Study Index Properties of Soil from Geotechnical Test in their Relation to Landslide

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Abstract. There are many methods in assessing landslide, one of them is examine the properties of soil. In this research measured several test on soil sample i.e. unit weight, Moisture content, Hydrometer test. The unit weight test yields a value $\gamma$ is 13.63kN/m³, water content value is 4.51%. Furthermore, the sieve analysis test and hydrometer analysis were carried out to determine the type of soil in the study area, namely little sandy silt. The combination of a steep slope with the type of material that makes up the slope makes the slope prone to landslides. Creep often occur in the slope, which are caused by vibrations from vehicles at the foot of the slope. This condition will make the slope even more unstable because the geometry of the slope will become steeper.

Keywords: Landslide, triaxial, index properties, geotechnical test, lampung.

1. Introduction
Landslides are natural disasters that often occur in the world, especially Indonesia. This is because Indonesia is traversed by the Ring of Fire, which causes Indonesia to have moderate to steep slopes. In addition, the material resulting from volcanic activity causes soil weathering. Weathering soil is on top of impermeable rock in areas with moderate to steep slopes. Areas with this condition have the potential for landslides to occur during the rainy season [1,2]. Padang cermin sub district is the only access to beach tourism in Pesawaran District, which is the main tourist destination in Lampung. Along Padang cermin road consists of cliffs and hills that are vulnerable to landslides [3]. One area that has a fairly steep slope is located on 05°34'4,9" SL and 105°13'55,2' EL Way Ratay, Teluk Pandan District, Pesawaran, Lampung. This area is a hilly area and also has access to major tourist objects that are very frequently visited in Lampung. So that if a landslide occurs in the area, it will close access to these tourist objects. In addition, it can close transportation access between Teluk Pandan District and Padang Cermin District.

To identify the area prone to landslides or not, it is necessary to conduct research related to slope stability. There are several parameters that are used as references in identifying slope stability, one of which is by knowing the property index of the soil. Soil property index is the physical properties of the soil which shows the type and condition of the soil related to the mechanical properties of the soil. Several parameters of the property index that can be used in this study are volume weight ($\gamma$), moisture content (w), pore number (e), porosity (n), and analysis of soil grains [4] - [6]. Some of these parameters are related to slope stability based on soil conditions on the slopes of the study area.

2. Theoretical Background
Landslide or ground motion is a movement of rocks, materials, soil or mixed materials on the slopes due to gravitational force activity, where the driving force on the slope is greater than the friction force of the anchoring.
Landslides occur when water enters the ground on the slopes. If the incoming water penetrates into the watertight soil layer will cause the weathering soil on it to move following the slope and out of the slope. The movement of rainwater into the soil layer is influenced by the physical properties (property index) of the soil on the slope. Basically landslide depends on the shape of the slope, slope, and type of constituent material. The following are the types of ground movements:

1. **Fall**
   Fall is a material movement on a steep slope or ravine. In general, the material in the fall is usually in the form of rocks. The entire fall material moves in free fall in the direction of gravity.

2. **Topple**
   Topple is the fall of rock blocks in vertical rotation due to the Earth's gravitational force. Topple is common in smooth, unconsolidated areas.

3. **Translational slide**
   Avalanche translation is defined as the movement of material along the sliding surface on the slope. Avalanche translation has sliding slope in the form of a planar surface (flat plane).

4. **Rotational slide (avalanche rotation)**
   On rotational landslides, the collapsing surface is circular in shape. In contrast to avalanche translation, the circular shape of the rotational avalanche is caused by damage derived from the geometric distribution of shear voltage on the slope.

5. **Flow**
   Flow is an avalanche of material that descends the slopes of varying sizes ranging from fine soil fragments to chunks mixed with water. Flow type landslides usually occur when heavy rains are continuous so that the constituent material of the slope becomes saturated water and flows along with the fluid that carries it.

6. **Lateral Spreading**
   Lateral spreading is the lateral movement of rocks or soil, often occurring widely on slopes that ramp almost like flat. Landslides of this type usually occur due to liquefaction so that the soil material becomes liquid. Landslides of this type can also occur because they are triggered by rapid movement of soil such as earthquakes.

7. **Complex**
   In landslides of complex types there is a change in nature during movement. This change in nature is in the form of an avalanche of rocks that turn into granular flows. This flow landslide occurs because the material loses cohesion during an avalanche, so the mass is fully mixed with the fluid[7]–[12].

It is very important for us to know the material that makes up the slopes in order to know what types of landslides will occur. To find out the slope constituent material, one thing that needs to be studied is the soil property index. Soil property index is the physical properties of the soil indicating the type and condition of the soil associated with the mechanical properties of the soil. Some soil property index parameters in the form of volume weight, water content, specific gravity, pore figures, porosity and soil grain analysis.

Soil material consists of 3 elements in the form of grains of soil, water and air. Each of these elements has a weight and volume, so to determine the weight of the soil volume can be written as follows (air $W_a = 0$ weight)

$$ \gamma = \frac{W}{V} $$

(1)

With $W$ is the weight of soil and water grains, $V$ is the total volume of soil.

Water content ($w$) in soil material is usually defined as the ratio between the weight of water ($W_w$) and the weight of ground solids ($W_s$).

$$ w = \frac{W_w}{W_s} $$

(2)

The value of moisture content can be used to calculate the weight of the volume of dry soil ($\gamma_d$), that is
Specific weight \( (G_s) \) of soil is defined as the ratio between the weight of the volume of soil material and the weight of the volume of water, can be written as follows:

\[
G_s = \frac{\gamma_s}{\gamma_w}
\]

Pore and porosity numbers
The pore number \( (e) \) can be defined as the ratio between the volume of the cavity \( (V_c) \) and the volume of ground solids \( (V_s) \). While porosity \( (n) \) is the ratio between cavity volume and total volume. Both of these parameters can be written in the formula:

\[
e = \frac{V_c}{V_s}
\]

Then

\[
n = \frac{V_c}{V}
\]

In addition, the pore number value can be known according to value of \( G_s \) and moisture content

\[
e = wG_s
\]

and porosity values can be calculated by formulas

\[
n = \frac{e}{1 + e}
\]

Soil grain analysis is used to determine the type of soil based on the size (diameter) of soil grains. Soil grain analysis is divided into two steps, i.e sieve analysis and hydrometer analysis. Sieve analysis and hydrometer analysis is used to determine the distribution of granular soil sizes[4], [6], [13].

3. Study Area
This research was conducted on one of the slopes in the hilly line of Jalan Raya Way Ratay, Teluk Pandan District, Pesawaran Regency, Lampung. This area is astronomically located a 05°34’4.9” South latitude and 105°13’55.2’ East longitude.
Based on information from the official website of Pesawaran District, the topography consists of lowlands and highlands. In highland areas in the form of hills to mountains, 90.93% of the hills in Pesawaran regency are in Teluk Pandan District with a fairly large slope, which is about 40% based on interpolation calculations. Teluk Pandan sub-district is also one of the districts that has the potential for landslides with an area of about 18,726.33 ha [14].
Based on Figure 2, several Pesawaran areas have a high level of threat, one of which is Teluk Pandan District. This is because these areas are areas that have slopes with high slopes. In addition, several factors in the form of weathering on rocks, the presence of fractures, and high rain intensity can be used as indications for determining the index of landslide hazards.

This study conducted a soil sample test in the study area to determine the properties of the soil property index. Some of the tests carried out are:
1. Unit weight
2. Water content
3. Hydrometer test

In addition to testing soil samples, this study also carried out topographic measurements to determine the slope angle of the slope, which would later be correlated with the soil property index value.
4. Result and Discussion

Based on the results of the soil property index test in the study area, several results were obtained as shown in Table 1. The weight value of the soil volume shows that the soil has moderate density, but the soil in the study area is very hard and dense rock. This is supported by the very small water content value of 4.51%. This water content value can be used to determine the value of soil porosity using Eq. (7) and Press. (8). The results of calculations using these two equations show a small soil porosity value, namely 11%.

| Test result data          | Sample mass used (grams) | Results                  |
|---------------------------|--------------------------|--------------------------|
| $\gamma$ (berat volume)  | 84.13                    | 13.6359 kN/m$^3$         |
| $w$ (Moisture content)   | 21.5                     | 4.51 %                   |
| Hydrometer analysis      | 500                      | Gravel 0%                |
|                           |                          | Sand 9.3%                |
|                           |                          | Silt 90%                 |
|                           |                          | Clay 0.7%                |
| $G_s$ (Spesific Gravity) |                          | 2.80                     |

The porosity value is related to the type of soil in the research area which is a slightly sandy silt. This can be seen based on sieve analysis and hydrometer analysis by classifying soil types using the USCS (Unified Soil Classification System) system [6]. Based on the USCS system silt has a grain size of less than 0.075mm, besides that silt is gritty (sandy). These silt grains undergo compaction due to mechanical weathering and consolidation so that they become solid, but have low moisture content and porosity [16] - [18].

If the property index value is correlated with the angle of the slope (59.87°), then the slope can be said to be prone to landslides. This can be seen from the soil conditions on the slopes in the form of solid silt rock with small porosity making the slopes prone to rock falls during the dry season. Rock fall occurs in the study area because it has steep slopes with rock material. The movement of rock fall is influenced by gravity and mechanical weathering processes which usually occur unevenly. Rock falls can also occur in the study area if the slopes often receive vibrations such as vibrations from vehicles or earthquakes. Even so, it is possible for the slopes to experience other types of landslides during the rainy season. The possibility of landslides that occur during the rainy season is debris flow. Debris flow will occur when it rains heavily at long intervals. This is because the soil in the study area is difficult to absorb water. If the soil is difficult to absorb water, then rainwater will flow down the slope surface (surface run-off). The flow of water on the surface will carry the mixed material on the slopes in the form of a mixture of soil and rock [7] - [11], [19].

5. Conclusion

Based on these results, the slope has a steep slope angle of 59.87°. The slope has a slightly sandy silt type of material, which consists of 90% silt; 9.3% sand and 0.7% clay. The combination of a steep slope with the type of material that makes up the slope makes the slope prone to landslides. Landslides that often occur in the area are rock falls, which are caused by vibrations from vehicles at the foot of the slope. This condition will make the slope even more unstable because the geometry of the slope will become steeper. This can allow the slopes to collapse again both in the dry season and in the rainy season.

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References

[1] M. R. Amri et al., RBI Risiko Bencana Indonesia. Jakarta: BNPB, 2016.
[2] Z. Umar, B. Pradhan, A. Ahmad, M. N. Jebur, and M. S. Tehrany, “Earthquake induced landslide susceptibility mapping using an integrated ensemble frequency ratio and logistic regression models in West Sumatera Province, Indonesia,” ELSEVIER, vol. 118, pp. 124–135, 2014.
[3] Ikah N.P. Permanasari. Determination of Slip Surface Using 2D Geoelectric Resistivity Method and
Laboratory Analysis for Landslide Prone Area Pesawaran, Lampung. IOP Conference Series: Earth and Environmental Science, vol. 537, 2019.

[4] R. F. CRAIG, *Craig’s Soils Mechanics*, SEVENTH ED. SPON PRESS Taylor & Francis Group, 2004.

[5] J. E. Bowles, *Foundation Analysis and Design*. Singapore: Mc Graw Hill, 1996.

[6] B. M. Das, *Principles of Geotechnical Engineering*, Fifth edition. THOMSON, 2006.

[7] T. Kusky, *LANDSLIDE: Mass Wasting, Soil, dan Mineral Hazards*. New York: Facts On File, 2008.

[8] C. C. Plummer, D. H. Carlson, and L. Hammersley, *Physical Geology*, Fifteenth. New York: Mc Graw Hill, 2016.

[9] F. V. De Blasio, *Introduction to the Physics of Landslides*. New York: Springer, 2011.

[10] A. S. Muntohar, *Tanah Longsor: Analisis-Prediksi-Migitasi*. GERC UMY.

[11] C. W. Montgomery, *Environmental Geology*, Ninth. New York: Mc Graw Hill, 2011.

[12] I. N. P. Permanasari, “Mekanisme Runtuhan Tebing dengan Bidang Gelincir Melengkung Sebagai Awal Longsoran Lereng, Studi Kasus Daerah Cililin Kabupaten Bandung Barat,” Institut Teknologi Bandung, 2017.

[13] Darwis, *Dasar-dasar Mekanika Tanah*. Yogyakarta: Pena Indis, 2018.

[14] “Situs Resmi Kabupaten Pesawaran,” Situs Resmi Pemerintah Daerah Kabupaten Pesawaran, 2018. [Online]. Available: pesawarankab.go.id. [Accessed: 11-Feb-2019].

[15] BPBD, “Kajian Risiko Bencana Provinsi Lampung Tahun 2019-2024,” Bandar Lampung, 2019.

[16] G. V. Chilingarian and K. H. Wolf, *Development in Sedimentology 1A: Compaction of Coarse-Grained Sediments, I*. New York: ELSEVIER, 1975.

[17] G. V. Chilingarian and K. H. Wolf, *Development in Sedimentology 1B: Compaction of Coarse-Grained Sediments,II*. New York: ELSEVIER, 1976.

[18] L. D. Wesley, *Fundamentals of Soil Mechanics for Sedimentary and Residual Soils*. New Jersey: John Wiley and Sons, 2010.

[19] G. R. Thompson and J. Turk, *Introduction to Physical Geology*. Brooks Cole, 1997.