International Journal of GEOMATE, Nov., 2019 Vol.17, Issue 63, pp. 323 - 330
ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2019.63.69945
Geotechnique, Construction Materials and Environment

SAFETY FACTOR CHARACTERIZATION OF LANDSLIDE IN RIAU-WEST OF SUMATRA HIGHWAY

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*Corresponding Author: Received: 03 April 2019, Revised: 28 April 2019, Accepted: 15 May 2019

ABSTRACT: The geological hazard is a heavy landslide often struck around Tanjung Balik area, Koto Baru Sub District, Lima Puluh Kota District, West of Sumatra Province. Located along the highway Riau – West Sumatra Kilometer 10-15 and the coordinates are in 00˚08'40"N- 0˚11'20 "N and 100˚45'20"E- 100˚47'00"E. The aim of current research work is to identify the slope safety factor that experienced landslides in the research area. The methods used are Direct Shear Stress and safety factor analysis was used Software Slide 6.0. The results of the analysis concluded that the value of cohesion and angle of the friction are obtained from Direct Shear Stress on the station research areas ranging from 0.261 to 0.321 kg/cm²1 with friction angle from 11 to 20˚. Safety Factor on the research areas classified into unstable classification with the lowest value *0.192* and the highest value 0.48.

Keywords: *Landslide, Slope, Safety Factor, Cohesion*

1. INTRODUCTION

Indonesia is a disaster-prone area. Therefore, the efforts of a deep understanding of the dangers of Earth (geo-hazards) and the resulting concept of disaster management is very important to continuously be improved [1][2][3][4][5][6]. In the regulations on the management of the governmental organizations in the fields of energy and mineral resources[7][8], geology hazards related aspect is included in the term "geological disasters" [9][10][11][12][13].

Geological disasters such as landslides [14] often plagued Koto Baru Sub District[2]. Recent data recorded of the year 2017 occurs twice, namely massive landslides on 3rd of March and 29th December, 2017. The impact of this landslide is the road from the direction Pekanbaru closed making it difficult for a vehicle to mobilize and cause fatalities [2]. Type of the material form debris avalanches is occurring on a slope on the side of the collapsed road and potholes along 15 meters. The conditions disaster area, in general, is undulating hills with a rather steep slope to steep. Elevation disaster site about is 70 meters above sea level. Based on the Geological Map Sheet of Pakanbaru, Sumatra, the disaster area is composed of red and mottled mudstone, conglomerate-breccias and conglomerates sandstones from Pematang Formation (Tlpe). The characteristics of this rock are consist of joint, water escapes, layering, highly weathered, especially in the bedding plane, with a relatively thick soil weathering [15][16][17][18][19].

Factors cause a landslide occurred in the region is the volume of the heavy rains [20][21], weathering of soil thickness, high porosity and passes the water to be saturated when it rains down, unstable slopes and steep [22][23][24].

Analysis of stability in the research area is needed to identify the balance safety factor of slope stability to test the condition of the balance at the time of the landslide began[25]. Slope stability analysis needs to know the physical properties and mechanical properties of rocks. Physical properties required data in the form of rock bulk density (γ), whereas the mechanical properties are the shear strength parameters of rock that are expressed in the cohesion (c) and the angle of friction (Θ) [26]. In principle on a slope actually happens are two kinds of styles of style retaining (R) and the driving force (W sin ψ). Slopes will be a landslide if the motive force greater than the retaining force or W sin ψ> R, shown in Figure 1. The style is secured to the anchoring of the driving masses in order to avoid avalanches, while the driving force is the force that causes the mass to move so that the occurrence of landslides. Cohesion is an attractive force between particles in rocks declared in units of weight per unit area. Value cohesion (c) obtained from the direct shear stress test. Relationship between consistency and cohesion are shown in Table 1, while the relationship between the values of cohesion and soil erodibility classes[26][27][28], shown in Table 2.

Friction angle (Θ) is an angle formed between the affirmation of the relationship normal to the shear stress in the soil or rock material. The relationship between density and friction angle are shown in Table 3. The safety factor (FK) to the avalanche slope depends on the ratio between soil shear strength (δ) and shear work (τm) in Eq. 1. If FK> 1 has a stable kind of slope stability, while FK <1 occurrence of landslides on the slopes [29][30]. The aim of the current research work is to identify the slope safety factor that experienced landslides in the research area.

$FK = \delta / \tau m$ (1)

Where:

(δ) = Soil shear strength

(τm) = shear work

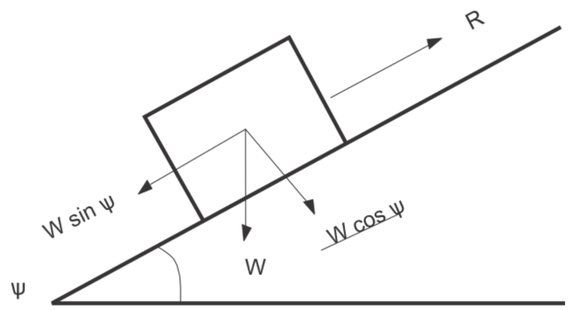

Fig. 1 The forces acting on a block on top of the incline

Table 1 The relationships between consistency and cohesion

Consistency	Cohesion
Very soft	< 1.25
Soft	1.25-2.50
Medium Stiff	2.50-5.00
Stiff	5.00-10.00
Very Stiff	10.00-20.00
Hard	>20.00

Table 2 The relationship between density and friction angle

Type of Density (g/cm^3)	Friction Angle (Ø°)
Very loose	< 30
Loose	30 – 35
Medium dense	35 – 40
Dense	40 – 45
Very dense	> 45

Table 3 The soil erodibility class

Cohesion value	Class Description
0 – 0.10	Very low
0.11 – 0.20	Low
0.21 – 0.32	Medium
0.33 – 0.43	Rather High
0.44 – 0.55	High
0.56 – 0.64	Very High

2. MATERIAL AND METHOD

The sample was collected around 10 samples and around 5kg which dug by the scope and bore pipe, but only 5 representative samples used for shear strength. Shear strength is an internal resistance per unit area of land to the collapse or shift along the plane of the shear in the land in question. Direct shear stress is a simple and direct test, are shown in Figures 2a and 2b. Testing is done by placing a soil sample into a sliding box. This box is split, with half of that under a fixed portion and the upper part is translating. This box is available in several sizes, but usually has a diameter of 6.4 cm or square 5.0 x 5.0 cm. The soils samples are carefully placed inside the box, a loading block including porous rocks scalloped for fast drainage, are laid on soil samples. Then a normal load Pv did. The second part of this box will be a little detached and loading blocks and the upper half of the box to merge into one. The shear strength is influenced by several factors, among others: effective pressure or pressure between the grains, the ability of the particles or the density, each lock among particles: thus, the particles that angle will be interlocked and has a shear strength of higher Φ) rather than rounded particles such as cliffs, cementation of particles, which occur naturally or artificially and appeal among particles or cohesion [27].

Calculation step in testing the shear strength directly among as follows, Eq. 2 [31]:

a. Calculate the shear force Ph: Ph = reading watch x calibration proving the ring
b. Calculate the shear strength
c. Calculate the normal stress (σn)
d. Graph relation ΔB / B versus τ, then each specimen get τmax
e. Draw a straight line through the points versus σn τ relationship also get the parameters c and Φ.
f. To get the parameter c and Φ could be solved by mathematical equation (linear regression). Formula shear strength is:

$\tau = c + \sigma \text{ to } \varphi$ (2)

where:

τ = shear strength (kN / m2)

c = cohesion of the soil

φ = friction angle in the soil (degrees)

Shear strength of soil could be considered as two parts or components:

a. Friction in, which is comparable to the effective stress acting on the shear field.
b. Cohesion depends on soil type and density of the soil is generally classified as follows: Land cohesion or fine-grained (clay), the soil is not cohesion or coarse-grained (sand), ground cohesion-friction (silt).

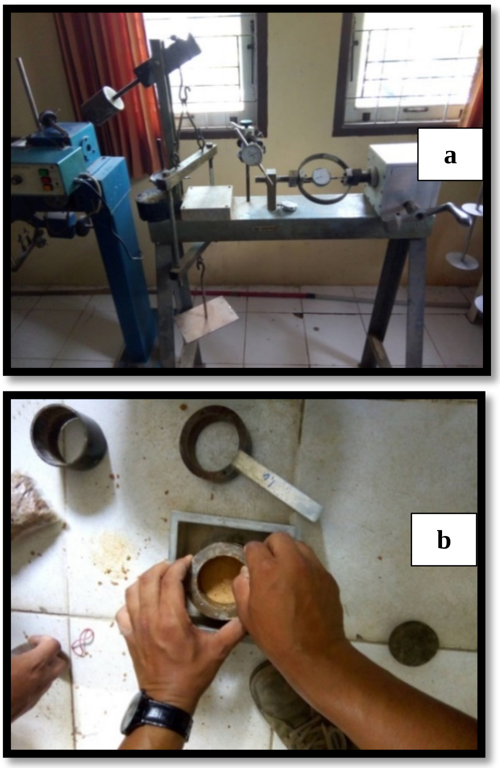

Fig. 2 Direct shear stress a) equipment b) tools

The safety factor is the security factor attached to the high point of the slope if c is set to zero, the high slope generally affecting stability. At low voltages, the material may not cohesion if ground voltage increases with the increase in altitude, the soil material will show the real value of cohesion [28].

The shear strength equation in a review effective voltage that can be deployed ground, until the achievement of equilibrium conditions with regard to boundary safety factor [29], Eq.3.

$$\tau = \frac{c}{F} + (\sigma - u)\frac{tg\emptyset}{F} \quad (3)$$

Where τ is the normal stress in the field of the landslide and u is the pore water pressure, Eq. 4.

$$F = \frac{1}{\Sigma W \, Sin} \Sigma\left[cb + (W - ub)tan\emptyset\right]\frac{sec\,\alpha}{1+(tan\,\varphi\, tan\,\alpha)/F} \quad (4)$$

Where: W= Weight; Cb= Material surface; φ= friction angle; α = ration of the tensile; F= yiel function) 3

Generally, slope stability and safety factor against shear strength are taken is greater than or equal to 1.2-1.5. Value of the safety factor represented the landslide intensity [30][26], shown in Table 4.

Table 4 The safety factors value and landslide intensity relationship.

Safety factor value	Landslide intensity
FK is less than 1.07	Landslide occurred regular / frequent (unstable slopes)
FK is between 1.07 to 1.25	Landslide case (critical slope)
FK is over 1.25	Rare Landslide (relatively stable slope)

A safety factor of the slope analysis had been performed by Software Slide 6.0 with *Bishop* method. The data included are the weight content of the soil, cohesion, angle of friction and slope geometry such as height, width and slope. In this program, the value entered (input) is as follows: Dimensions slope elevation, slope length, slope angle in the x and y-axis. Projections slope safety factor analysis using Software *Slide 6.0* [29] is shown in Figure 3.

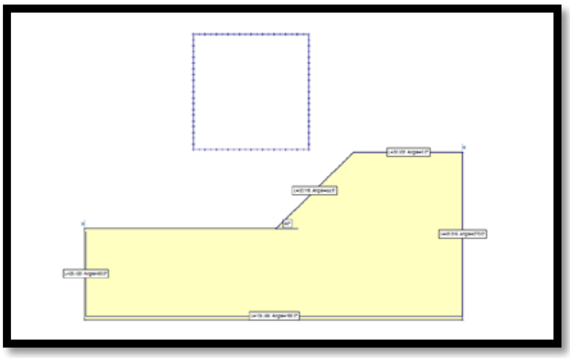

Fig. 3 Input data from the volume of soil, cohesion, and friction angle in slope safety factor analysis using software *slide 6.0*

Flowchart implementation of the research consisted of the preparation phase, the field data collection phase, direct shear test analysis, analysis of the slope safety factor, safety factor level of slope analysis, and writing scientific articles, is shown in Figure 4.

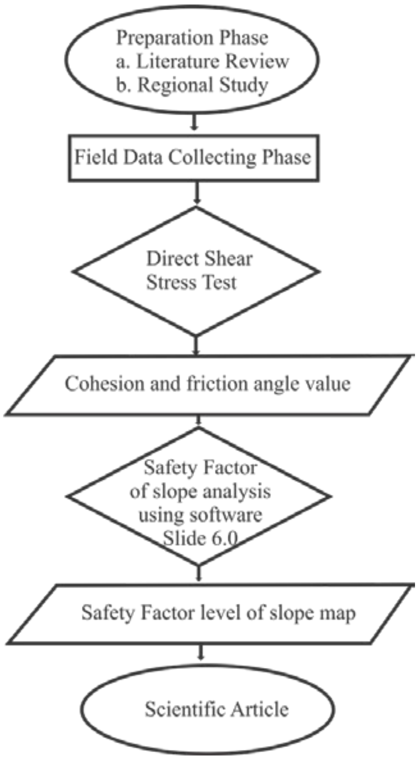

Fig. 4 Flowchart implementation of the research

3. RESULT AND DISCUSSION

Result of the slope safety factor of the landslide in the research area, taking some representative samples at Station 1, Station 4, Station 6, Station 9 Station 10, and then run data is used *bishop* methods. Several factors are inputted values and processed into Software *Slide 6.0* consists of the value of the slope geometry, cohesion, friction angle and slope. Cohesion values are obtained from the value 0.296 to 0.321, conclude the consistency value of the research area are classified types of very soft and the erodibility is classified in medium class, shown in Table 5. Degrees of the friction angle is obtained in 11-25 then compactness of rock types in the study area are classified very loose, shown in Table 6.

Table 5 Present the relationship between the value of cohesion, consistency and credibility in the research area

No	Station	Cohesion (Kg/cm^2)	Consistency	Erodibility
1	ST 1	0.301	Very soft	Medium
2	ST 4	0.301	Very soft	Medium
3	ST 6	0.296	Very soft	Medium
4	ST 9	0.311	Very soft	Medium
5	ST 10	0.321	Very soft	Medium

Table 6 Present the relationship between degrees of friction angle (θ) and compactness

No	Station	Ө (°)	Compactness
1	ST 1	20	Very loose
2	ST 4	25	Very loose
3	ST 6	18	Very loose
4	ST 9	11	Very loose
5	ST 10	17	Very loose

A. STATION 1

The geometry of the slope landslide at Station 1 in the research are as follows: high, length, wide of the slope are 25m, 10m, 15 m, respectively and degree of the slope is 67°. Based on a direct shear stress test of samples are gotten the results of cohesion value is 0.301 kg/cm^2, friction angle is 20 ° angle, soil bulk density is 3.750 g/cc. Based on the result of the analysis of values is obtained *Safety Factor* the slopes is 0.192 and has been included in the class of labile/unstable with the possibility of landslides often occur which are shown in Figure 5a.

B. STATION 4

The geometry of the slope landslide at Stations 4 in the research area are as follows: high, length, wide of the slope are 5m, 4 m, 7m, respectively and degree of slope is 45°. Based on a direct shear stress test of samples are gotten the results of cohesion value is 0.301 kg / cm^2, friction angle is 25°, soil bulk density is 7.00 gr/cc. Based on the result of the analysis of values is obtained *Safety Factor* the slopes is 0.480 and has been included in the class of labile/unstable with the possibility of landslides often occur as shown in Figure 5b.

C. STATION 6

The geometry of the slope landslide at Station 6 in the research areas as follows: High, length, wide of the slope are 25m, 7m, 10 m, respectively and degree of slope is 50°. Based on a direct shear stress test of samples are gotten the results of the cohesion value is 0.296 kg/cm^2, friction angle is 18°, soil bulk density is 1.775 gr/cc. Based on analysis of *Safety Factor* the slopes is 0.278 and has been included in class labile/unstable with the possibility of landslides often occur as shown in Figure 5c.

D. STATION 9

The geometry of the slope landslide at Station 9 in the research area as follows: High, length, wide of the slope are 10 m, 25m, 28m, respectively degree of slope is 43°.

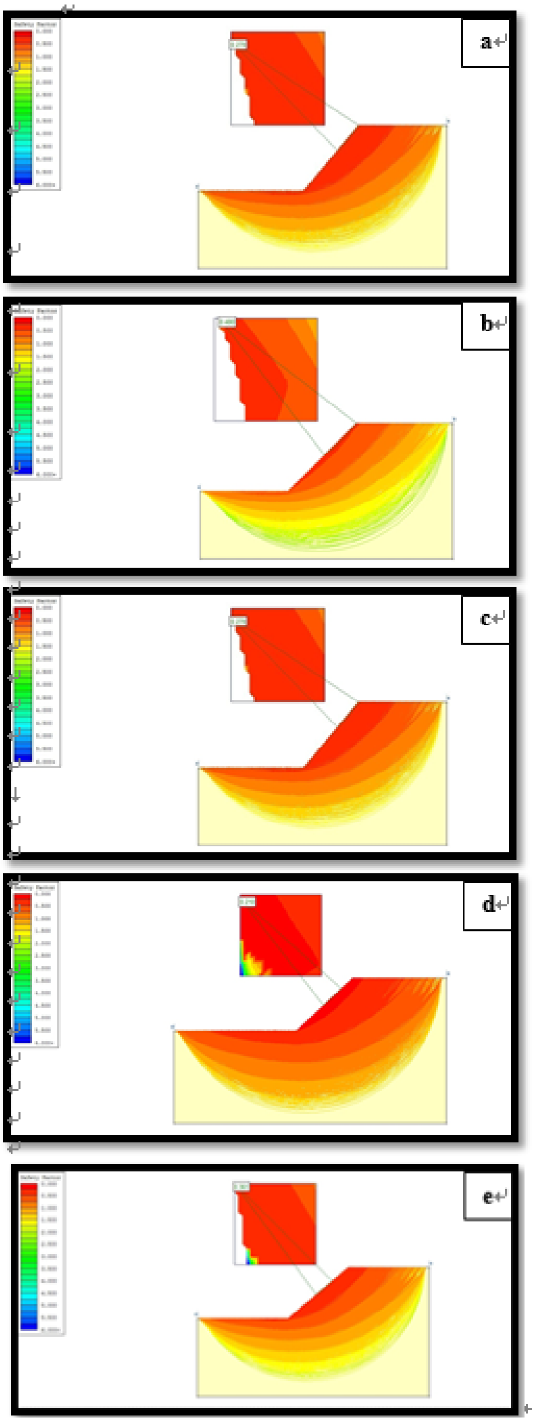

Fig. 5 Analysis of Slope Safety Factor with a value of a) Station 1 is 0.192 at, b) 0480 at Station 4, c) 0278 at station 6, d) 0210 at station 9, e) 0361 at station 10, using Bishop method and software *Slide 6.0*.

Based on a direct shear stress test of samples are gotten the results of the cohesion value is 0,311 kg/cm^2, friction angle is 11°, soil bulk density is 7,075 gr/cc. Based on the analysis result is obtained value Safety Factor slope is 0.210 and has been included in the class labile/unstable with the possibility of landslides often occur is shown in Figure 5d.

E. STATION 10

The geometry of the slope landslide at Station 10 in research areas are as follows: High, length, wide of the slope are 25 m, 11 m, 29 m, respectively and degree of slope is 40°. Based on a direct shear stress test of samples are gotten the results of cohesion value is 0.321 kg / cm^2, friction angle is 17°, soil bulk density is 7.975 gr/cc. Based on the results of the analysis of values is obtained *Safety Factor* the slopes is 0.361 and has been included in the class of labile/unstable with the possibility of landslides often occur as shown in Figure 5e.

Based on the analysis of the slope safety factor which has been obtained, it is concluded the safety factor level of slopes in the area of research is classified as an unstable class or labile, shown in Table 7. Landslides often occur especially in the North and South of the research area, as indicated by the characteristic wavy roads, with the value of slope safety factor of 0.192 to 0.480. Map safety factor level of slope along the highway Riau-West Sumatra Km 10-15 Tanjung Balik area, Koto Baru Sub District, Lima Puluh Koto District, West of the Sumatra Province, is shown in Figure 6.

Table 7 The relationship between safety factor and landslide intensity

No	Station	Safety Factor	Landslide Intensity
1	ST 1	0.192	landslides are frequent (unstable)
2	ST 4	0.480	landslides are frequent (unstable)
3	ST 6	0.278	landslides are frequent (unstable)
4	ST 9	0.210	landslides are frequent (unstable)
5	ST 10	0.361	landslides are frequent (unstable)

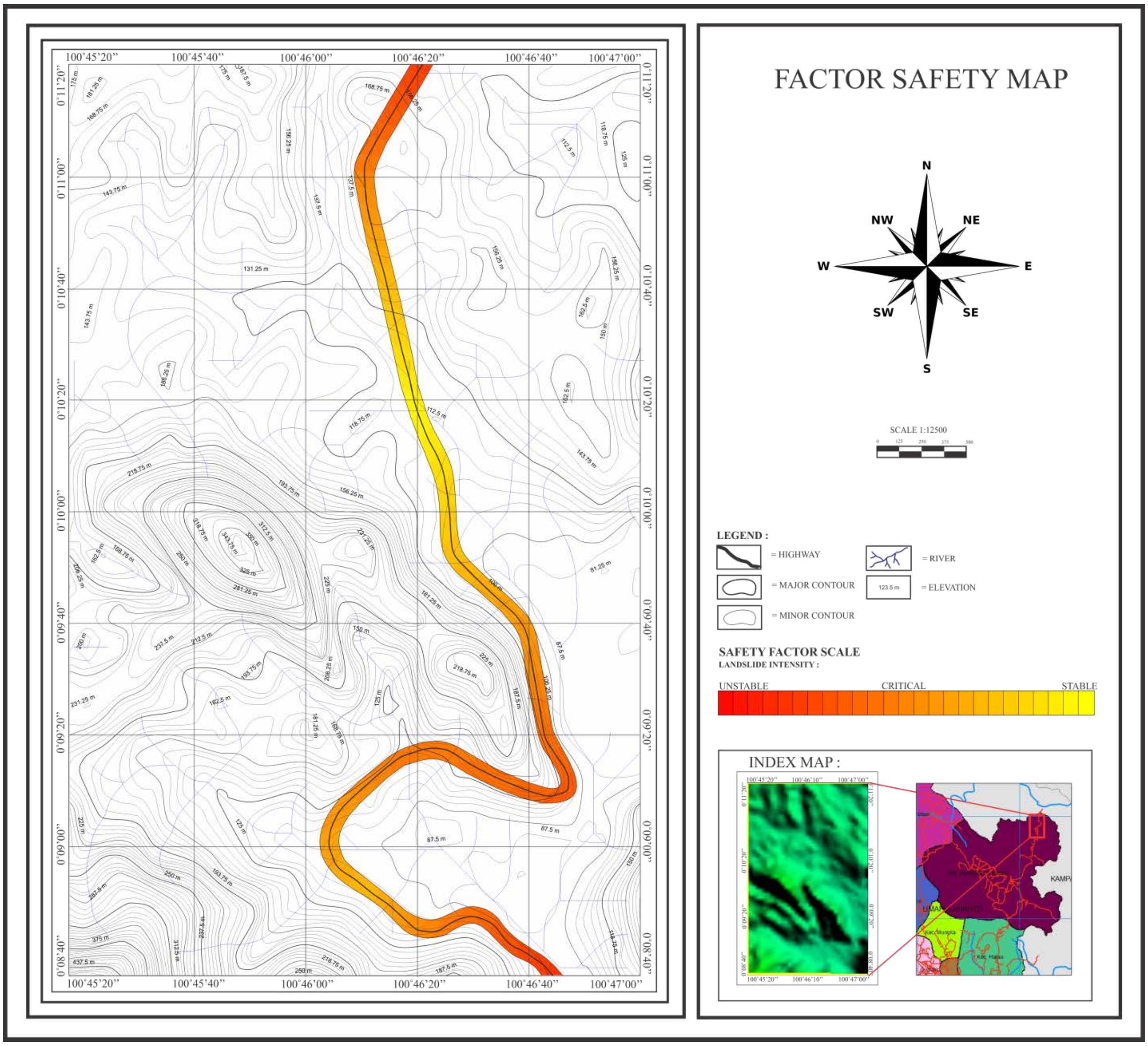

Fig. 6 Map of safety factor level of slopes along the Riau-West of Sumatra Highway Km 10-15 Tanjung Balik area, Koto Baru Sub District, Lima Puluh Koto District, West of Sumatra Province.

4. CONCLUSION

Based on the results of data collection in Tanjung Balik Region, Sub Base of Koto Baru, District of the Lima Puluh Koto, West Sumatra Province along Riau-West Sumatra highway Km 10-15, cohesion values obtained with the number it concluded consistency in the study area were classified types of very soft and erodibility is a kind of medium. From the result of the friction angle, the compactness of the rock types in the study area are classified very loose. Safety factor analysis of slope that has been obtained, it is concluded the safety factor level on the slopes of the study area were classified unstable class, landslides often occur especially in the North and South of the study area, as indicated by the characteristic meander roads.

5. ACKNOWLEDGMENTS

Acknowledge to LPPM Universitas Islam Riau and all team in Department of Geological Engineering and Department Regional Urban Planning, Universitas Islam Riau. Thanks to staff laboratory of Faculty of Engineering, Universitas Islam Riau which provides facilities such as Direct Shear Stress Test. This research has been supported by the Ministry of Research, Technology and Higher Education of the Republic of Indonesia (Grant no. SP DIPA 042.06.1.401516/2018) and Research Institute of Universitas Islam Riau.

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