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The Stability of the Soil Slope at the Entrance of Edu Hub Pagoh – A Case Study

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Abstract: Slopes whether natural or man-made can be analyzed their stability in various ways and methods. In this study by using several slope features such as the soil type, soil stratification, groundwater, seepage and slope dimensions to estimate its stability. The use of field data to identify possible failure modes or to locate most possible slip surfaces of soil slopes is the challenge in the slope analyzation in this study. In order to estimate the safety factor of the chosen slope at entrance of Edu Hub Pagoh, soil samples were taken from six sites to be analysed. Disturbed and undisturbed soil were taken at three locations left and right of the road by using core cutter. All tests such as shear strength and the soil classification through the common test such as sieve analysis test, plastic limit test (PL), liquid limit test (LL), and specific gravity (G_s) test were conducted on all soil samples. The results is the relationship between shear stress and normal stress are linearly increase. Soil parameters; namely, unit weight, shear strength (in terms of c and Ø values) are used in performing the Geoslope Software in calculating the safety factors of the slopes.

Keywords: Slope dimension, soil shear strength c and Ø, soil testings, disturbed undisturbed soil samples

1. Introduction

Soil is a permeable material due to the presence of interconnected voids that allow the flow of liquids from the location high energy to low energy location [3]. Slope stability refers to the potential of inclined soil or rock slopes to continue sliding falling apart or movement considered as failure of the slope as a whole [1]. Tropical region where most of the days throughout a year filled with rains can easily trigger landslides. Two monsoon seasons in Malaysia are can caused up to more than 80% of landslides are induced by design and construction errors by human that could caused fatalities [4]. Common definition of safety factor; F, is the ability of soil held together before the weight of the saturated bulky soil mass overcome the shear strength of the slope and cause landslide known as surface

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rupture. Embark on this, Terzaghi [5] divides the landslide causing the outside reasons that cause shear stress increase (eg geometric changes, unloading slopes) foot, slope, shock and vibration, resignation, change in water regime) and internal which causes a decrease in shear resistance (eg, progressive failure, weathering, seepage erosion) [2].

However, Varnes [6] points to some of the possible external or internal causes whether to lower the shear resistance or to inprove shear pressure. Geotechnical aspects concern both the stability and damage caused from the slope failure [7] undisturbed soil shall preserve its original shear strength that considered as basic soil criteria in geotechnics [8]. Many studies have been carried out in order to understand the shear strength behavior of undisturbed soil [9]. The objective of this study is to analyse the soil parameter of the slope and to analyse the Safety Factor (SF) of the slope by using Geoslope Software (student version). The requirement of these objectives based on the assumption, where the soil criteria maintain the same properties in all directions of slopes.

2. Materials and Methods

Slope dimensions were obtained manually by measuring the slope on site and using the trigonometric method in estimating the angle of slopes at all level as well the width of berm at the intermediate level.

Figure 1 : Manually dimensioning of slope

The unsaturated and undisturbed sample of soil is an important part of this study in predicting soil resistance to failure which is shear strength [10]. In practical, collecting undisturbed samples has to be done carefully, otherwise only small portion of the undisturbed soil gained and largely contain the disturbed soil. For example, the samples may contain a small portion of the undisturbed soil at the top and bottom of the sample. Undisturbed soils are taken by using core cutter and rammer. After taking the soil at each site, the soil is taken to the laboratory to conduct a direct shear test. Unit weight, γ of the soil samples were obtained by weighing sampler with and without soil. Volume is calculated by measuring of the inner diameter of the sampler and these parameters are to be used in Geoslope Software along with cohesion, c and angle of friction, ϕ of the soil obtained from direct shear test.

Undisturbed soil was tested by using direct shear test. Direct shear test is to determine the parameter of shear strength of soil, cohesion, c and angle of friction, ϕ for soil. The general relationship between maximum shearing resistance, v_f and normal stress, σ_n for soils can be represented by the equation and known as Coulomb's Law :

$$v_f = c + \sigma_n \tan Ø \qquad \text{Eq.1}$$

Disturbed soil were prepared by some excavation for a few cm deep (See Figure 2(a)). Disturbed soil samples also do not retain the in-situ properties of the soil during the collection process (See Figure

2(b)). They were taken from each site, put in a plastic bag, labelled, brought to the laboratory and left air dried in trays as early ppreparation before the start of any experiment. Disturbed soil samples were tested by using sieve analysis test, liquid limit test, plastic limit test and specific gravity test.

Sieve analysis is a method in which grain size distribution is obtained by passing them by mean of vibrating them through a stack of sieves with decreasing mesh opening sizes and by measuring the soil weight retained on each sieve (See Figure 2(c)). This method of sieve analysis is generally suitable for soil grains more than 75µm. Liquid limits of soil obtained by using cone penetrometer methods(See Figure 2(d)). The specific gravity (G_s) of a soil is defined as the ratio between the unit masses of soil particles and water (See Figure 2(e)). G_s is useful for determining weight-volume relationships while direct shear apparatus (See Figure 2(f)) used to find the values of cohesion, c and angle of friction, ϕ.

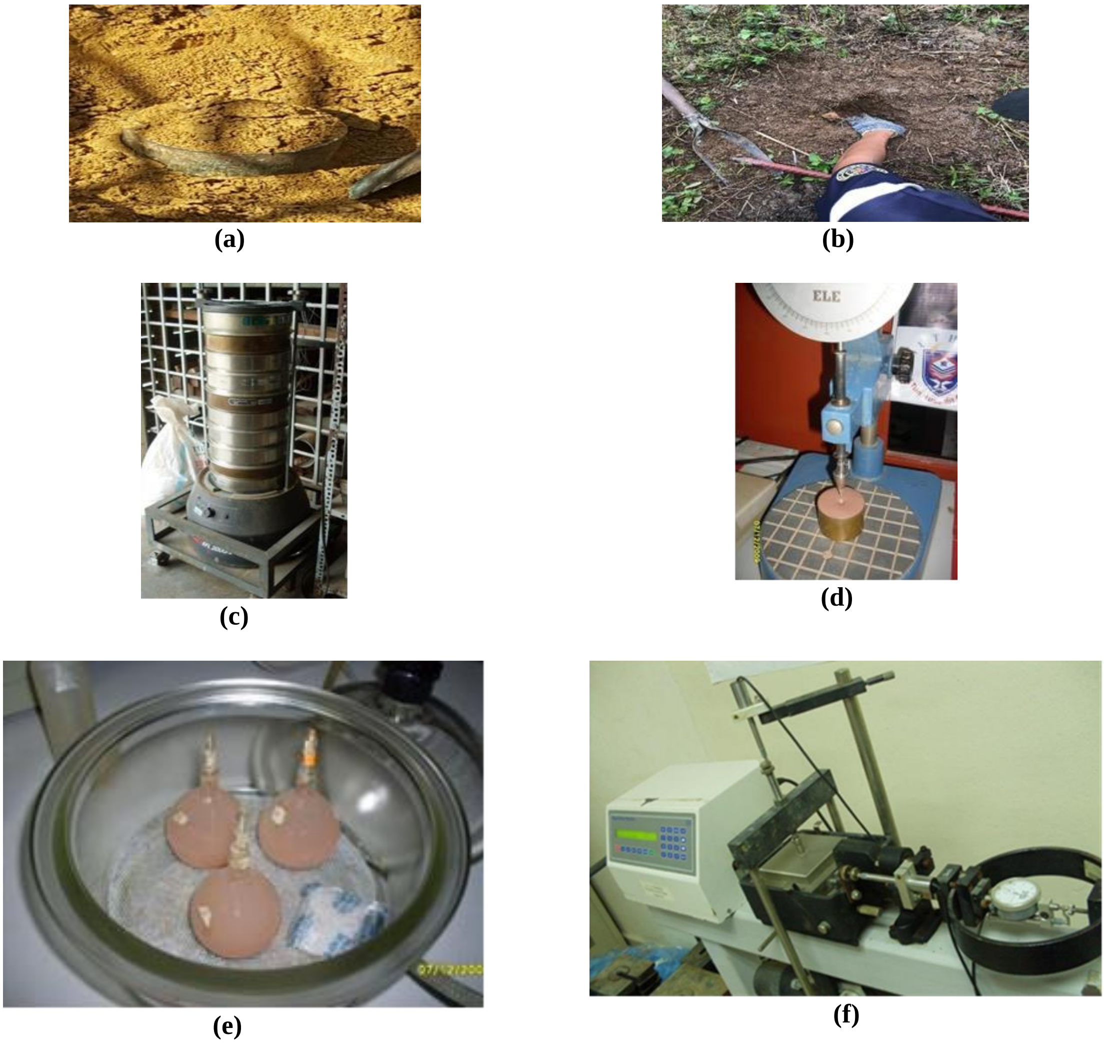

Figure 2: The apparatus used during the study, (a) : Sampling of undisturbed soil, (b) : Disturbed soil, (c): Sieve analysis, (d) : Cone penetrometer, (e) : SG analysis and, (f): Direct shear apparatus

Geoslope Software (See Figure 3) - The software is used to estimate the safety factor's of the slope and several methods of analysis were installed in it namely, method of slices, Bishop's, Mogenstern's and Skempton's.

Figure 3 : Icon of Geoslope

The GeoStudio Student edition; though with certain limitations on the slope analysis but still has vast benefit for student training as introductory exercise for determination of slope stability. It is a free product and offer an economical way on learning geotechnical numerical modelling of slope with given few soil parameters as input. Its an ideal teaching tool for lecturer both at undergraduate and graduated levels. The software consist of many version of all eight product which are SLOPE/W, SWEEP/W, SIGMA/W, QUAKE/W, TEMP/W, CTRAN/W, AIR/W and VADOSE/W.

3. Results and Discussion

All tests were conducted in Geotechnic Laboratory of Faculty of Engineering Technology in UTHM Pagoh. The main objective of the laboratory tests is to estimate the values of certain soil parameters and data for all sites and Site 1 is taken as sample calculation in this study, as follows :

3.1 Sieve Analysis

Figure 4 shows the curve resulted from the sieve analysis of disturbed sample from Site 1. The uniformity coefficient (Cu) value using Eq.2 is 3.57 which is in uniform condition and the uniformity curvature coefficient (Cc) using Eq.3 is 0.94 which is in poorly graded.

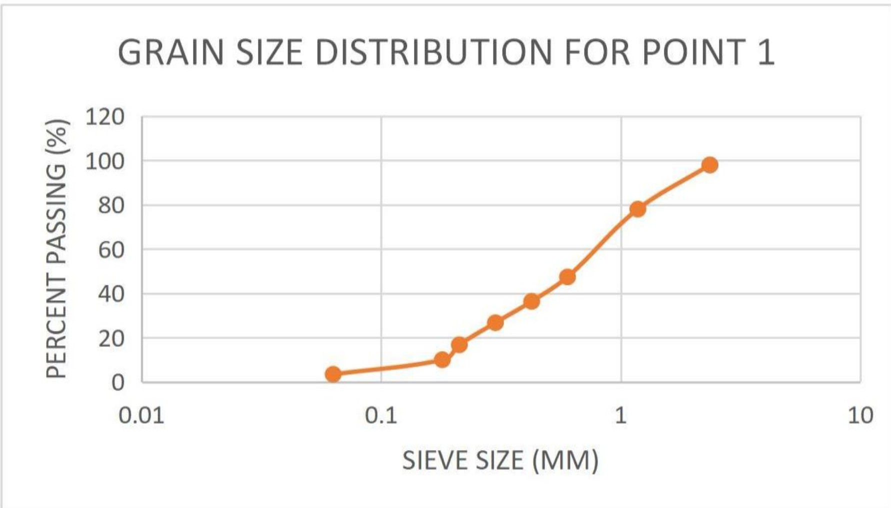

Figure 4 : Grain size distribution curve

$$C_u = \frac{D_{60}}{D_{10}} \quad ; \text{Uniform } 5 < C_u < 15 \qquad \text{Eq.2}$$

$$C_c = \frac{(D_{30})^2}{(D_{60})(D_{10})}; \text{Poorly graded } 1 \leq C_c \leq 3 \qquad \text{Eq.3}$$

3.2 Liquid Limit (LL) and Plastic Limit (PL).

One of the properties of fine grains soils is their consistency; in which directly measured from its moisture content. Moisture content of a dry sample gradually changes from solid, through semi-solid, through plastic and finally into a liquid form by varying its moisture content (See Table 1 and Figure 5).

Table 1 : Liquid Limit, LL

	Can (g)	Can + Moist Soil (g)	Can + Dry Soil (g)	Moisture Content(%)	Penetration (mm)
SITE 1	19.21	48.63	39.41	45.64	12.24
	18.32	47.66	37.71	51.32	20.44
	19.33	41.21	33.43	55.18	25.45
	19.52	56.54	42.8	59.02	32.98
	18.79	56.03	41.76	62.12	36.01

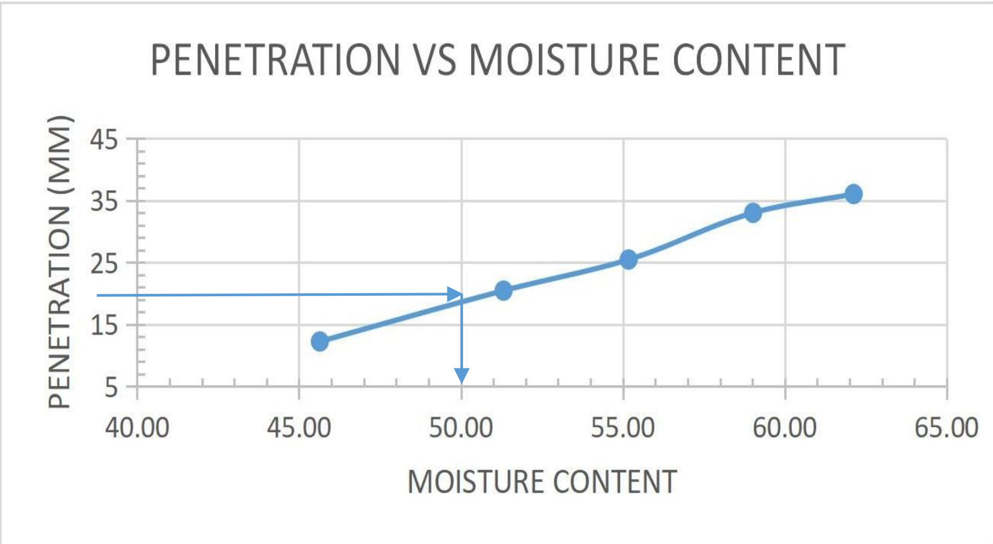

Figure 5 : Penetration vs Moisture Content, LL = 51%

Plastic limit (P_w) of soil is the water content at the moment which a soil sample begin to crumble when rolled into a thread of approximately 3 mm in diameter. Plasticity index (PI or IP) is the numerical difference of the liquid and plastic limit (See Eq. 4, 5 and Table 2), and indicates the range of water content through which the soil remains plastic and the value of PI in this study is 21%.

$$w = \frac{M_w}{M_s} \qquad \text{Eq.4}$$

$$Plastic\ Limit, PI = \text{LL} - \text{PL} \qquad \text{Eq.5}$$

Table 2 : Plastic Limit, PL

SITE 1	Can (g)	Can + Moist Soil (g)	Can + Dried Soil (g)	Moisture Content
	19.96	27.68	25.9	29.97

3.3 Specific Gravity, G_s

The specific gravity (Gs), of a material is defined as the ratio of the weight (or mass) of a given volume of the material to the weight (or mass) of an equal volume of water (See Eq.6). The result for G_s for this study is 2.57.

$$G_s = \frac{M_2 - M_1}{(M_4 - M_1) - (M_3 - M_2)} \qquad \text{Eq.6}$$

Table 3 : Specific Gravity

SITE 1	M1	M2	M3	M4
	Dried Bottle (g)	Dried Bottle + Soil (10 g)	After Vacuum Bottle (g)	Bottle+Water (g)
	38.03	48.04	145.96	139.85
	G_s value is 2.57			

3.4 Direct Shear

The general relationship between maximum shearing resistance, v_f and normal stress, o_n for soils can be represented by the equation and known as Coulomb's Law :

$$v_f = c + \sigma_n \tan \varnothing \qquad \text{Eq.7}$$

From slope at site 1, the cohesion (c) value is 138.57, while the friction angle (ϕ) is 86.5 (See Figure 6 and 7), Table 4 shows the displacement and proving ring for site 1 using 1kg weight.

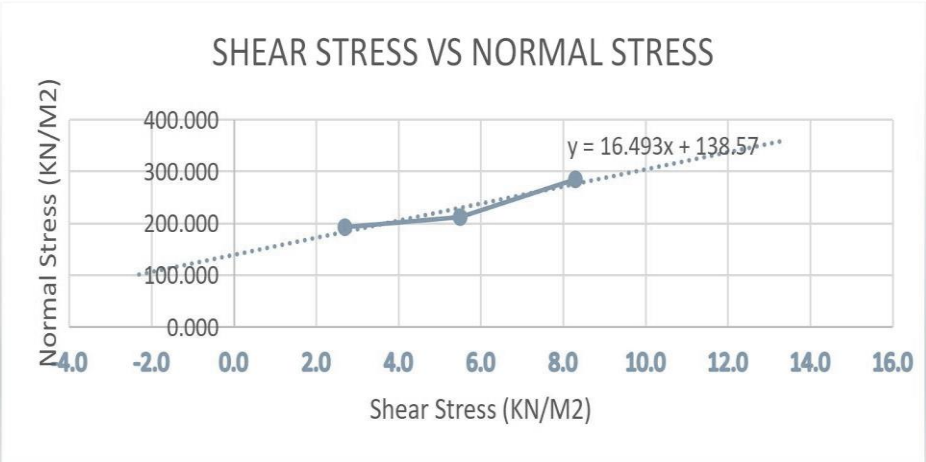

Figure 6 : Normal stress versus shear stress for soil sample at site 1.

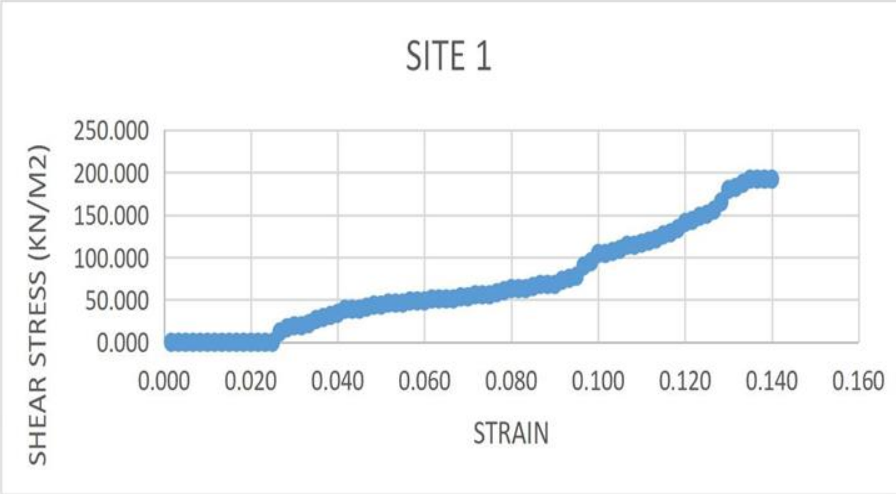

Figure 7 : Direct Shear (Shear Stress vs Strain) for site 1.

Table 4: Displacement and Proving Ring

DISPLACEMENT		PROVING RING	
DIAL GAUGE	ΔL (MM)	DIAL GAUGE	LOAD, P (KN)
100	0.2	0	0
200	0.4	0	0
300	0.6	0	0
400	0.8	0	0
500	1	0	0
600	1.2	0	0
700	1.4	0	0
800	1.6	5	0.04375
900	1.8	8	0.07
1000	2	9	0.07875
1100	2.2	12	0.105
1200	2.4	14	0.1225
1300	2.6	16	0.14
1400	2.8	17	0.14875
1500	3	18	0.1575
1600	3.2	19	0.16625
1700	3.4	20	0.175
1800	3.6	20	0.175
1900	3.8	21	0.18375
2000	4	21	0.18375
2200	4.4	23	0.20125
2300	4.6	24	0.21
2400	4.8	26	0.2275
2500	5	26	0.2275
2600	5.2	28	0.245
2700	5.4	28	0.245
2800	5.6	31	0.27125
2900	5.8	37	0.32375
3000	6	43	0.37625
3100	6.2	44	0.385
3200	6.4	47	0.41125
3300	6.6	48	0.42
3400	6.8	50	0.4375
3500	7	53	0.46375
3550	7.1	55	0.48125
3600	7.2	58	0.5075
3700	7.4	61	0.53375
3800	7.6	64	0.56
3900	7.8	74	0.6475
4000	8	77	0.67375
4100	8.2	79	0.69125
4200	8.4	79	0.69125

3.5 Slope W Analysis

The output of slope W analysis would be in the form of most probable slip failure that produce by the highest possible set factor of safety, as shown in **Figure 7**. The green region is the assumed failure would take place. From the analysis it was shown that site 1 produced Safety Factor of 25.104 which is extremely stable.

This would consistent with the condition of slope that had no sign of deterioration and the assumption of having a hogenious soil condition in the area is quite relevant, **Figure 8**.

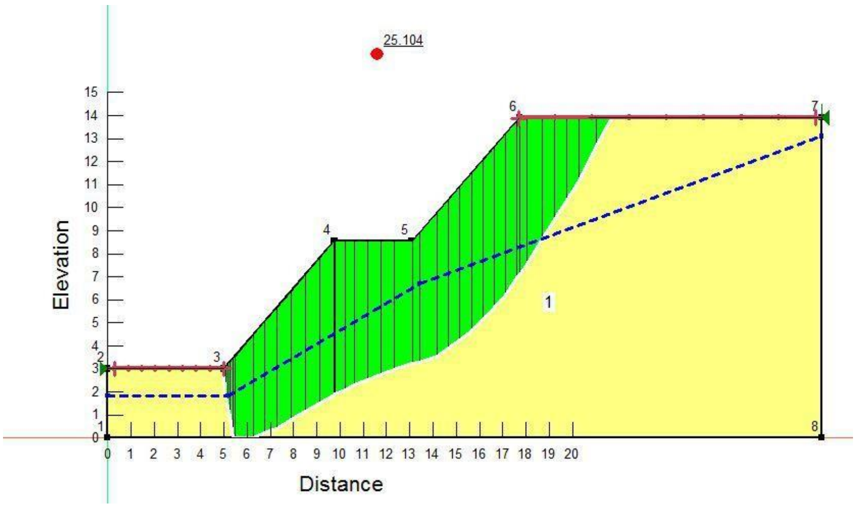

Figure 8 : Safety Factor analysis of Slope W Geoslope for Site 1

4. Conclusion

In conclusion, sieve analyses for all samples showed that at most part of the slope soil are WG (well graded) with few spots of PG (poorly graded). All the graphs of grain size distribution are directly proportional. As the sieve size increase, the percentage passing increase too. Based on the data of all of the six samples, the graphs obtained show that the penetration and the moisture content of the soil samples are directly proportional. This occurred when the relative density of the soil is high. The values of liquid limit ranges from 50.8% to 51%. While the plasticity index confirm the value that ranges from 14.9% to 24.17%.

Values of plastic limit varies from 29.97% to 36.10%. Plastic limit test determines the lowest moisture content at which the soil behaves plastically. Based on the results, site 2 has the highest moisture content while site 4 has the lowest moisture content. The specific gravity values in this study fall in the range of 2.23 to 2.73 where the value of most common soils fall within a range of 2.6 to 2.9. Soils containing organic mater and porous particles may have specific gravity values below 2.0, while soils having heavy substances may have values above 3.0. This is to confirm that the soil sample a few cm from the surface contain some percentage of organic matter.

Direct shear test gives values of shear strength of soil, cohesion and angle of friction for sand. In this study the values of c is realatively high of between 66 to 266 kN/m^2. Angle of friction record the values of 85.3˚ to 87.5˚ Based on the graph of normal stress vs shear stress at every sample, the sample of site 2 has the highest value of cohesion, c and soil sample of site 6 has the biggest angle of friction, ϕ.

Acknowledgement

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Appendix A

Listed are the summary of result with all other sites

1. **Soil Grading**; From Table 6, it show that soil characteristic at all site are mostly is well graded

Table 6 : Soil grading characteristics for each location

Site	d_{10} (mm)	d_{30} (mm)	d_{60} (mm)	C_u	C_c	Symbol
1	0.3	0.5	0.8	2.67	1.04	WG
2	0.2	0.25	0.7	3.50	0.446	PG
3	0.15	0.4	0.8	5.30	1.33	WG
4	0.15	0.28	0.5	3.33	1.04	WG
5	0.2	0.4	0.6	3.00	1.33	WG
6	0.18	0.2	0.6	3.33	0.37	PG

2. Atterberg Limit for each site, **Table 7**.

Table 7 : Result of Atterberg Limit Test for all sites

Site	PL (%)	LL (%)	PI (%)
1	29.97	50.9	20.93
2	36.10	51	14.9
3	34.96	50.9	15.94
4	26.63	50.8	24.17
5	32.95	51	18.05
6	35.94	50.9	14.96

3. Specific Gravity, G_s ; **Table 8** shows values of specific gravity for each site. Based on experimental results, the specific gravity of the six sites ranged from 2.20 - 2.80.

Table 8: Specific Gravity for each site

Site	**Specific Gravity**
1	2.57
2	2.23
3	2.48
4	2.58
5	2.25
6	2.73

4. Direct Shear Test

Table 9: Summary according to site and corresponding Safety Factor

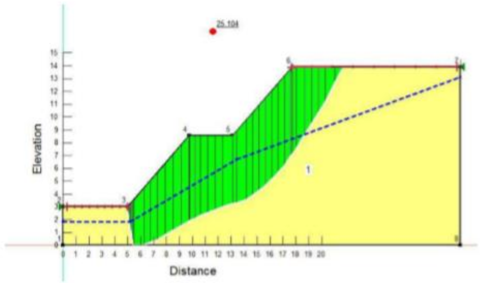
Site	Cohesion, c (kN/m^2)	Friction angle, ϕ (˚)	Gamma, γ (kN/m^3)	Safety Factor
1	138.57	86.5	14.48	25.104
2	153.53	85.3	12.67	29.445
3	66.035	87.5	12.67	39.260
4	138.58	86.0	14.48	38.845
5	266.33	86.0	14.48	38.609
6	129.59	86.5	16.29	56.368

The values of c, Ø and γ were obtained from the series of direct shear test conducted using undisturbed samples from the six sites. While the safety factors were from software SlopeW analyses, **Table 10**.

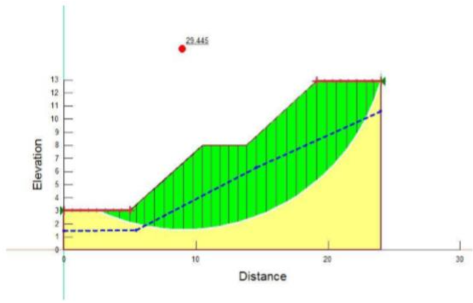
5. Outcome from Geoslope – SlopeW for factor of safety.

Table 10 : Output of SlopeW for all six slopes analyzed

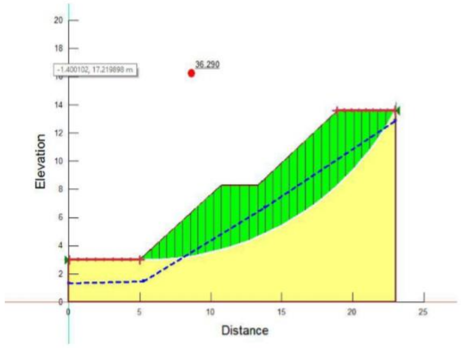
i. SITE 1



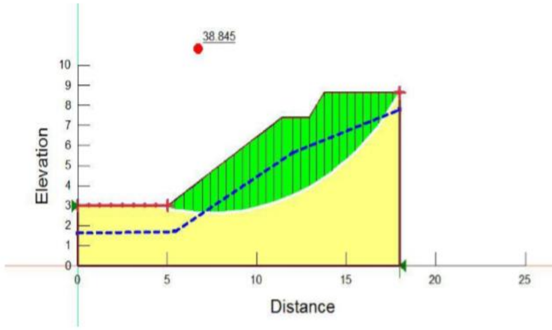
ii. SITE 2



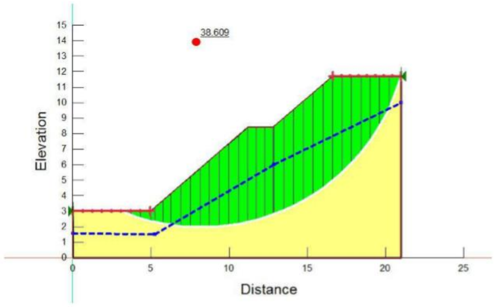
iii. SITE 3



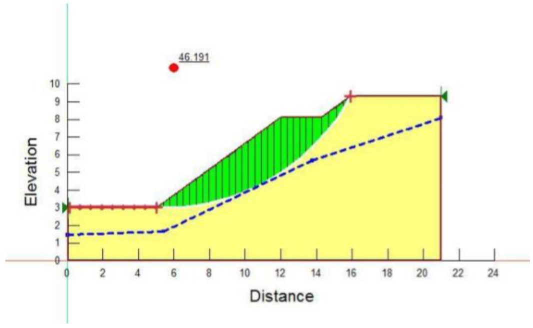
iv. SITE 4



v. SITE 5



vi. SITE 6



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