) and American Association of State Highway and Transportation Officials (AASHTO), the type of soil identified in borehole 1 is sandy lean clay.

Table 4-4: Summary of Test Results for BH 2

Specimen	Depth (m)	Moisture Content (%)	Atterberg Limit			Sieve & Hydrometer Analysis			
			Plastic Limit (%)	Liquid Limit (%)	Plasticity Index (%)	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
UD1	1.5	23	22	35	13	31	24	45	0
D2	3.0	28	22	38	16	35	29	32	4
D3	6.0	47	23	46	23	52	38	10	0
D5	9.0	47	22	42	20	47	36	10	7
D7	12.0	38	22	45	23	51	40	9	0
D10	16.5	23	21	41	20	44	30	26	0
D11	18.0	27	21	43	22	52	37	11	0

Table 4-4 shows the summary of test results which consists of moisture content, atterberg limit and sieve and hydrometer analysis for borehole 2. There are several results for disturbed samples and one result for undisturbed sample at 1.5 m depth. As the depth of the specimen increasing, the value of moisture content and atterberg limit are fluctuated. Sieve and hydrometer analysis result shows that the percentage of clay is the highest among the other type of soil which are silt, sand and gravel. By referring to the Unified Soil Classification System (USCS) and American Association of State Highway and Transportation Officials (AASHTO), the type of soil identified in borehole 2 is sandy lean clay.

Based on the result of open pit sampling and rotary wash boring sampling, the group name of soil sample for both sampling is different which are sandy fat clay and sandy lean clay respectively. Sandy fat clay means it has high content of plastic limit while sandy lean clay has low content of plastic limit.

Table 4- 5: Result of Triaxial Test for BH1 and BH2

<table>
<tr><th rowspan="2">Borehole</th><th rowspan="2">Specimen</th><th rowspan="2">Depth (m)</th><th colspan="2">Triaxial Test (CIU)</th></tr>
<tr><th>c’ (kPa)</th><th>ϕ’ (kPa)</th></tr>
<tr><td rowspan="6">BH1</td><td>D2</td><td>1.5</td><td colspan="2"></td></tr>
<tr><td>UD1</td><td>3.0</td><td>21</td><td>32</td></tr>
<tr><td>D3</td><td>4.5</td><td colspan="2" rowspan="4"></td></tr>
<tr><td>D5</td><td>9.0</td></tr>
<tr><td>D9</td><td>15.0</td></tr>
<tr><td>D11</td><td>18.0</td></tr>
<tr><td rowspan="7">BH2</td><td>UD1</td><td>1.5</td><td>5.5</td><td>37</td></tr>
<tr><td>D2</td><td>3.0</td><td colspan="2" rowspan="6"></td></tr>
<tr><td>D3</td><td>6.0</td></tr>
<tr><td>D5</td><td>9.0</td></tr>
<tr><td>D7</td><td>12.0</td></tr>
<tr><td>D10</td><td>16.5</td></tr>
<tr><td>D11</td><td>18.0</td></tr>
</table>

Table 4- 5 shows the result of consolidated isotropic undrained test for boreholes 1 and 2. The undisturbed samples were taken at depth of 3.0 and 1.5 m for boreholes 1 and 2 respectively. Triaxial test is only done UD1 for BH1 and BH2 also it have high value friction angle which means that the soil specimen at the depth 1.5 to 3 m is still strong. In designing the slope stability, parameter of residual soil is used in order to determine the strength parameter of the failure area.

There are three samples being tested for this CIU test and *Figure 4-10* shows the graph of deviator stress against axial strain for borehole 1 which at 24% of axial strain, it shows the critical state of strength. At 24% of axial strain, the values of deviator stress for each sample are 120kPa, 154kPa, and 224kPa respectively. The critical state pore pressure is also at 24% as shown in *Figure 4-* 11. As stated in *Table 4-6*, the Mohr-circle in critical condition is shown in *Figure 4-12* and the value friction angle is calculated using Equation 4.1 while cohesion value is obtained from the intersection of the y-axis and effective stress failure line. Thus, the value of critical friction angle is 19.36° and cohesion is 22 kPa.

$$\phi_c = \sin^{-1}\left[\frac{\sigma_1 - \sigma_3}{\sigma_1 + \sigma_3 - 2(\Delta U_d)f}\right] \qquad \text{(Equation 4.1)}$$

Where;

ϕ_c is Critical Friction Angle (in deg)

σ_1 is Maximum Compressive Stress (in kPa)

σ_3 is Minor Effective Principal Stress (in kPa)

$(\Delta U_d)_f$ is Pore Pressure at Failure (in kPa)

Table 4-6: Conditions at Critical State of BH 1

Conditions at Critical State	A	B	C
Deviator Stress (kPa)	120	154	224
Pore Pressure at Failure, $(\Delta U_d)_f$ (kPa)	480	488	523
Minor Effective Principal Stress, σ_3 (kPa)	21.6	42.7	70.2
Maximum Compressive Stress, σ_1 (kPa)	141.6	196.7	294.2

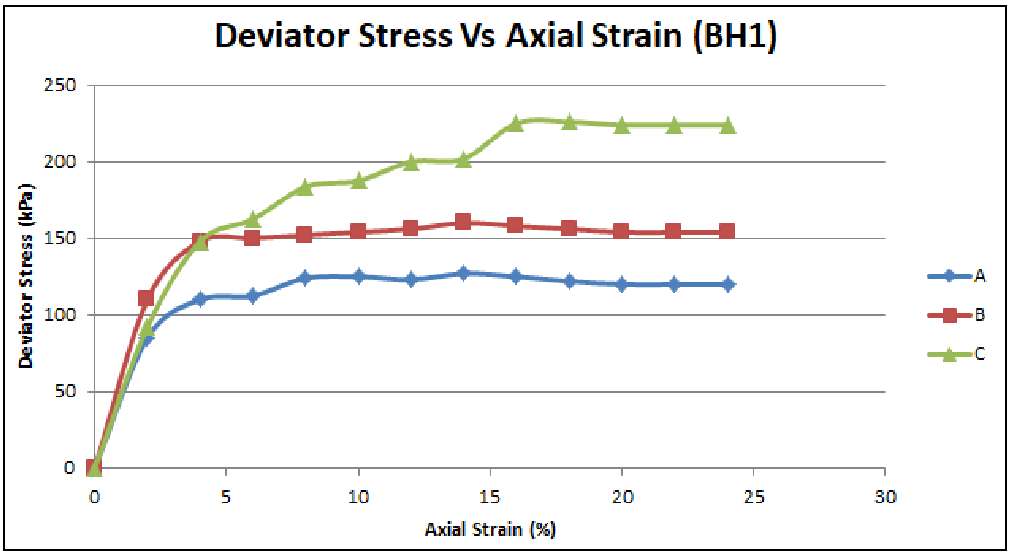

Figure 4-10: Graph of Deviator Stress vs Axial Strain for BH 1

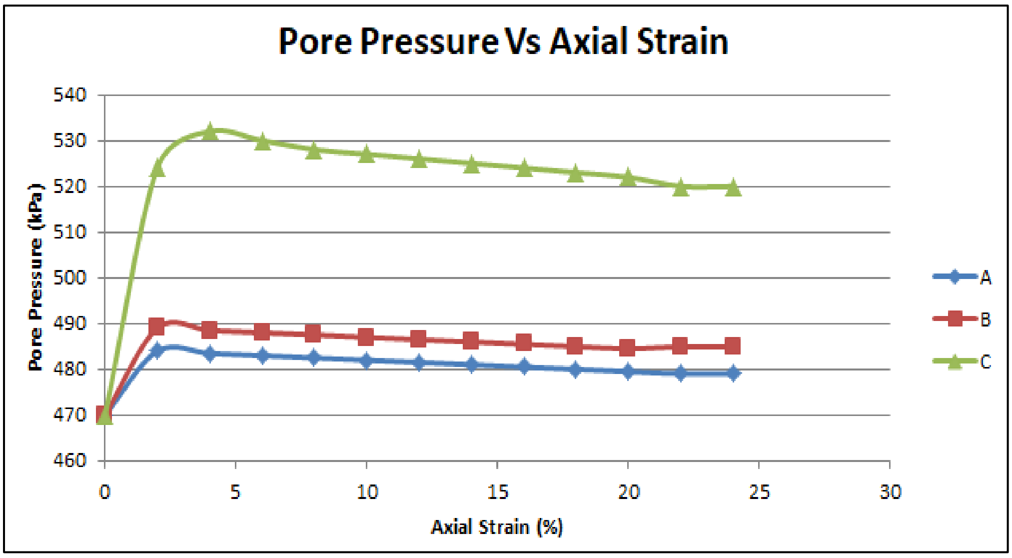

Figure 4- 11: Graph of Pore Pressure vs Axial Strain for BH1

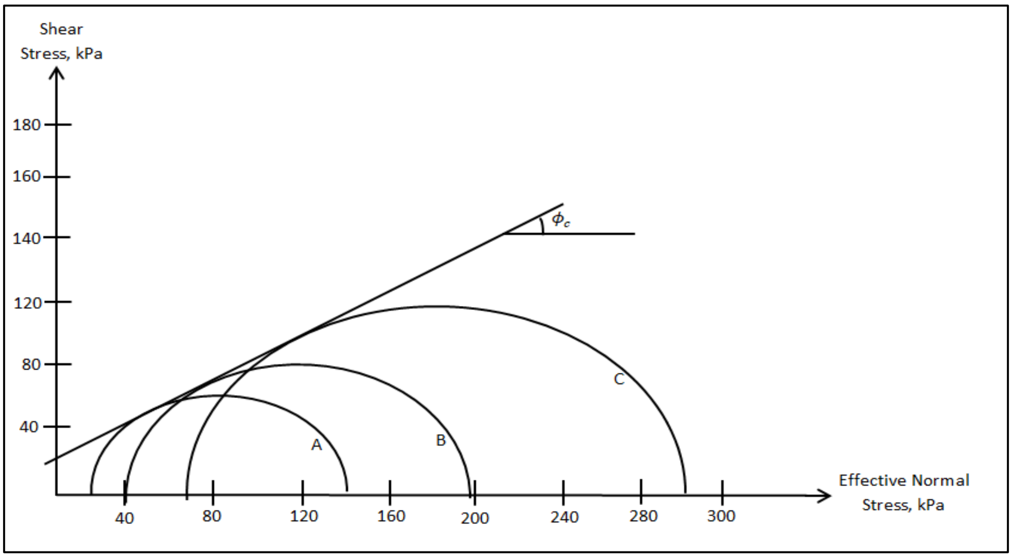

Figure 4-12: Mohr Circle of Residual Soil (BH1) at Critical Effective Stress

For borehole 2, the calculation of the friction angle and cohesion is same as borehole 1. *Figure 4-13* shows the graph of deviator stress against axial strain which at 24% of axial strain as it shows the critical state of strength. At 24% of axial strain, the values of deviator stress for each sample are 74kPa, 84kPa, and 112kPa respectively. The critical state pore pressure is also at 24% as shown in *Figure 4-14.* As stated in *Table 4-7* the Mohr-circle in critical condition is shown in *Figure 4-15* and the value friction angle is calculated using Equation 4.1 while cohesion value is obtained from the intersection of the y-axis and effective stress failure line. Thus, the value of critical friction angle is 7.36° and cohesion is 8 kPa.

Table 4-7: Conditions at Critical State of BH 2

Conditions at Critical State	A	B	C
Deviator Stress (kPa)	74	84	112
Pore Pressure at Failure, $(\Delta U_d)_f$ (kPa)	490	500	525
Minor Effective Principal Stress, σ_3 (kPa)	16.3	22.5	31.8
Maximum Compressive Stress, σ_1 (kPa)	90.3	106.5	143.8

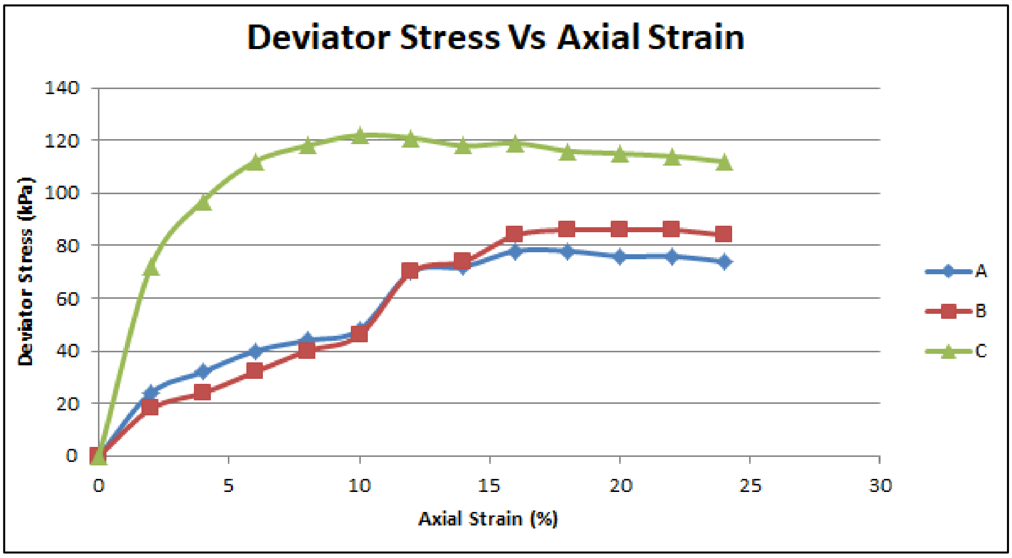

Figure 4-13: Graph of Deviator Stress vs Axial Strain for BH 2

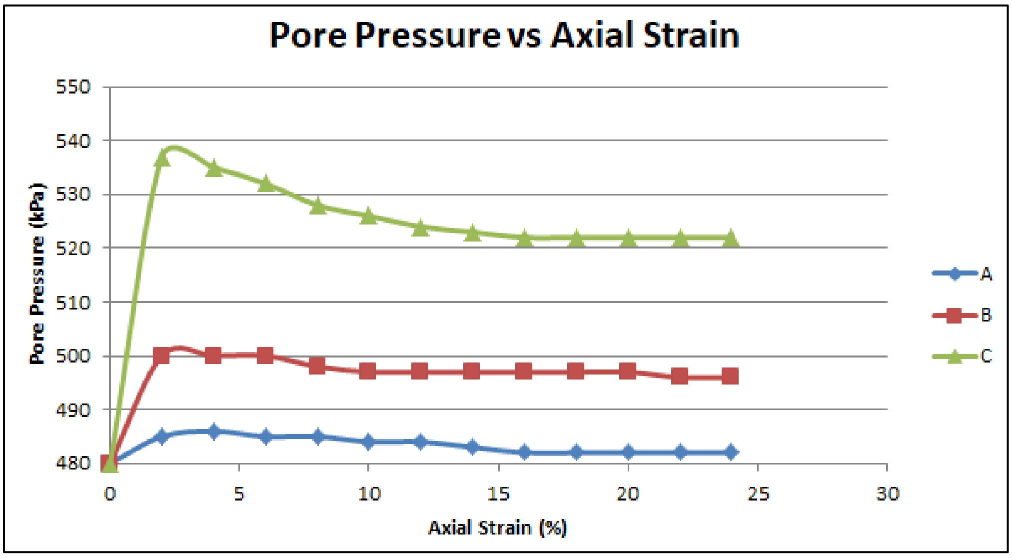

Figure 4-14: Graph of Pore Pressure vs Axial Strain for BH2

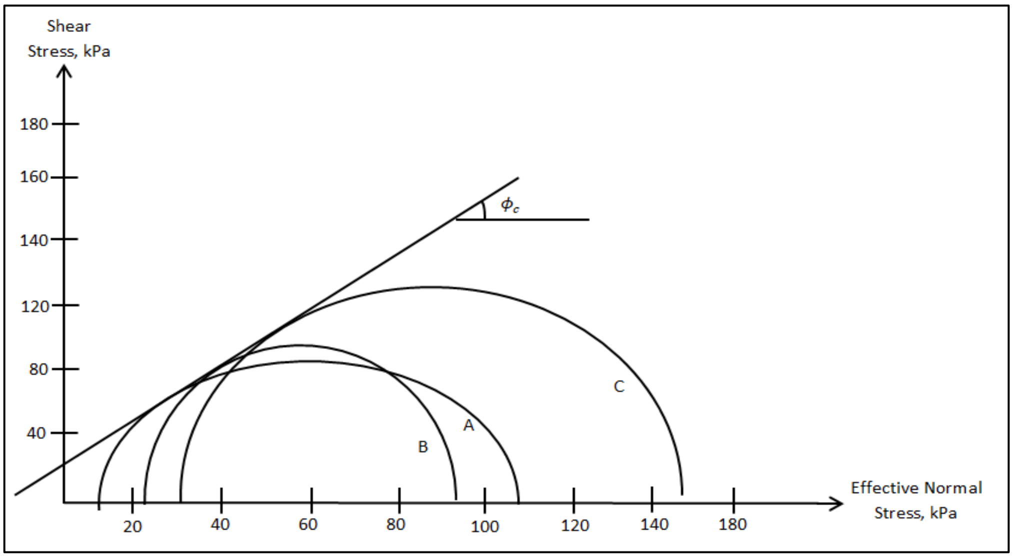

Figure 4-15: Mohr Circle of Residual Soil (BH2) at Critical Effective Stress

4.5 DESIGN OF SLOPE STABILITY

4.5.1 Existing Slope Modeling with Lab Test Soil Parameter

The design of the slope stability consists of checking the Factor of Safety (FOS) of the cut slope. Numerical modeling was used which is Slope/W (Limit Equilibrium) application in identifying the FOS value. The dimension geometry and cross-section B-B as shown in *Figure 4-5* and *Figure 4-6* respectively are used as the failure area is located at cross-section B-B. There are three methods of analyzing have been used in order to obtain the FOS value which are Morgenstern, Spencer and Ordinary.

Based on *Figure 4-16*, it shows the value of FOS by using Morgenstern analysis method which 375 of slip surface has been analyzed. The soil parameter in *Table 4-8* is utilized in the numerical modeling and basically the soil parameter is obtained from laboratory result. The following are the value of FOS from the two other methods;

Spencer: 2.628

Ordinary: 2.358

By using the soil parameter in *Table 4-8,* the values of FOS of the three methods shows the slope is in good condition as the FOS value is greater than 1.The slip is located at the failure area with depth about 4 m. Unfortunately, in reality the slope failure had occurred at the second berm of the cut slope and this has caused re-analysis of the soil parameter is made.

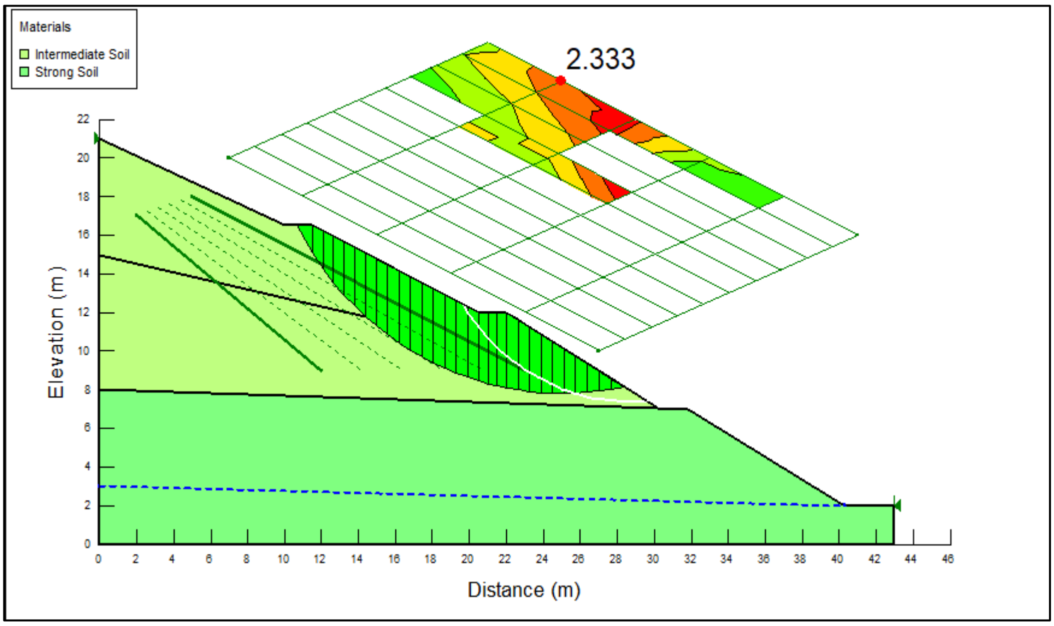

Figure 4-16: FOS of the Cut Slope using Lab Test Parameter which in Morgenstern Analyse Method

Table 4-8: Soil Parameter used Lab Test Result Analysis

Type of Soil	Cohesion, c (kN/m^2)	Friction angle, ϕ (°)	Unit weight, γ (kN/m^3)
Intermediate Soil	5.5	37	19
Strong Soil	20	37	19

4.5.2 Existing Slope Modeling in Failure Mode as at the Site

Based on *Figure 4-17*, the FOS value using Morgenstern analysed method is 1.098 which is low value of FOS and its means the slope condition is already failed as in reality. The calculated lowest FOS from the other two methods of Limit Equilibrium is as below;

Spencer: 1.099

Ordinary: 1.060

By using the soil parameter in *Table 4-9*, the FOS values of the three methods show the low result of FOS which means the second level berm of the cut slope is already failed. The value of soil parameter is using residual soil which at the critical point 24% of axial strain. According to Chin, T.Y. and Sew, G.S. (2001), they mentioned the critical state of the residual soil is in the range of 10% to 30% of axial strain as the shearing state continues at constant volume and constant effective stress.

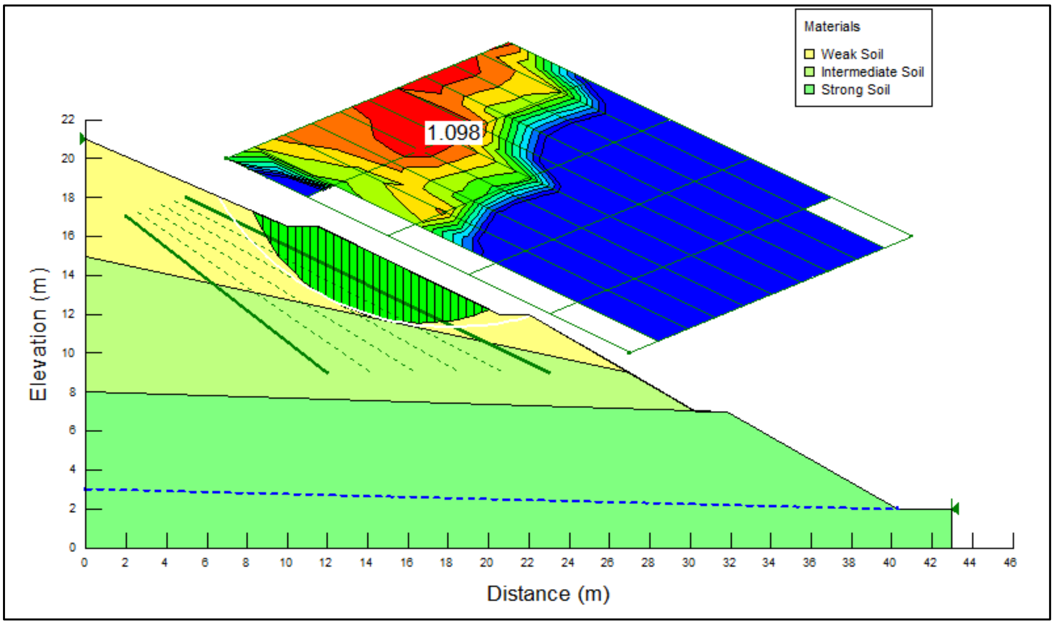

Figure 4-17: FOS of the Existing Cut Slope in Failure Mode which in Morgenstern Analyse Method

Table 4-9: Re-analysed the Soil Parameter of Cut Slope

Type of Soil	Cohesion, c (kN/m^2)	Friction angle, ϕ (°)	Unit weight, γ (kN/m^3)
Weak	8	7.36	19
Intermediate Soil	30	21	19
Strong Soil	37	20	19

4.5.3 New Modified of Cut Slope with Rock Filling

In order to recover the cut slope failure at the second level berm, new modified design of cut slope has been done by filling the rock at the failure area. Rock filling or gabion is used in designing the modified cut slope because it has good interlocking between rock and its flexible as it able accommodate significant differential settlement. It also cost effective because it only require minimal labour during the installation work. Other than that, it has low maintenance which the structure of gabion itself is strong.

Figure 4-18 shows the new modified cut slope design at the second level of berm. The grey colour is representing rock which act as a gabion to re-stabilize the slope. It consists of benching which it can increase the strength of the slope. The volume of each gabion is 1 m^3.

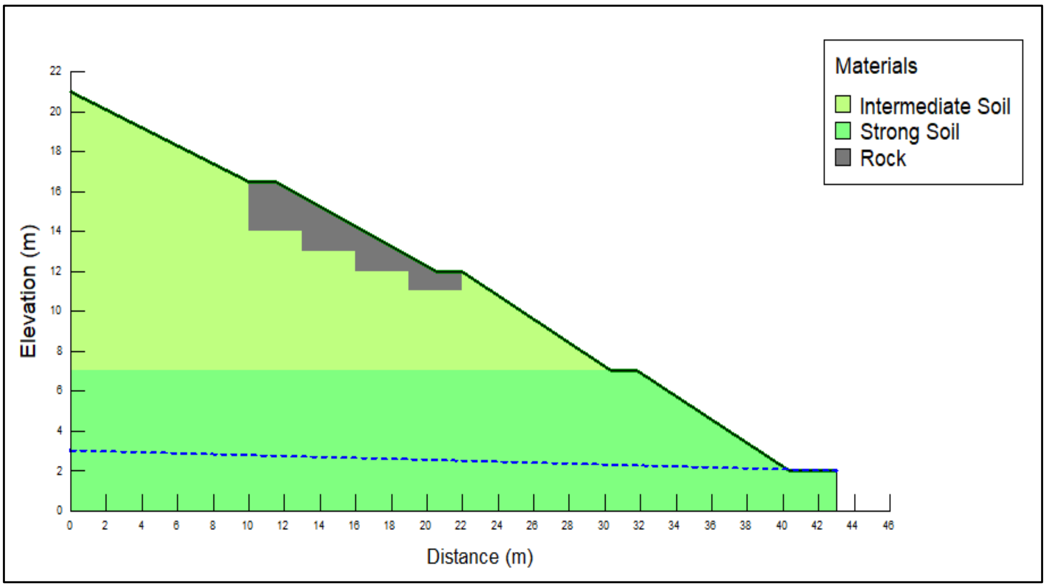

Figure 4-18: Slope Modelling with Rock Filling

Based on *Figure 4-19*, the value of FOS shows is 3.270 which greater than 1 after the failure area is covered with gabion and using soil parameter in *Table 4-10*. It can be said that the usage of gabion in remedial works is very useful which it can be stabilized the cut slope. The following are the FOS value of the other two methods;

Spencer: 3.372

Ordinary: 3.080

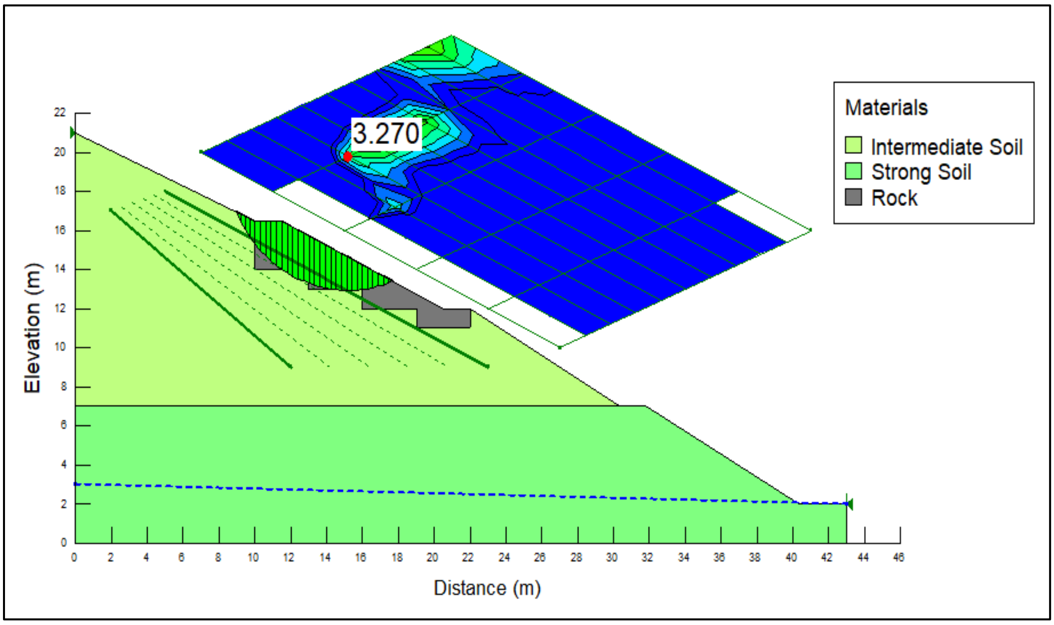

Figure 4-19: FOS of the Modified Cut Slope in Failure Mode which in Morgenstern Analyse Method

Table 4-10: New Modified Design of Cut Slope Soil Parameter of Cut Slope

Type of Soil	Cohesion, c (kN/m^2)	Friction angle, ϕ (^{o})	Unit weight, γ (kN/m^3)
Rock	0	37	22
Intermediate Soil	20	30	19
Strong Soil	20	37	19

CHAPTER 5

CONCLUSION & RECOMMENDATION

As a conclusion, poor maintenance at the drainage channels of the cut slope has caused the slope failed. It is because water does not have proper line flow to discharge thus, it makes the soil have high water content. The amount of high water content in soil has resulted damaging of the drain. The groundwater level not a caused of the slope failure as the level is in the range of 4 to 5m from the ground surface.

The type of soil at the slope failure area is sandy fat clay and sandy lean clay by open pit sampling and rotary wash boring method. The soil type is different because of the value of plastic limit for both methods are different which sandy fat clay means have high content of plastic limit and vice versa for sandy lean clay. The value of CIU test shows high strength soil at depth of 3m, thus re-analysed of the soil parameter has been done using residual soil as to know the value of the soil strength at the critical state which in failure mode.

The FOS's of the slope have been identified with three types of ways which are existing slope with laboratory test parameter, existing slope with residual parameter and modified design of the slope. The FOS in existing slope with laboratory test parameter does not show the current failure at site as it produce high value of FOS. After re-analysed the soil parameter, obtaining the soil parameter using residual soil has been made and it shows an expected result as in the current condition of the slope which in failure mode. The modified design of the slope that filled with rock has shown positive value of FOS which are greater than FOS in existing slope with laboratory test and FOS in existing slope with residual parameter. Thus, the rock filled is the good choice in order to recover and stabilize the cut slope.

For the future work, the slope maintenance needs to be performed frequently to prevent any blockage in the drainage channels. If it is not made, the slope failure will occur again and might be harmed to the environment and surrounding

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APPENDICES

Type of boring: Rotary Wash Boring

Borehole No: BH 1

Sheet: 1 of 2

Type of Rig: TOHO D2K

Diameter Of Boring: 76mm

Project: KERJA2 UKUR KEATAS CERUN RUNTUH DI BLOCK 13, UNIVERSITI TEKNOLOJI PETRONAS (UTP) SRI ISKANDAR, PERAK.

SLOPE AT BLOCK 13 UTP SRI ISKANDAR

Drilling Progress	Casing Depth &	Water Level	Sample & Tests: Depth	Sample	Tests	Permeability test	Depth	Reduced Level	Core Recovery	R.Q.D.	Fracture Index	Joint Inclination	Legend	Description	Piezometer Installation
2017	NW	m	m				m	m	%	%	N				
06/09/17 09.30hr	0		0.00 0.10	D1	Top soil		0					0m		Medium Stiff Yellowish Silty Clay with some Fine Sand.	
			1.50 1.95	D2 • P1 s	1/1,1/2,1/1 N=5		1							Ditto	
							2					2.80			
			3.00 3.60	UD 1	REC:35/60		3							Stiff Reddish with Yellowish patches Silty Clay with some Fine Sand.	
			4.50 4.95	D3 • P2 s	1/1,2/3,3/3 N=11		4							Ditto	
							5					5.60			
			6.00 6.60	UD 2	REC: 60/60		6							Stiff Reddish, Yellowish Silty Clay with a few pieces of laterite Gravels.	
							7					7.20			
			7.50 7.95	D4 • P3 s	0/0,0/0,1/1 N=2		8							Stiff Reddish with Yellowish patches Silty Clay with some Fine Sand.	
												8.80			
			9.00 9.45	D5 • P4 s	1/1,0/1,1/2 N=4		9							Medium Stiff Yellowish, Reddish Silty Clay with traces of Fine Sand.	
							10								

- • Small disturbed sample
- \+ Large disturb sample
- ▪ undisturbed sample
- S Standard penetration test
- ▼ Water sample
- □ Drill core sample
- χ Vane shear test
- ϕ Field permeability test
- Moisture content

Date Started: 06/09/2017

E :________

N :________

Tricone Drilling

Scale : AS Shown

Logged by: Lim

Type of boring: Rotary Wash

Borehole No: BH 1

Sheet: 2 of 2

Type of rig: TOHO D2K
Diameter Of Boring: 76mm

Project:KERJA2 UKUR KEATAS CERUN RUNTUH DI BLOCK 13, UNIVERSITI TEKNOLOJI PETRONAS (UTP) SRI ISKANDAR, PERAK.

SLOPE AT BLOCK 13 UTP SRI ISKANDAR.

Drilling Progress	Casing Depth & Size	Water Level	Sample & Tests: Depth	Sample & Tests: Sample	Sample & Tests: Tests	Permeability test	Depth	Reduced Level	Core Recovery	R.Q.D.	Fracture Index	Joint Inclination	Legend	Description	Piezometer Installation
2017	NW	m	m				m	m	%	%	N				
			10.50 10.95	D6 • P5 s	1/1,2/2,2/2 N=8		10 11							Medium Stiff Yellowish, Reddish Silty Clay with traces of Fine Sand.	
												11.60			
			12.00 12.45	D7 • P6 s	2/2,3/2,2/2 N=9		12							Stiff Yellowish Silty Clay with traces of Fine Sand.	
			13.50 13.95	D8 • P7 s	2/5,5/6,6/6 N=23		13 14							Ditto	
												14.70			
			15.00 15.45	D9 • P8 s	3/6,6/6,6/6 N=24		15 16							Very Stiff Yellowish, Brown Silty Clay with some Fine Sand.	
												16.30			
17.00hrs 07/09/17 09.00hrs	16.50 16.50	2.90 5.60	16.50 16.95	D10 • P9 s	3/4,4/4,4/5 N=17		17							Very Stiff Yellowish Light Brown Silty Clay with traces of Fine Sand.	
												17.70			
			18.00 18.45	D11 • P10 s	4/6,10/11,14/15 N=50		18 19							Hard Yellowish Silty Clay with traces of Fine Sand.	
												19.20			
			19.50 19.95	D12 • P11 s	3/4,7/11,13/15 N=46									Stiff Grey Silty Clay with traces of fine Sand.	
10.30hrs 09.30hrs	20.00 20.00	3.60 5.60	20.00				20					20.00		END OF BOREHOLE	

END OF BOREHOLE AT 20.00m B.G.L.

- • Small disturbed sample
- + Large disturb sample
- ▮ undisturbed sample
- S Standard penetration test
- ▼ Water sample
- □ Drill core sample
- χ Vane shear test
- ϕ Field permeability test
- ∿ Moisture content

Date Started: 06/09/2017
Date Completed: 07/09/2017
Coordinates: E :________ N :________

Scale : As Shown

Logged by: Lim

Checked By: BT

Tricone Drilling

Type of boring:Rotary Wash Boring

Type of Rig: TOHO D2K
Diameter Of Boring: 76mm

SLOPE AT BLOCK 13 UTP SRI ISKANDAR

Borehole No: BH 2

Sheet: 1 of 2

Project:KERJA2 UKUR KEATAS CERUN RUNTUH DI BLOCK 13, UNIVERSITI TEKNOLOJI PETRONAS (UTP) SRI ISKANDAR, PERAK.

Drilling Progress	Casing Depth &	Water Level	Sample & Tests: Depth	Sample	Tests	Permeability test	Depth	Reduced Level	Core Recovery	R.Q.D.	Fracture Index	Joint Inclination	Legend	Description	Piezometer Installation
2017	NW	m	m				m	m	%	%	N				
10/09/17 09.30hr	0		0.00 0.10	D1	Top soil		0					0m 0.20		Yellowish Silty Clay with some Fine Sand & grass roots	
			1.50 2.10	UD 1	Rec:40/60		1							Medium Stiff Yellowish Silty Clay with traces of Fine Sand.	
							2					2.50			
			3.00 3.45	D2 • P1 s	1/1,1/2,2/2 N=7		3							Stiff Reddish Brown Silty Clay with traces of Fine Sand.	
							4								
			4.50 5.10	UD 2	Rec: 40/60		5							Ditto	
												5.70			
			6.00 6.45	D3 • P2 s	2/2,3/3,3/4 N=13		6							Stiff Reddish Brown Silty Clay with some Sand..	
							7					7.20			
			7.50 7.95	D4 • P3 s	2/2,3/3,3/3 N=12		8							Stiff Yellowish patches Silty Clay with traces of Fine Sand.	
												8.80			
			9.00 9.45	D5 • P4 s	3/3,2/3,4/3 N=12		9							Stiff Yellowish, Reddish Brown Silty Clay with traces of Fine Sand.	
							10								

- • Small disturbed sample
- \+ Large disturb sample
- ▪ undisturbed sample
- S Standard penetration test
- ▼ Water sample
- □ Drill core sample
- χ Vane shear test
- ɸ Field permeability test
- Moisture content

Date Started: 10/09/2017

E :________

N :________

Tricone Drilling

Scale : AS Shown

Logged by: Lim

Type of boring: Rotary Wash

Type of rig: TOHO D2K
Diameter Of Boring: 76mm

SLOPE AT BLOCK 13 UTP SRI ISKANDAR

Borehole No: BH 2

Sheet: 2 of 2

Project:KERJA2 UKUR KEATAS CERUN RUNTUH DI BLOCK 13, UNIVERSITI TEKNOLOJI PETRONAS (UTP) SRI ISKANDAR, PERAK.

Drilling Progress	Casing Depth & Size	Water Level	Sample & Tests: Depth	Sample & Tests: Sample	Sample & Tests: Tests	Permeability test	Depth	Reduced Level	Core Recovery	R.Q.D.	Fracture Index	Joint Inclination	Legend	Description	Piezometer Installation
2017	NW	m	m				m	m	%	%	N				
			10.50 10.95	D6 ● P5 s	1/1,2/2,2/3 N=9		10 11							Stiff Reddish Brown Silty Clay with traces of Fine Sand.	
												11.60			
			12.00 12.45	D7 • P6 s	2/2,3/2,2/2 N=9		12							Stiff Yellowish with pink patches Silty Clay with traces of Fine Sand.	
			13.50 13.95	D8 ● P7 s	2/5,5/6,6/6 N=23		13 14							Ditto	
												14.20			
			15.00 15.45	D9 ● P8 s	3/6,6/6,6/6 N=24		15							Very Stiff Yellowish, Brown Silty Clay with traces of Fine Sand.	
			16.50 16.95	D10● P9 s	3/4,4/4,4/5 N=17		16 17							Ditto	
												17.50			
			18.00 18.45	D11● P10 s	4/6,10/11,14/15 N=50		18							Very Stiff Yellowish with pink paches Silty Clay with traces of Fine Sand.	
			19.50 19.95	D12 ● P11 s	3/4,7/11,13/15 N=46		19							Ditto	
16.00hrs	20.00	3.60	20.00				20					20.00		END OF BOREHOLE	

END OF BOREHOLE AT 20.00m B.G.L.

- ● Small disturbed sample
- \+ Large disturb sample
- ∎ undisturbed sample
- S Standard penetration test
- ▼ Water sample
- ◻ Drill core sample
- χ Vane shear test
- ϕ Field permeability test
- Ꝟ Moisture content

Date Started: 10/09/2017
Date Completed: 10/09/2017
Coordinates: E :_________ N :_________

Tricone Drilling

Scale : As Shown

Logged by: Lim

Checked By: BT