Identification of Testing Soil Physical Properties Through Landslide Material Characterization

Suhairiani Suhairiani[1], Nahesson H Panjaitan[2], Siti Zulfa Yuzni[3], Enny Keristiana Sinaga[4], Hafiz Achmad Fauzan[5], Fairuza Marhamah[6]

{suhairiani@unimed.ac.id[1], nahessonpanjaitan@gmail.com[2], sitizulfa@unimed.ac.id[3]}

Universitas Negeri Medan, at the Street of Willem Iskandar - Pasar V, Medan, Indonesia[1,2,3]

Abstract. The characteristics of soil material that has landslide are known by carrying out initial soil testing, that is the physical properties of the soil which is carried out in the laboratory. Aek Parombunan, Hutabarangan, Pancuran Gerobak, and Pancuran Dewa in Sibolga city, are areas where landslides have occurred and this is used as a place for taking soil samples. The test results show soil samples for all four areas are classified as silty/clayey types of gravel and sand material, based on the AASHTO classification. The influence of the Atterberg value on the soil plasticity index value is included in low category (no potential for the soil to expand), but if you look at the porosity value of the soil material that has collapsed, it is on the medium threshold, which means that there is still space or gaps for water movement and this can cause subsidence or landslides.

Keywords: Landslide, Sibolga, Soil Physical Properties.

1 Introduction

Landslide is the movement of land moving down or off the slope with plane in the form of rotation and translation [1]. Landslide can occur on the slopes of hills, mountains, riverbanks or embankment structure. Soil landslide is caused by two things, these are triggers of (rain, earthquakes and volcanic activity) and it also causes of (geology, morphology and human)[2]. Sibolga is a city on the west coast of the island of sumatera which is part of the Province of North Sumatera, stretching along the coast from North to South and it is in the bay area of Tapian Nauli. Sibolga has an area of 10.77 km², which has 4 (four) sub-districts, these are sub-districts in Sibolga town, sub-districts in Sibolga Sambas, sub-districts in South Sibolga and sub-districts in North Sibolga. Sibolga town is also influenced by its location, that is on coastal land, slope and mountain. It is Located at heights range between 0-150 meters above sea level, with the slope of the land in this town area varies between 0-2% to more than 40%.[3]. At the end of 2022, it is noted that every sub-districts in Sibolga experienc landslide that are caused by high rainfall and heavy rain, it is shown in the Table 1 below:

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Table 1. Data of landslide incidents at the end of 2022

No	Date	Area locations where the landslide has occurred	Explanation
1	24th August 2022	Aek Parombunan, sub-districts in South Sibolga[4]	Heavy rainfall in the area of hill
2	4th December 2022	Aek Manis, sub-districts in South Sibolga [5]	Heavy rainfall in the area of hill
3	4th December 2022	Hutabarangan, sub-districts in North Sibolga [5]	Heavy rainfall in the area of hill
4	7th December 2022	Bukit Aido Pancuran Gerobak, sub-districts in City Sibolga [6]	Heavy rainfall in the area of hill

From the incident data that has been presented above (Table 1), the landslide that has been occurred, the trigger is rain. Theoretically, [7] the water resulting from the rain that is occurred will result in high water intensity which cause infiltration of water that comes into the ground, so that causing a decrease in soil strength and resulting in collapse [8]. The effect of soil collapse that is not strong will cause landslide, for this reason, it is necessary to carry out initial identification, through experimental tests (laboratory tests) testing soil physical properties[9].

As an analysis to determine the low strength of the soil that is landslide has been occurred, then it will be taken soil material that landslide has been occurred to analyze the characteristics of the soil material against the landslide that has been occurred, testing soil material will be started by testing soil physical properties, so that the results of the test are expected can assist in construction work in areas where landslide has been occurred and it can determine appropriate methods and actions that are related to the potential danger of landslide.

2 Method

2.1 Sample locations and test materials

The types of soil that will be tested in this research are taken from four (4) locations on the land slopes where landslides have occurred. The first location is in the area of Aek Parombunan which is at the Street of Sudirman, in the sub-districts of South Sibolga, the second location is in the area of Hutabarangan which is at the street of Sudirman, in the sub-districts of North Sibolga, the third location is in the area of Pancuran Gerobak which is at the street of SM Raja, in the sub-districts of Sibolga town and the fourth location is in the area of Pancuran Dewa which is at the street of Sisingamangaraja, in the sub-districts of Sibolga Sambas that can be shown as in the Figure 1 below**.**

(a) (b) (c) (d)

Fig. 1. Sampling Location (a). Aek Parombunan; (b). Hutabarangan; (c). Pancuran Gerobak; (d) Pancuran Dewa.

2.2 Sampling method

At each samples location are taken at three points, these are in the top, middle and bottom. Taking soil using a hoe dug 50 cm, which the functions to remove grass or plant roots. This soil taking will represent the taking of soil at each soil sample location.

2.2 Implementation of testing

To determine the characteristics of landslide is done by testing soil physical properties first before, which consists of: (1) testing Water Content in accordance with sni 03-1965-1990 [10]; (2) testing Sieve Analysis in accordance with sni 3423:2008 [11]; (3) testing soil Specific Gravity in accordance with sni 1964:2008 [12]; (4) testing Liquid Limit in accordance with sni 1967:2008 [13]; (5) testing Plastic Limit in accordance with sni 1964:2008 [14]; (6) testing Shrinkage Limit in accordance with sni 3422:2008 [15]; (7) testing soil Density in accordance with SNI 1742:2008 [16].

3 Research and discussion

3.1 Results

Location of soil samples in Aek Parombunan. Where the test for location of soil samples that is landslide, it is located in the area of Aek Parombunan which is at the street of Sudirman, in the sub-districts of South Sibolga, the area is located in a hilly area, then there is the data on the soil physical properties that have been tested and obtained are shown in Table 2 below.

Table 2. Landslide data of Aek Parombunan

No	Testing soil physical properties/paramater	Unit	Score
1.	(Water content)/w	%	12.94
2.	(Specific gravity)/Gs	-	2.60
3	(Sieve analysis)/Cu/CC	%	4.84/0.01
4.	(Liquid limit)/LL	%	38.92
5.	(Plastic limit)/PL	%	28.97

No	Testing soil physical properties/paramater	Unit	Score
6.	(Indeks plastic)/PI	%	9.95
7.	(Shrinkage limit)/SL	%	51.35
8.	(Optimum water content)/Wopt	%	15.40
9.	(Maximum dry weight)/ γ_{dmax}	Gr/cm^3	1.78

Location of soil samples in Huta Barangan. Where the test for location of soil samples that is landslide, it is located in the area of Huta Barangan which is at the street of Sudirman, in the sub-districts of North Sibolga, the area is located in a hilly area, there is the data on the soil physical properties hat have been tested and obtained that are shown in the Table 3 below.

Table 3. Landslide data of Huta Barangan

No	Testing soil physical properties/paramater	Unit	Score
1.	(Water content)/w	%	21.24
2.	(Specific gravity)/Gs	-	2.53
3	(Sieve analysis)/Cu/CC	%	7.16/0.05
4.	(Liquid limit)/LL	%	42.71
5.	(Plastic limit)/PL	%	34.04
6.	(Indeks plastic)/PI	%	8.67
7.	(Shrinkage limit)/SL	%	36.13
8.	(Optimum water content)/Wopt	%	15.40
9.	(Maximum dry weight)/ γ_{dmax}	Gr/cm^3	1.56

Location of Soil Samples in Pancuran Gerobak. Where the test for location of soil samples that is landslide, it is located in the area of Pancuran Gerobak which is at the street of SM. Raja, in the sub-districts of City Sibolga, the area is located in a hilly area, there is data on the soil physical properties that have been tested and obtained that are shown in the Table 4 below.

Table 4. Landslide data of Pancuran Gerobak

No	Testing soil physical properties/paramater	Unit	Score
1.	(Water content)/w	%	17.79
2.	(Specific gravity)/Gs	-	2.69
3	(Sieve analysis)/Cu/CC	%	4.13/0.26
4.	(Liquid limit)/LL	%	31.37
5.	(Plastic limit)/PL	%	22.50
6.	(Indeks plastic)/PI	%	8.87
7.	(Shrinkage limit)/SL	%	43.62
8.	(Optimum water content)/Wopt	%	11.10
9.	(Maximum dry weight)/ γ_{dmax}	Gr/cm^3	1.83

Location of soil samples in Pancuran Dewa. Where the Test for location of soil samples that is landslide, it is located in the area of Pancuran Dewa which is at the street of Sisingamangaraja, In the sub-districts of Sibolga Sambas, the area is located in a hilly area, there is data on the soil physical properties that have been tested and obtained that are shown in the Table 5 below.

Table 5. Landslide data of Pancuran Dewa

No	Testing soil physical properties/paramater	Unit	Score
1.	(Water content)/w	%	27.76
2.	(Specific gravity)/Gs	-	2.64
3	(Sieve analysis)/Cu/CC	%	4.47/0.36
4.	(Liquid limit)/LL	%	48.65
5.	(Plastic limit)/PL	%	33.31
6.	(Indeks plastic)/PI	%	15.34
7.	(Shrinkage limit)/SL	%	57.91
8.	(Optimum water content)/Wopt	%	29.20
9.	(Maximum dry weight)/ γ_{dmax}	Gr/cm^3	1.393

3.2 Discussion

Physical properties of landslide materials. Soil physical properties indicate soil properties based on shape, size, color, smell of soil, typeof soil and other soil conditions including the relation of mechanical properties such as soil compression. Based on the AASHTO classification results, the landslide samples from Aek Parombunan, Hutabarangan, Pancuran Gerobak, and Pancuran Dewa are classified as the type of silty soil and based on the soil classification from USCS as the type of ML and OL (soil of inorganic clay with low to medium plasticity, gravelly clay, sandy clay, silty clay [17], [18] it is shown as in the Table 6 below.

Table 6. Data of physical properties characterizing landslide materials

No	Location of soil samples	Liquid limit (LL) %	Index plastic (%)	Soil classification based on AASHTO	Soil classification based on USCS
1	Aek Parombunan	38.92	9.95	A4 & A5	ML & OL
2	Hutabarangan	42.71	8.67	A-7-5	ML & OL
3	Pancuran Gerobak	31.37	8.87	A4 & A5	ML & OL
4	Pancuran Dewa	48.65	15.34	A-7-5	ML & OL

Relation of atterberg score. In general, the Atterberg score consists of the liquid limit, plastic limit and shrinkage limit, if the soil with a high liquid limit, it usually has bad engineering properties, that is low strength and high compressibility and it is difficult to compact it [19], [20], because if the soil has low strength, the soil has potential to expand. based on the data from the test of the four soil samples, it can be seen that there is no potential for the soil to expand which is obtained from the soil plasticity index score that is still in the low category. In the journal Physical Properties of Soil and Its Implication to Slope Stability of Nungbi Khunou, NH-150, Manipur [21] it is said a slope becomes less stable if the liquid limit value is greater than the water content value which results in potential expansion of the soil, because the liquid limit value can indicate the relative deformation of the soil and indicate the degree of soil firmness, if our analysis is based on research. In this case, there is a result that the LL value > w value, which means there is potential for soil expansion to occur but the soil expansion that occurs is still at a low level.

From the results of the teststing soil physical properties that has been carried out on the four soil samples where landslide has occurred, it can be seen that there is no potential for the soil to expand which can be analyzed from empirical technical score in estimating the potential to expand based on the Chen, Snethen and Raman criteria [22] that are shown in the Table 7 below.

Table 7. Comparison of expanding soil criteria

No	Location of soil samples	Score LL/PI	Criteria Raman		Criteria Chen	Criteria Snethen		*Potential Swelling Classification*
			Plasticity Index (%)	*Shrinkage Index (%)*	*Plasticity Index* (%)	LL (%)	PI (%)	
1	Aek Parombunan	38,92/ 9,95	<12	<15	0 -15	<50	<25	Low
			12 – 23	15 – 30	10 – 35	50 – 60	25 – 35	Medium
			23 – 30	30 – 40	20 – 35	>60	>35	High
			>30	>40	>35	>60	>35	Very high
2	Hutabarangan	42,71/ 8,67	<12	<15	0 -15	<50	<25	Low
			12 – 23	15 – 30	10 – 35	50 – 60	25 – 35	Medium
			23 – 30	30 – 40	20 – 35	>60	>35	High
			>30	>40	>35	>60	>35	Very high
3	Pancuran Gerobak	31,37/ 8,87	<12	<15	0 -15	<50	<25	Low
			12 – 23	15 – 30	10 – 35	50 – 60	25 – 35	Medium
			23 – 30	30 – 40	20 – 35	>60	>35	High
			>30	>40	>35	>60	>35	Very high
4	Pancuran Dewa	48,65/ 15,34	<12	<15	0 -15	<50	<25	Low
			12 – 23	15 – 30	10 – 35	50 – 60	25 – 35	Medium
			23 – 30	30 – 40	20 – 35	>60	>35	High
			>30	>40	>35	>60	>35	Very high

Relation of porosity score. Theoretically, porosity is the part of the soil that is not filled with soil solid material but it is filled with air and water [23], if the soil is porous, it means the soil has pore space for the movement of air and water to enter and exit freely. Pore is largely determined by the arrangement of solid grains for coarse textured soil has greater percentage of total pore space than fine textured soil [24], if the porosity score is less than 30%, then the porosity is low, the porosity score of 31-60% is categorized as medium porosity, and porosity score is greater than 60, it can be categorized as high or very good porosity [25],[26] The porosity score will describe the level of density of soil which is determined from the ratio of the density of soil mass with the specific gravity of soil [27]. From the results of testing soil physical properties that has been carried out on the four soil samples where landslide has occurred, soil porosity score is obtained, it is shown as in the Table 8 below.

Table 8. Porosity of soil samples

No	Location of soil samples	Porosity score (%)	Porosity class	
1	Aek Parombunan	31.54	< 30	low
			30 – 60	medium
			>60	high
2	Hutabarangan	38.34	< 30	low
			30 – 60	medium
			>60	high
3	Pancuran Gerobak	31.97	< 30	low

No	Location of soil samples	Porosity score (%)	Porosity class	
			30 – 60	medium
			>60	high
			< 30	low
4	Pancuran Dewa	47.34	30 – 60	medium
			>60	high

In the Table 8 above, it can be seen that the porosity score is on the medium threshold which is shown as in the Table 8 below, it means that there is still space or gaps for water movement and it can cause subsidence or landslide, because the space is not filled with soil solid material, but it is still filled with air and water, so that if excess water comes in will cause the soil to become saturated and the water content to increase so that it is no longer able to support the load above and landslide can be occurred.

4 Conclusion

The results of testing soil physical properties that are carried out that testing soil samples based on the AASHTO and USCS systems for landslide material from Aek Parombunan and Pancuran Gerobak are included in the group of A-4 & A-5 and ML&OL, for landslide material from Hutabarangan and Pancuran Dewa is included in the group of A-7-5 and ML&OL.

The influence of the Atterberg score in the soil plasticity index score is included in the low category, it means that there is no potential for the soil to expand, but, if it is seen from the porosity score of the soil material that landslide, it is on the medium threshold, it means there is still space or gaps for water movement and it can cause subsidence or landslide.

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