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Slope Stability Analysis Based on Type, Physical And Mechanical Properties Rock In Teluk Pandan District, East Kutai Regency, East Kalimantan Province

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Abstract

The research title is Slope Stability Analysis Based On Type, Physical And Mechanical Properties Rock In Teluk Pandan District, East Kutai Regency, East Kalimantan Province. Aimed to determine the lithology in the research area and to find out how the amount of slope that will be a landslide at that location.

How the research with the analysis of coring drilling results are then analyzed in the laboratory of rock mechanics to get the characteristic of physical and mechanical properties of the rocks. Methods of data analysis using Hoek and Bray Methode with Rockslide Software.

The results showed that in the area study has a sedimentary rock lithology fine to medium detritus, such as claystone, siltstone and sandstone, as well as inserts are coal and shale. Based on the results of laboratory analysis of rock mechanics obtained density between 2,648 to 2,770. While the test results obtained value triaxial cohesion between (6.66 - 9:05) Kg / cm^2, friction angle in between (37.19 - 44.08)°, cohesion residual (2.72 - 3.10) Kg / cm^2, residual friction angle (27.22 - 32.44)°. While the direct shear test the cohesion of the summit between (6.66 - 9:05) Kg / cm^2, friction angle in the cohesion peak (36.15 - 43.00)°, cohesion residual (2:22 to 3:10) Kg / cm^2, friction angle in the cohesion residual (37.22 - 33.85)°. The simulation results stability of the slope stability Hoek and Bray using rockslide software, the result is that if the slope with a single slope stability, the stability of the slope is 60°, and if the slope with the stability of the slope overall stability of the slope is 48°.

Keywords: Slope Stability, rock type, rock physical properties, mechanical properties of rocks

1. Introduction

In principle, landslides occur when the driving force on the slope is greater than the barrier force. Retaining force is generally influenced by rock strength and soil density. While the driving force is influenced by the magnitude of the slope angle, water, weights and soil type of rock soil. The threat of landslide usually occurs in wet months, due to increased rainfall intensity. The long dry season causes the evaporation of water in the soil surface in large quantities, resulting in the emergence of pores or cavities in the soil, which resulted in cracks and ground fractures. When it rains, water will infiltrate the cracked soil so that the soil will quickly expand again. At the beginning of the rainy season and the high intensity of rain usually occurs water content in the soil becomes saturated in a short time (Hoek and Bray, 1974 in Koesnaryo.et. al., 2003).

Heavy rains that descend at the beginning of the season can cause landslides, because through soil fractures or water rocks will enter and accumulate at the bottom of the slope, causing lateral movement. With the vegetation on the surface will prevent the occurrence of landslides, because the water will be absorbed by plants and plant roots will also work to bind the soil. The steep slopes or cliffs form will enlarge the driving force (Nandi, 2007).

The study associated with avalanches in 2012 mention that stable slope design studies are needed in the exploitation of coal mines, especially in open pit systems. Mining requires slope design in various ways. In rock formations containing a layer of loose material such as quartz sand in the Balikpapan Formation as well as Kampung Baru Formation in Sangasanga, East Kalimantan, the determination of the weighting of the slope masses needs to be corrected to find the safest slope angle. The SMR (Slope Mass Rating) correction results involving the SMR value and RMR (Rock Mass Rating) are: 1) SMR = 68.22 ln (RMR) - 225.5 (for logarithmic equations); 2) SMR = 1,262 RMR - 22.30 (for linear equations); 3) 0.082 RMR 1.580 (for power equations); And 4) SMR = 9,191e0,029 RMR (for exponential equations). Meanwhile, according to Azizi., MA, and Handayani., R. in 2011, on Characterization of Input Parameters For Single Slope Stability Analysis (Case Study At PT Tambang Batubara Bukit Asam Tbk, Tanjung Enim, South Sumatera) the results showed

the distribution of cohesion function and friction angle in is uniform, the distribution of density function is beta, and the distribution of security factor function is uniform. Up to 40-meter slope height and slope angle of 60o, the slope is still stable (probability slope of zero slopes).

The landslide disaster in various parts of the world is so devastating, such as the incident in Madukara Sub-district, Banjarnegara District, Central Java on March 27, 2016. The Regional Disaster Management Agency reported that the damaged houses 17 units were lightly damaged 2 units, and were directly threatened by landslide 7 units, with a total of 267 refugees from 73 families (Tempo.Co. Banjarnegara dated March 29, 2016).

Implementation of the model applied by Hoek and Bray is expected to overcome the problem of avalanche, especially in East Kalimantan.

2. Methodology

The mass of rocks scattered in nature is a collection of unequal materials (heterogeneous). Each rock/material has characteristics that differ from each other.

Characteristics of rock mass in a particular area, it is necessary to measure or observe directly to the material or rocks in the area.

The field investigation that has been conducted, intends to take samples of rock material located in the research area. The samples taken are cores from full coring geotechnical drilling. Each layer of lithology is sampled as a representation of lithology in the field.

Method of drilling activity is by coring method. Boring Unit has used the type of Jacro 175 with the ability to penetrate layers of rock up to a depth of ± 100-150 m below the surface.

Coring is a coal drilling activity to sample coal seams using a core barrel with double tube. The coring results obtained an example of rock layers, which will be used for coal quality analysis and physical analysis and geomechanics analysis.

Table 1. Bore Hole location

No.	Bore Hole	Location	Easting (m)	Northing (m)	Elevation (m)
1	GEOTECNIC	TELUK PANDAN	25,252	527,998	122

Laboratory Testing.

Laboratory testing is done to know the material characteristics that are in the research location. The parameters to be used in the modelling are the physical properties and mechanical properties of the material (soil/rock). Rock samples for geotechnical studies were tested in rock mechanics laboratories.

Types of tests that have been carried out are physical properties, namely: original sample weight, sample volume, original content weight, moisture content, dry content weight, specific gravity, pore number, porosity, degree of saturation and dry content weight, saturated content weight, triaxial test, Un-confined Compressive Strength (UCS), and Shear Test.

The results of laboratory testing from the field are physical properties test, uniaxial traction strength test and triaxative compressive strength test, then analyzed using Hoek and Bray method (1974), with rockslide system

3. Results and Discussion

The material in nature is generally is a stable state (stabile), meaning that the stress distribution of the material is in equilibrium. However, if there is any activity causing the disruption of the slope material stress, the forces present in the soil or rock will seek to achieve a new equilibrium by reducing the load, especially in the form of landslide.

Factors affecting Slope Equilibrium. Stability of a slope is influenced by several things, among others:

1. *Geometry of Slope*
   Geometry slopes consisting of slope and altitude greatly affect the stability of a slope. The bigger the slope and the height of the slope, the steadiness diminishes. In addition, hoarding and slaughtering activities will cause the addition and subtraction of the load so that the material stability will change.
2. *Physical and mechanical properties of rocks*
   Physical properties of rocks that affect the steepness of stability include: the weight of the contents (density), porosity, and water content. While the mechanical properties of rocks that affect the steepness of the slope include: compressive strength (UCS), tensile strength, and shear strength (cohesion and internal shear angle).
3. *Geological structure and characteristics*
   Geological structures that influence the steepness of the slope include: fault, Joint, fold, bedding plane, and crack. The geological structure is a weak field and as well as a place to seep the water and can cause the occurrence of tension crack causing rocks to become easily landslides.
4. *Hydrological and hydrogeological conditions on the slope*
   The existence of water, especially ground water, affects the stability of a slope, because the soil water has a pressure known as pore water pressure which can cause an uplift force which is very influential on the occurrence of landslide due to decrease Shear strength.
5. *External styles*
   External forces that can affect the stability of a slope include: vibrations caused by earthquakes, explosions, loading and others.
6. *Weathering*
   Weathering greatly affects the stability of the slope. Temperatures that quickly change in a short time will accelerate the process of weathering rocks. For tropical weathering occurs faster. Therefore, rock outcrops on the tropical slopes will be more rapidly weathered and this leads to an avalanche of slopes.

3.1 Condition of Lithology of Research Area

Based on the topographic map of the study site, there are variations in elevation ranging from 30 - 100 m. Weakly to moderate corrugated morphological conditions are found 100% in the work area (5 - 20º slope angle). The lithology of the research area was sedimentary rock which is dominated by sandstone, siltstone and claystone with main composition is quartz. In addition, there are rocks, sometimes present conglomerates.

The geological structures encountered are shear faults and the presence of synclinal structures. The flow patterns in the study area are controlled by rock resistance levels that tend to be the same between the formations. The growing flow pattern is subdendritic.

Subterranean lithologic conditions in the Drilling Location from the ground up are as follows: Rocky, grey, medium hard, open packing, medium sorting, coating structures, medium permeability, sometimes very delicate sandstones. The thickness of this rock unit is 9.6 meters. Above it is deposited in harmony of claystone, grey colour, coating structure, medium hardness, silica, good sorting, closed packing, poor permeability, clay grain size, thickness of this rock unit is 8.70 meters.

Next is deposited again sandstone unit, light gray, medium hardness, fine grain, layer structure, there are carbonstone clay inserts, clay and coal, good sorting, closed pack, medium permeability, thickness of this rock unit is 21.65 meter.

Above the sandstone unit there is a unit of claystone, the thickness of this rock unit is 26.25 meters, with sandstone inserts, coal and carbonaceous clay. Above it again there are rocks, with thick 10.63 meters, with coal inserts and carbonaceous clay. Then on top of it there are a claystone 5.42 meters thick with coal inserts, and carbonaceous clay.

Constantly precipitated consecutively rocks, then sandstones, clay again and sandstones, last claystone then sandstone.

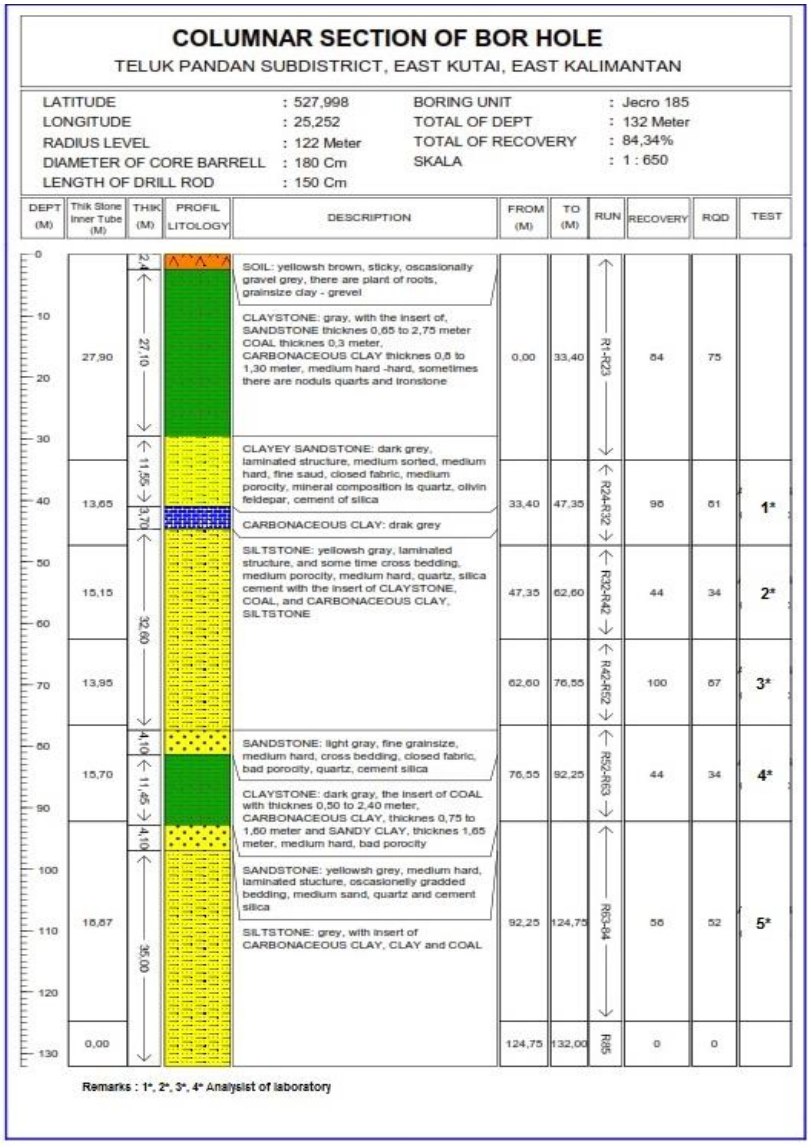

Fig. 1. Columnar Section of Borehole in Teluk Pandan District. East Kutai. East Kalimantan

3.2 Slope-forming Materials

The most dominant type of drilling is 31,04%, followed by 22,02% in sequence of stone, 15,6% sandstone, 15.12% carbonaceous clay, 7.28% sandstone, 6.80% coal and 1.98% soil. Rock types can be seen in Table 2 and Fig. 2.

Table 2. Lithology Type of Drilling

No.	Lithology	Percent
1	Soil	1.98%
2	Claystone	31.04%
3	Carbonaceous Clay	15.12%
4	Siltstone	22.02%
5	sandstone	7.28%
6	Coal	6.80%
7	Sandy Clay	15.76%

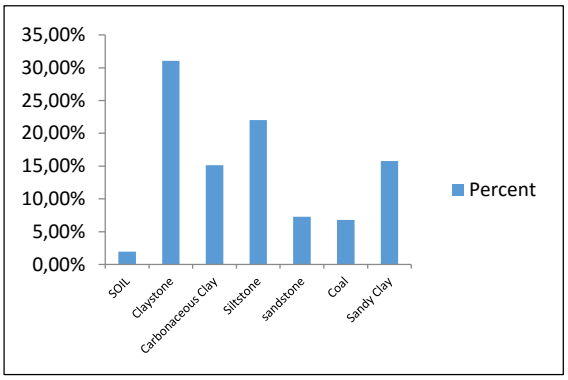

Fig 2. Type of rock in drilling research area

3.3 Strength of rock

In the drilling based on RQD (Rock Quality Designation) the bottom layer has an ugly strength and then above the coal coating strength is good to very good, then the rocks above. The types of lithology and drilling can be seen in Table 3.

Condition of rock strength at drill hole based on result of laboratory analysis of rock mechanics obtained by weight of type between 2,648 until 2,770. In the triaxial test there was total cohesion between (6.66 - 9.05) Kg / cm2, total angle between (37.19 - 44.08)°, residual cohesion (2.72 - 3.10) Kg / cm2, residual slide angle (27.22 - 32.44)°. While on the direct shear test the peak cohesion between (6.66 - 9.05) Kg / cm2, the inner shear angle at peak cohesion (36.15 - 43.00)°, residual cohesion (2.22 - 3.10) Kg / cm2. deep sliding angle on residual cohesion (37.22 - 33.85)°. This indicates that the rocks at the study sites are included in moderate strength. The existing lithology in the study area is generally moderate to moderate sedimentary rocks, such as claystone, limestone and sandstone, and there are coal inserts, flakes. The condition of drilling result lithology in Telukpandan Sub-district of East Kutai Regency. East Kalimantan Province can be seen in Fig. 3.

Table 3. Lithology and RQD of research area

Nomor	Lithology	RQD (%)
1	Claystone	87
2	Sandstone	27 - 87
3	Claystone	50 - 89
4	Sandstone	67-97
5	Claystone	53-93
6	Sandstone	100
7	Claystone	33-100
8	Carbonaceous clay	99
9	Sandstone	100
10	Clayey Sand	90-100
11	Carbonaceous clay	31
12	Siltstone	11-87
13	Claystone	85
14	Siltstone	78
15	Coal	100
16	Siltstone	81-100
17	Sandy Clay	38-96
18	sandstone	10-97
19	Coal	57-100
20	Claystone	90
21	Sandy Clay	32
22	Claystone	32
23	Siltstone	56-66
24	Claystone	0
25	Siltstone	0

Fig. 3. Drilling lithology conditions in Telukpandan Sub-district, East Kutai Regency. East Kalimantan Province.

Table 4. Characteristics of rock strength at drilling

No. Lab			1	2	3	4	5
Rock code sample			R13	R24	R33	R53	R64
Soil and rock classification			Zst	Sst	Zst	Sst	Sst
HEAVY-VOLUME CHARACTERISTICS							
Water Content	W	%	5.38	6.84	4.88	9.75	5.19
Specific gravity	Gs	-	2.770	2.676	2.692	2.648	2.703
Original content weight	ɣ	g/cm^3	2.494	2.210	2.455	2.244	1.979
Weight of dry contents	ɣd	g/cm^3	2.366	2.069	2.340	2.044	1.881
Weight of saturated content	ɣsat	g/cm^3	2.512	2.296	2.471	2.272	2.185
Porosity	N	%	14.56	22.70	13.05	22.78	30.40
Pore number	e	-	0.17	0.29	0.15	0.30	0.44
The degree of saturation	Sr	%	87.51	62.38	87.49	87.48	32.11
PLASTICITY CHARACTERISTICS							
The liquid limit	LL	%	28.31	NP	NP	NP	23.38
Plastic limit	PL	%	15.61	NP	NP	NP	14.86
Shrinkage limit	PI	%	12.69	NP	NP	NP	8.52
Shrinkage index	SL	%	0	NP	NP	NP	0
Activity	A	%	1.81	NP	NP	NP	1.06
GRAIN GRADUATED CHARACTERISTICS							
Clay (BS < 0.002 mm)		%	7	0	Hard of	0	8
(ASTM < 0.005)		%	27	0	Sedimentary	0	20
Silt		%	63	4	Rock	4	32
Fine Sand		%	10	86	Hard of	91	21
Medium Sand		%	0	0	Sedimentary	5	27
Coarse Sand		%	0	0	Rock	0	0
Gravel		%	0	0		0	0
CHARACTERISTICS OF STRENGTH							
Triaxial test							
Total Cohesion	c	Kg/cm^2	8.22	7.28	9.05	6.66	7.79
Total Shear Angle	Φ	…^{o}	37.19	44.08	39.28	43.61	43.57
Residual Cohesion	cr	Kg/cm^2	2.79	2.54	3.10	2.32	2.72
Residual Shear Angle	Φ	…^{o}	27.22	32.44	29.28	31.72	32.23
Direct shear test							
Peak Cohesion	cp	Kg/cm^2	8.22	7.28	9.05	6.66	7.79
Total of Shear Angle	Φ	…^{o}	36.15	43.00	38.22	42.52	42.48
Residual Cohesion	cr	Kg/cm^2	2.74	2.43	3.02	2.22	2.60
Angle of Internal Friction	Φ	…^{o}	27.22	33.85	29.53	33.41	33.37

Note: NP : Non-Plastics, Cst : Claystone, Zst : Siltstone, Sst : Sandstone

3.4 Analysis and Recommendations of Slope Stability of Research Areas

3.4.1. Highwall Slope Research Area

a) Single Slope (Individual Slope)

Stability analysis for single slopes is done with the following approach:

a. Single slopes that will be studied in the form of slopes that will occur avalanches.
b. Single slope modelling was performed on each lithology with 10 m high simulation with a slope angle of 60º.
c. The value of FK (Security Factor) as the basis that the slope in steady condition is FK ≥ 1.30.
d. Modeling is applied with the average properties approach of each lithology in the borehole.
f. The simulation results can be seen in Fig. 3.

3.4.2. Overall Slope (Overall Slope)

The approach to performing an overall slope analysis that is represented by the properties of the drill hole slope stability simulation results in order to simplify the various parameters is as follows.

a. The entire slope to be studied is a slope that will occur avalanches.

b. The overall slope modelling is done on each cross section of geotechnical drilling by taking each rock unit in the study area.
c. The overall slope in accordance with the recommendation is at the location of the drilling with angle 48° for all rock type material.
d. The value of FK (Security Factor) as the basis that the slope in steady condition is FK ≥ 1.30.
e. Model data input with average lithologic properties approach on drill hole.
f. Analysis on high condition of single slopes 10 meters by 3 meters.
g. The simulation results can be seen in Fig. 4.

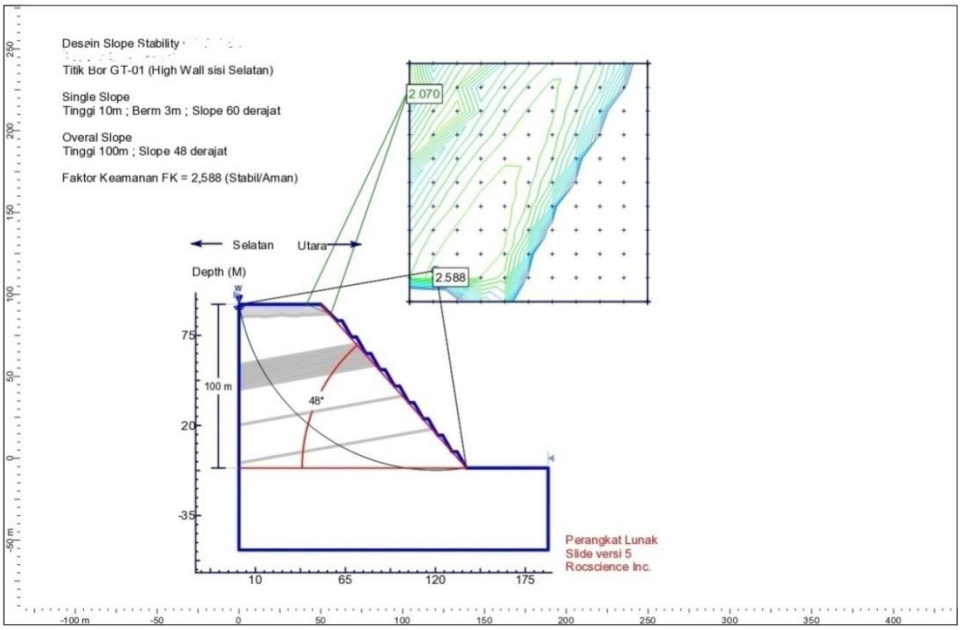

Fig. 4. Results from simulation without blasting in the research area

Conclusion

The study, which is located in Teluk Pandan Sub-district, East Kutai Regency, East Kalimantan Province, has the following conclusions:

1. From the drilling results made known that the rocks that make up the research area are moderate-grained sandstone rocks with very fine-grained (clay). While based on RQD (Rock Quality Designation) rock layers are rocks that have medium to good strength, but sometimes low power.
2. The result of slope stability analysis in the study area, with single slope and done on existing rock layers, then obtained a height of 10 m slope and slope angle of 60 º with security factor 1.30. But for the overall slope height slope of 100 m with slope angle of 48o and 3 meters, for all layers of rock with security factor 2,588.

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