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Measurement of Slope Stability on Stone Mines Around Pengsong Hills, West Lombok Area

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Abstract: The slope stability angle of the surface landslide stability depends on the friction coefficient between the rock particles in the area. Measurement of slope stability is very useful for the safety of miners in mining areas. Measurement of slope stability is based on the friction coefficient. Measurements are made with a friction coefficient measuring instrument that has been designed and tested. Rock samples were taken at 3 rock mines around Mount Pengsong in West Lombok Regency. The measurement of the friction coefficient was carried out at the Physics Laboratory of the University of Mataram. The measurement results of the friction coefficient are then converted into slope stability angles. The results show that the slope stability angle in the mountains around the rock quarry around Mount Pengsong has a maximum value 5,71 degree of dry sample and 81,0 degree of moisture sample.

Keywords: Friction coefficient; Slope stability angle; Stone mines

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Introduction

Slope stability is very important in the safety of the mining industry. Many accidents occur in mining areas caused by landslides due to unstable slopes. The angle of slope stability must be taken into account so that landslides do not occur.

Landslides occur due to slope instability because of an imbalance of forces acting on the material on the slope. At the time of the landslide, the resultant force on the slope material has a value that is not equal to zero. This happens because the downward force (in the direction of the slope plane) is greater than the upward force on the plane. The upward force in this direction acts as a resisting force called the frictional force.

The value of the frictional force is proportional to the normal force and static friction. The value of the normal force is proportional to the mass of the material on the slope.

The friction coefficient between the particles that make up the soil can be measured using the coefficient of friction which depends on the slope of the material composing the rock. This angle is the maximum (critical) angle of soil stability.

Lucas, et al., (2014) examined landslides and found that the larger the mass of the soil that experienced the landslide, the smaller the frictional force . Pares and Aharonov, (2015) made an avalanche model assuming a rolling rigid body grain so that it does not involve frictional forces. Johnson et al., (2016) hypothesized acoustic fluidization with results showing the relationship between vibration wavelength and rock fragment size to runout. Yamada et al. (2018), estimates the dynamic coefficient of friction through the inversion of synthetic seismic numerical data. The results show that the landslide velocity is proportional to the square root of the change in height of the center of mass due to the landslide.

Basic Theory

The coefficient of friction of an object can be determined by measuring the slope angle of the object's landslide on a plane.

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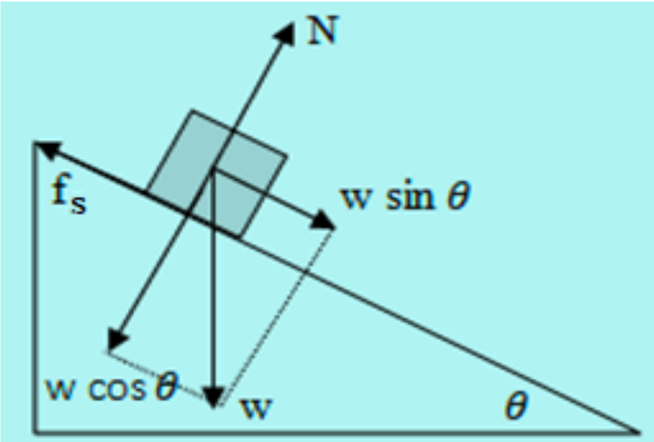

Figure 1. A rock model on an inclined plane

Figure 1 shows the components of the force acting on an object during a landslide. The weight of the object w can be broken down into w sin and w cos . The force w sin is the force in the direction of the plane that causes the landslide. The force w cos is the weight in the direction normal to the plane. The reaction force of w cos is called the normal force.

The frictional force fs is the force that holds the material so that it doesn't slide. The fs value is proportional to the normal force and the coefficient of friction which can be written as equation iven by Halliday et al (2001):

$$f_s = \mu_s N \quad (1)$$

$$f_s = \mu_s w \cos \theta \quad (2)$$

where fs is the static friction force, N is the normal force and my s is the coefficient of static friction of the material making up the slope.

At equilibrium, the value of fs is equal to the value of w sin θ. At the maximum slope, the fs value is the largest value that shows the friction coefficient value of the material, so it can be written

$$f_s = w \sin \theta \quad (3)$$

$$\mu_s w \cos = w \sin \theta \quad (4)$$

$$\mu_s = \tan \theta \quad (5)$$

From equation (5) it can be seen that the coefficient of friction depends on the maximum slope angle at the time of the landslide. The greater the angle of the landslide, the greater the coefficient of static friction between the materials and vice versa. An object with a small friction coefficient will have a small sliding angle, while an object with a large friction coefficient will have a large sliding angle.

Method

The measuring Instrument is designed in such a way as to have high accuracy. One effort to increase the accuracy is to make the test plane in such a way that the plane is completely flat. This is done by installing 2 nivo tubes which are installed perpendicularly to get a completely flat plane. To get a completely flat plane is done by leveling. Leveling on the tube nivo is done with 3 flat positioning screws, namely screws A, B and C. The number of screws as many as 3 pieces is based on the reason that 3 points will always be in the same flat plane. The leveling step is started by turning screw A, or B, or both, so that the bubble in tube 1 is centered. If this is successful, then screws A and B should not be turned again. Next, to get leveling at the second nivo, screw C is turned so that the bubble on the nivo is in the middle.

The landslide plane shaper is made with the aim of ensuring that friction occurs between the soil material and the soil material itself, not the soil material against the floor of the container. Angle measurement is done by measuring the height (h) of the tip of the lever or the horizontal distance of the lever (x) from the landslide tool. Measurements were made using an angled ruler with an uncertainty of up to ± 0.5 mm. The glide plane length(s) is measured once very carefully and written on the instrument.

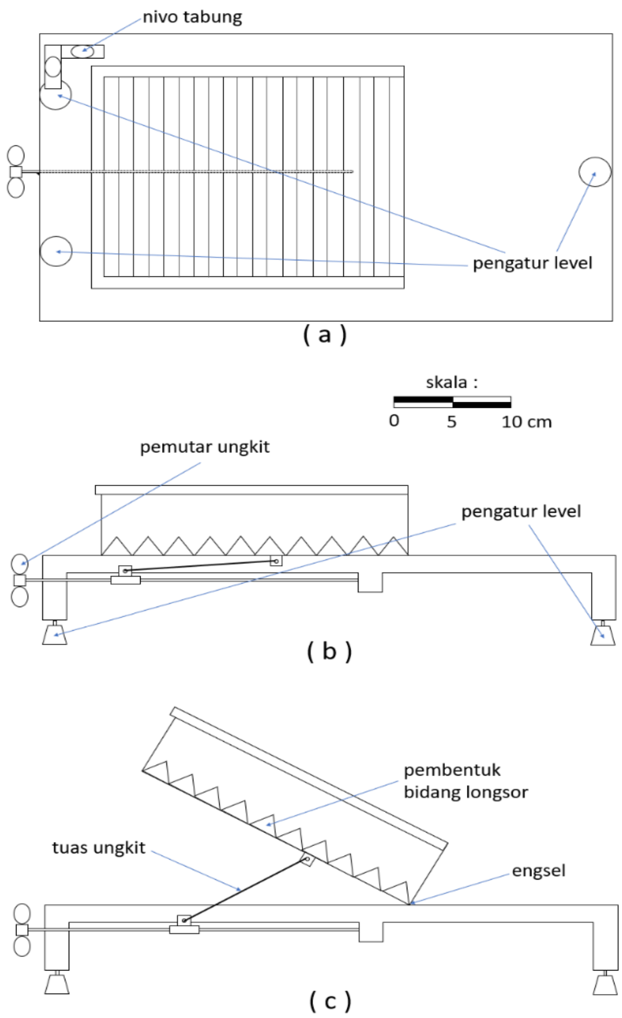

Figure 2. The design of the coefficient of friction test tool (a) top view (b) side view flat position (c) side view tilted position(Zuhdi, 2019)

August 2022, Volume 1, Issue 2, 36-39

The value of the angle of inclination is equal to the inverse cosine of the horizontal distance of the lever divided by the length of the plane of the lever, so that the angle of inclination can be written by the equation:

$$\theta = \arccos(x/s) \tag{6}$$

The equation 6 allow us to calculate slope stability angle from the distance (x) and space (s).

(a)

Site A Site B Site C

(b)

Figure 3. Location of site 1, site2 and site 3 on rock mines (a) map (b) photograph

Figure 3. shows location of site 1, site2 and site 3 on rock mines around Pengsong Hills, West Lombok Area, Nusa tenggara province. The map Is taken from google map with satellite view setting. The location is in south direction of Mataram City on Lombok Island. The photograph consists of 15 pictures and have been selected as the 3 best pictures.

Leverage measurement was carried out to the order of 1 mm with an uncertainty (error) of ± 0.5 mm. The measurement of the length of the lever has an accuracy of up to 0.1 mm with an error of ±-0.05 mm.

Figure 4. Measuring friction coefficient measuring instrument

Figure 4. the above one shows a tool that is levered with a slope that still shows slope stability. The bottom image shows a tilt with a maximum angle of marble so that landslides occur.

Results and Discussion

In this research, this tool was used to measure the coefficient of friction of 3 samples taken from 3 different site around Pengsong Hills, Western Lombok Area. The sites are located near Steam Power Plant of PLN.

The test results of this tool are shown in table 1. In this it appears that the variables measured are the projection of the plane on the x-axis and the length of the plane of leverage. The competencies emphasized in this practicum are measurement accuracy, understanding of true dip and leveling as well as the ability to calculate error propagation.

Measurements were carried out under humidity conditions in accordance with the humidity conditions of the laboratory room. When the sample is taken in the field, the humidity is maintained by placing the sample in a waterproof plastic and stored in the laboratory without special treatment.

Table 1. Results of measurement and calculation of dry sample friction coefficient

Location Sampel	x distance ±0,5 mm	Length (s) ±0,05 mm	θ degree	μ_s ±0,05
Site 1	19.70	32.15	52.20	1.29
Site 2	17.50	32.15	57.10	1.54
Site 3	18.22	32.15	55.50	1.45

Humidity affects the coefficient of friction of a soil material. Water can be used as an adhesive for soil constituents so that the slope becomes more stable. The number of water molecules at a certain level can strengthen the bonds between the particles that make up the soil. In principle, water particles can increase the cohesive force between soil particles because of the small contact angle between water particles and hydrophilic soil constituent mineral grains (Ludman, 1982).

In dry conditions, the particles are more prone to landslides than the moist soil particles. This is due to the loss of water which strengthens the bonds between the particles that make up the soil. Thus, the presence of water in a certain amount can increase the coefficient of friction between soil constituent materials. However, the amount of water that is too much can also reduce the coefficient of friction of a soil constituent material. Excess water particles will actually make the soil turn into a viscous fluid that can flow so easily Avalanche. Abundant water molecules can make soil particles float between water molecules. This condition is often referred to as liquefaction.

Table 2 shows the friction coefficient for 3 samples which is the same as Table 1, but in humid conditions. Humidification is done by spraying water using a water sprayer and stirring using a cement ladle. The quantity of addition of water moisture is 20 cc per liter of dry sample.

Table 2. Results of measurement and calculation of coefficient of friction for moist samples

Location Sampel	x distance ±0,5 mm	Panjang (s) ±0,05 mm	θ degree	μ_s ±0.05
Site 1	9.15	32.15	73.50	3.37
Site 2	5.01	32.15	81.00	6.34
Site 3	7.37	32.15	76.70	4.25

By comparing table 1 to table 2, it can be concluded that the coefficient of static friction in humid conditions is greater than the coefficient of friction in dry conditions. This occurs due to the increase in the attraction between the particles as a result of the addition of water.

Conclusion

From Table 1 it can be seen that the soil with sample of site 2 has the largest coefficient of friction, namely 1.54, while sample of site 1 has the smallest coefficient of friction with a value of 1.29. From table 2 it can be seen that in humid conditions, the mineral with sample of site 2 has the largest coefficient of friction, namely 6.34, while sample of site 1 has the smallest coefficient of friction with a value of 3.37.

Measurement of lever height, length of horizontal distance and length of inclined plane with high accuracy produces friction coefficient with high accuracy as well. Based on the theory of propagation of error, the resulting friction coefficient value has a fairly high accuracy of 0.05. Leverage that is done slowly allows us to get the best, accurate and optimal value of the landslide angle. The use of nivo allows us to increase the accuracy with the measure of the slope angle which is the true dip value.

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