The Effect Of Physical and Mechanical Properties of Rock on Erosion Potential in Coal Mine Disposal

by Frinsyah Virgo

IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

THE EFFECT OF PHYSICAL AND MECHANICAL PROPERTIES OF ROCK ON EROSION POTENTIAL IN COAL MINE DISPOSAL AREAS

Desi Natalia[1], Frinsyah Virgo[2], Siti Sailah[2*]

[1]Student of Magister Program of Physic, Faculty of Mathematics and Natural Sciences, University of Sriwijaya, Palembang, South Sumatera, Indonesia

[2]Lecturer of Physic Department, Faculty of Mathematics and Natural Sciences, University Of Sriwijaya, Indralaya, Ogan Ilir, South Sumatera, Indonesia

*Corresponding author : siti.sailah@unsri.ac.id

Abstract: This research studies the effect of rock physics and mechanics on the potential for erosion in the disposal area of coal mines. The research data is secondary data in the form of geotechnical data from the geotechnical laboratory of PT. Bukit Asam. The physical properties analyzed in this study were water content and particle size distribution, while the mechanical properties analyzed in this study were plasticity index and shear stress. The correlation between physics and rock mechanics properties against erosion potential is calculated using empirical equations, while the magnitude and effect of correlation among the three calculated using Pearson correlation SPSS version 16. Based on this analysis it is known that there is a very strong positive influence between the plasticity index of the shear stress, with a value of $R^2 = 0.9955$ or has a correlation of 0.998. While the shear stress has a strong influence with the erodibility coefficient of $R^2 = 0.7225$ or with a correlation level of 0.85. The correlation between the two is negative, which means erodibility coefficient decreases with increasing critical shear stress.

Keywords: disposal, erosion, physics properties, mechanics properties, rock.

I. INTRODUCTION

Along with the increasing development of technology, the world's need for energy is also increasing. This increasing need has caused every country to strive to increase its energy sources, one of which is by using coal. The large demand for coal in a country causes it to import coal from other countries. Several countries in the world import coal from Indonesia, as one of the largest coal exporting countries in the world Indonesia, has several coal mining companies, both state-owned and private companies. Coal mining companies in Indonesia use an open-pit mining system to extract coal deposits that are in the earth. This mining system is carried out by first digging the coal cover (soil or rock), then placing it in certain areas such as stock soils, disposal, or revegetation areas.

Of the three locations for placing the overburden, the disposal area is the area with the largest erosion rate (Sri Sarminah, 2017). A disposal area is a place for piling up soil or rock layers covering the coal seam. This seam can be above the coal seam (overburden) or between the coal seams (inter burden). The disposal area is an area that is very susceptible to erosion because it is in the open and has little cover vegetation. If exposed to rainwater, this area would be eroded, so that soil nutrients will be carried away by the water flow. It would result in degradation of ecosystem functions, landscapes, and a decrease in agricultural productivity (Yellishetty, 2013). If this erosion process is allowed to continue continuously, it would be damage existing facilities, so it will cost a lot to repair it (Miscevic & Vlastelica, 2014). Therefore, this erosion event threatens people's lives, agriculture, and economic conditions (Stephen F. Mueller, 2015).

Erosion is a natural process that is quite complex because it involves many factors. Erosion occurs in three stages, namely: Several factors that influence the level of erosion are water erosivity, soil or rock erodibility, land slope, land cover management (Sri Sarminah, 2017) (Stacey & Karim, 2017) (Liu, et al., 2015), rainfall, climate, and duration of erosion (Shasta M Marrero, 2018). Erodibility of rocks is whether the soil/rock is easily eroded or the resistance of soil/rock particles to peeling and transport of the particles due to the kinetic energy of rainwater. This erodibility factor is determined by rock characteristics such as physical properties (grain size, porosity, rock density, permeability, plasticity, and water content), organic and chemical content, as well as mechanical properties such as shear stress and rock shear strength. The level of erosion in a stream can be predicted using the equation below this (Jason P. Julian, 2006) (Clark & Wynn, 2007)) ;

$$E = k(\tau - \tau_c) \quad (1)$$

Dimana:

E : Erosion rate (m/s)
k : Erodibility Coefficien (m^3/N.s)
τ : shear stress caused by water flow (Pa)
τ_c : Critical shear stress (Pa)

Stacey and Karim (2017) explain that soil with high erodibility has low critical shear stress and the plasticity index below 10. The critical shear stress which is defined as land detachment began to occur or conditions that initiate the detachment of soil. The rate of corrosion does not occur (zero) if the critical stress is higher than the effective stress (Clark & Wynn, 2007). The critical stress is influenced by several rock properties (rock texture, moisture, rock type, and cohesion) and cannot be modeled with only one parameter. Another factor affecting the rock erodibility is grain size, according to (Yellishetty, 2013) rocks below 0.1 mm more prone to erosion than rock measuring 0.1 mm - 2 mm.

Because the role of soil/rock characteristics in the erosion process is very large, it is necessary to research to analyze how much influence the physical properties (water content and grain size distribution) and rock mechanics (plasticity index and critical shear stress) have on the potential for erosion in the area. So that later we can take even better steps to prevent erosion

II. MATERIAL AND METHOD

II.1.Data Sources

In this study, the data source used is secondary data in the form of geotechnical data. This geotechnical data is data generated based on test results and rock sample analysis conducted by the geotechnical and exploration laboratory of PT. Bukit Asam Muara Enim. Samples were obtained from 5 drill points with various drilling depths in the mine area of Pit III Banko Barat PT. Bukit Asam Muara Enim, South Sumatra Province, which is located at coordinates 3 ° 43.734'S - 3 ° 44.244'S and 103 ° 49.649'E - 103 ° 50.173'E.

II.2.Method

Several methods are used to calculate and analyze research data, including:

III.2.1. Critical Shear Stress

To calculate the critical shear stress, it can be done by conducting a direct test (in situ) using the Jet Test equipment (Clark & Wynn, 2007) and testing samples in the laboratory. Whereas for non-cohesive soils and soils with fine grains, the calculation of the critical shear stress can be estimated using a shield diagram. However, the prediction of critical shear stress using the Shield diagram produces a value that is below the estimate, resulting in an erosion rate that is beyond the predictions (Hanson & Simon, 2001).

The erosion process begins when the shear stress exerted by flowing water exceeds the critical shear stress of the soil (Smerdon & Beasley, 1959). The critical shear stress can be defined from a graph plot of the level of erosion and shear stress (Clark & Wynn, 2007). Smerdon and Beasley (1961) conducted a study on eight cohesive Missouri soils, by linking basic soil properties such as plasticity index, dispersion ratio, particle size, and clay content to critical shear stress. The empirical relationship between soil characteristics and the critical shear stress generated by this study can be seen in the equation below;

$$\tau_c = 0{,}161(I_w)^{0{,}84} \quad (2)$$

$$\tau_c = 10{,}2\ (D_r)^{-0{,}63} \quad (3)$$

$$\tau_c = 3{,}45\ \times 10^{-28{,}1\ D_{50}} \quad (4)$$

$$\tau_c = 0{,}49\ \times 10^{0.0182 P_c} \quad (5)$$

With:

τ_c : Critical shear stress (Pa)
I_w : Platicity Index
D_r : Dispersion ratio
D_{50} : Average particle size
P_c : percentage of clay content

III.2.2. Erodibility

Erosion-resistant soil or rock tends to have low erodibility, and erosion-prone soil/rock will have high erodibility. The value of the soil/rock erodibility coefficient is influenced by several factors, including rock characteristics (Small, Blom, Hancock, Hynek, & Wobus, 2015). However, until now the simple empirical relationship between rock characteristics is not known. Although this relationship is not yet known, we can use the results of calculations made by Hanson and Simon (2001) on the results of the calculation of critical shear stress using the jet test (Hanson & Simon, 2001) (Clark & Wynn, 2007).

$$k_d = 0{,}2\ \tau_c^{-0{,}5} \quad (6)$$

With :

E : erosion rate (m / s)
k_d : Coefficient erodibilitas (m^3/N.s)
τ : shear stress caused by water flow (Pa)
τ_c : critical shear stress (Pa).

III.2.3. Statistical Methods

To determine the magnitude of the influence and the relationship between physical and mechanical properties of rock on the potential for erosion in the disposal area, Pearson correlation analysis was used with a significance level of = 0.05 or 5%. This test involves two variables (bivariate analysis), namely the independent variable and the dependent variable. All analyzes will be carried out using SPSS statistical version 16 with the following interpretation of the correlation coefficients (Sugiyono, 2012):

Table 1. Guidelines For Interpretation Of Correlation Coefficients

Correlation Interval	Correlation level
0,00 – 0,199	Very low
0,20 – 0,399	Low
0,40 – 0,599	Moderate
0,60 – 0,799	Strong
0,80 – 1,000	Very Strong

III. RESULTS AND DISCUSSION

III.1. Analysis of Physical Properties and Mechanical Properties Of Rocks

Based on the analysis of the test results from the five sample points above, it is known that each sample point has a different grain size distribution and rock type. The distribution of rock grain size followed by different water content will cause differences in the rock plasticity index. The difference in the average grain size distribution, moisture content, and plasticity index of each drill point can be seen in the table below:

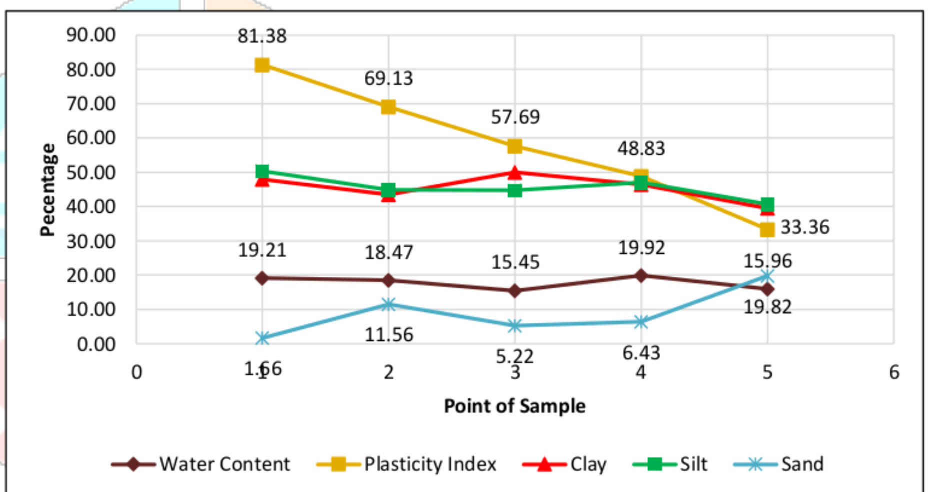

Figure 1. Graph Of Average Sample Test Results

The graph above shows the differences in the characteristics of the sample rocks at the five drill points. The sample from the first point (BKGT.34) has a very high average plasticity index (81.38%), with an almost balanced content of clay and silt grains, and a very small amount of sand (1.66%), and water content. which is quite high from the other points. While the sample from the second point (BKGT.35) experienced a decrease in the average plasticity index of 69.13% (high plasticity) with almost balanced clay and silt content and 11.56% sand grains and 18 moisture content. 47%.

The sample from the third point (BKGT.36) has a high plasticity index, which is 57.69%, with slightly more clay content than silt and the number of sand grains is 5.22%. The rock samples at this point have a relatively low water content when compared to other sample points. This decrease in water content certainly affects the decrease in the average plasticity index of the sample rocks. A decrease in the average plasticity index also occurred in the sample from the fourth point (BKGT.37). Based on the graph above, the sample at the fourth point has a medium plasticity index (48.83%). However, the decrease in the plasticity index was not followed by a significant increase in the number of sand grains. The sand grains at this fourth point only amounted to 6.43% of the entire rock, the rests were clay and silt grains which had almost the same amount. As for the water content, the sample from the fourth point has a water content of 19.92% which is the highest moisture content when compared to other samples.

Geotechnical data from the fifth drill point (BKGT.38) shows that the fifth point has a medium plasticity index with an average value of 33.36%. This decrease in the plasticity index has a negative correlation with the number of grains of sand contained in the sample rock at this point. As seen in the graph above, the sample point BKGT.38 has almost the same amount of clay and silt content and a high enough amount of sand compared to the previous four samples, which is 19.82%.

Based on the data above, in general, the Pit III Banko Barat disposal area consists of three types of rock, namely clay, silt, and sand with varied distributions, as can be seen in the diagram below;

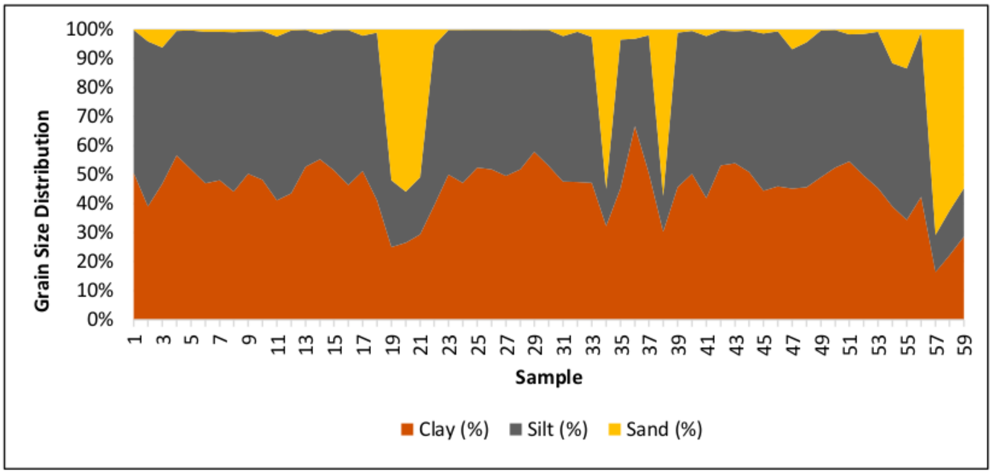

Figure 2. Particle Size Distribution Diagram In The Disposal Area Of Pit III Banko Barat

From the diagram above, it can be seen that the size distribution of clay with silt is almost the same, with the average size distribution of 45.39% and 45.28%, while the amount of sand is only 9.32%. Pei Zhao et al (2011) found that high clay - silt content (> 40%) is more resistant to erosion because the aggregate structure is stronger than sands (Zhao, Shao, Omran, & Amer, 2011).

Besides having variations in grain size distribution, samples from the five drill points also showed variations in water content. Variations in water content and grain size distribution will affect the plasticity index of the rock, where the average water content of the five drill points is 17.73% and the average plasticity index is 57.47%. Thus, the soil/rock of the West Banko Barat III disposal pit has high plasticity. Based on the results of research conducted by Hooke (1979), it was found that rock or soil with high clay - silt content has a strong relationship with water content (Jason P. Julian, 2006) (Zhao, Shao, Omran, & Amer, 2011). The relationship between the water content and the plasticity index in the Pit III Banko Barat disposal area can be seen in the graphic image below;

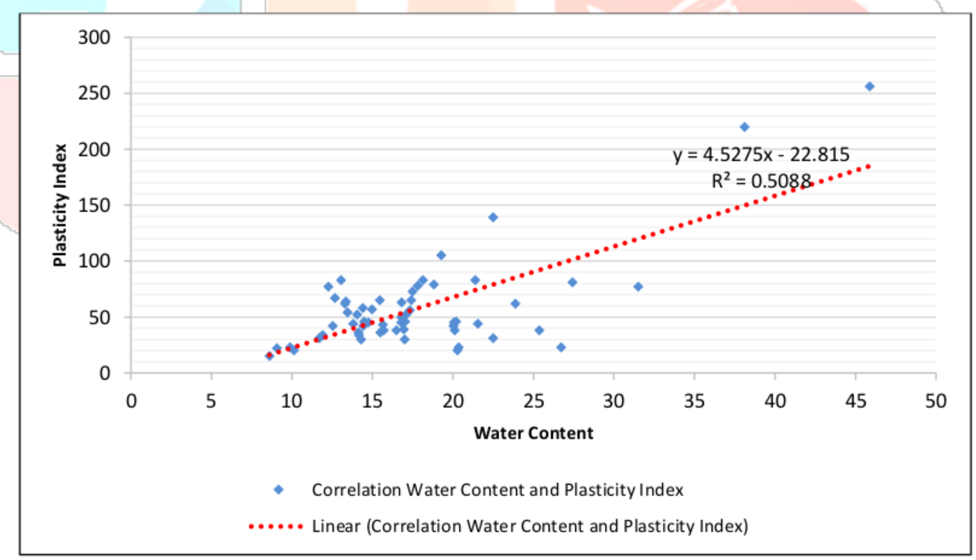

Figure 3. Graph Of The Correlation Between Water Content And Rock Plasticity Index

The linear regression graph above shows a strong correlation between water content and plasticity index with a value of $R^2 = 0.5088$ or 0.7133. The correlation between the two also satisfies the linear regression equation

$$y = 4{,}5275x - 22{,}815 \qquad (7)$$

the value of y in the above equation is positive, indicates a positive correlation between the water content and plasticity index, where the increase of water content in a rock the plasticity index will be increasing.

III.2. Correlation between physical and mechanical properties of rock on erosion potential

One of the factors that influence the rate of erosion is rock erodibility. Simple empirical equations for estimating rock erodibility by rock characteristics yet, but we can use equation (6) to estimate the value of erodibility. But before that, we must first know the critical shear stress value. In this study, the shear stress is estimated using equation (2). Based on these two equations, it is known that the estimated magnitude of critical shear stress and erodibility coefficient is as follows ;

Table 2. Estimated Shear Stress And Erodibility Coefficient

No	Sample	IP	τ_c	k	No	Sample	IP	τ_c	k
1	BKGT.34 - 1	45	3.92	0.10	31	BKGT.36 - 8	64	5.26	0.09
2	BKGT.34 - 2	220	14.85	0.05	32	BKGT.36 - 9	52	4.42	0.10
3	BKGT.34 - 3	39	3.47	0.11	33	BKGT.36 - 10	42	3.70	0.10
4	BKGT.34 - 4	139	10.10	0.06	34	BKGT.36 - 12	77	6.15	0.08
5	BKGT.34 - 6	53	4.49	0.09	35	BKGT.36 - 13	38	3.40	0.11
6	BKGT.34 - 8	54	4.56	0.09	36	BKGT.36 - 15	31	2.86	0.12
7	BKGT.34 - 9	44	3.84	0.10	37	BKGT.37 - 1	38	3.40	0.11
8	BKGT.34 - 10	57	4.78	0.09	38	BKGT.37 - 2	23	2.23	0.13
9	BKGT.35 - 1	23	2.23	0.13	39	BKGT.37 - 3	77	6.15	0.08
10	BKGT.35 - 3	20	1.98	0.14	40	BKGT.37 - 4	42	3.70	0.10
11	BKGT.35 - 4	83	6.55	0.08	41	BKGT.37 - 6	30	2.79	0.12
12	BKGT.35 - 6	43	3.77	0.10	42	BKGT.37 - 7	79	6.28	0.08
13	BKGT.35 - 7	78	6.22	0.08	43	BKGT.37 - 8	46	3.99	0.10
14	BKGT.35 - 8	256	16.87	0.05	44	BKGT.37 - 9	56	4.71	0.09
15	BKGT.35 - 10	65	5.33	0.09	45	BKGT.37 - 10	42	3.70	0.10
16	BKGT.35 - 11	58	4.85	0.09	46	BKGT.37 - 11	38	3.40	0.11
17	BKGT.35 - 13	83	6.55	0.08	47	BKGT.37 - 13	81	6.42	0.08
18	BKGT.35 - 16	46	3.99	0.10	48	BKGT.37 - 17	34	3.09	0.11
19	BKGT.35 - 17	67	5.47	0.09	49	BKGT.38 - 1	44	3.84	0.10
20	BKGT.35 - 18	62	5.13	0.09	50	BKGT.38 - 2	38	3.40	0.11
21	BKGT.35 - 19	83	6.55	0.08	51	BKGT.38 - 3	62	5.13	0.09
22	BKGT.35 - 22	34	3.09	0.11	52	BKGT.38 - 4	46	3.99	0.10
23	BKGT.35 - 23	36	3.25	0.11	53	BKGT.38 - 6	36	3.25	0.11
24	BKGT.36 - 1	45	3.92	0.10	54	BKGT.38 - 7	31	2.86	0.12
25	BKGT.36 - 2	45	3.92	0.10	55	BKGT.38 - 11	30	2.79	0.12
26	BKGT.36 - 3	63	5.19	0.09	56	BKGT.38 - 14	23	2.23	0.13
27	BKGT.36 - 4	73	5.88	0.08	57	BKGT.38 - 17	15	1.56	0.16
28	BKGT.36 - 5	50	4.28	0.10	58	BKGT.38 - 18	20	1.98	0.14
29	BKGT.36 - 6	105	7.98	0.07	59	BKGT.38 - 19	22	2.15	0.14
30	BKGT.36 - 7	65	5.33	0.09					

III.2.1. Correlation Between Plasticity Index and Critical Shear Stress

The results of the research by Stacey and Karim (2017) show that the critical shear stress increases with increasing the plasticity index of the rocks. Estimation of critical shear stress based on rock plasticity index provides a very strong correlation, as seen in the graphic image below;

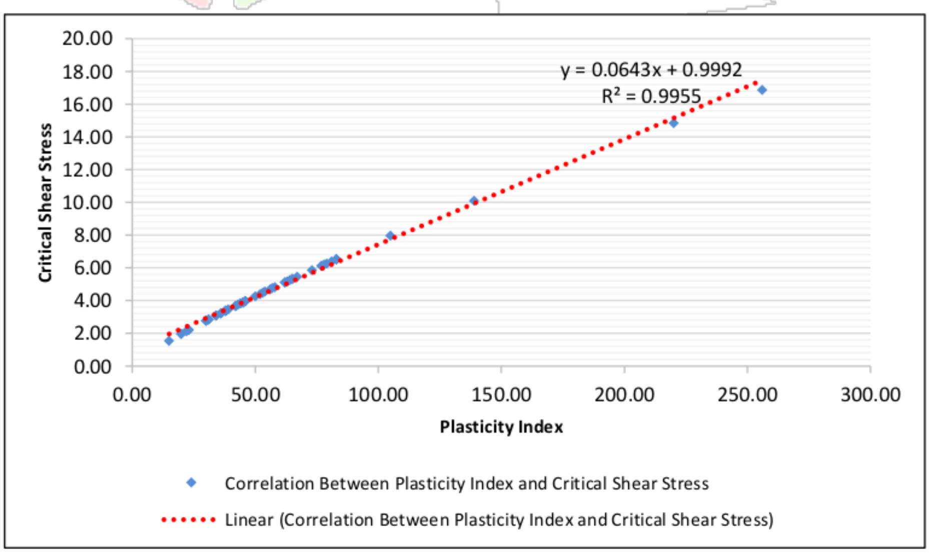

Figure 4. Graph Of The Correlation Between Plasticity Index And Critical Shear Stress

Based on the graph above, it is known that the plasticity index has a very strong influence on the critical shear stress, with a value of $R^2 = 0.9955$ or 0.998. This effect also satisfies the linear regression equation

$$y = 0{,}0643x + 0{,}9992 \qquad (8)$$

The positive y value shows that the correlation between the plasticity index and the critical shear stress is positive. Where the greater the plasticity index of soil or rock, it will be the greater the value of the critical shear stress.

III.2.2 Correlation between Critical Shear Stress and Erodibility Coefficient

Erodibility has a great influence on the erosion potential of a rock, which is based on research results of Kimiaghalam, Clark, & Ahmari on 2015 that critical shear stress has a very significant relationship to the level of erosion. A very strong correlated is also seen in the graph of the critical shear stress relationship with the erodibility coefficient below;

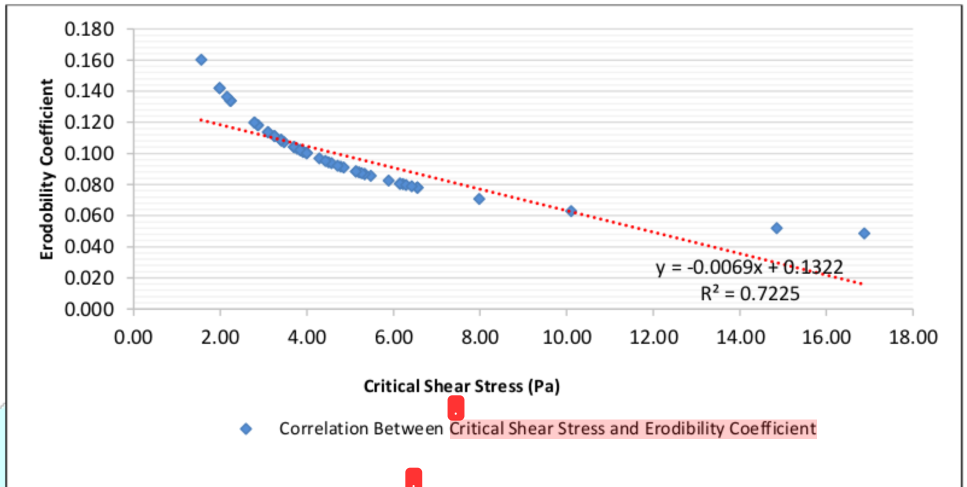

Figure 5. Correlation Between Critical Shear Stress And Erodibility Coefficient

The graph above shows the pattern of a strong correlation between the critical shear stress and the erodibility coefficient, with $R^2 = 0.7225$ or 0.85. This relationship satisfies the linear regression equation;

$$y = -0{,}0069x + 0{,}1322 \qquad (9)$$

The negative y value (-) shows that the relationship between the critical shear stress and the erodibility coefficient is negative. Where the greater value of the erodibility coefficient shear stress will be smaller, and vice versa. If the shear stress value increases, the erodibility coefficient will decrease.

IV. CONCLUSION

Based on the results of this study, it was found that:

1. The disposal area for Pit III Banko Barat has a variety of rock contents, with the main rocks being clay, silt and sand. From the results of the size distribution average, it is known that the number of clay grains is 45.39%, silt 45.28%, while the amount of sand is only 9.32%. The distribution of the high number of clay and silt grains (40%) has a high level of resistance to the potential for erosion.
2. The plasticity index of the sample rock has a very strong influence on the critical shear stress. This influence is positive, which means that the higher the plasticity index of rock, the critical shear stress will be even greater. Based on data analysis, the Pit III Banko Barat III disposal area has an average plasticity index of 57.47%. Thus, the soil/rock of the Banko Barat III disposal pit area has high plasticity.
3. The critical shear stress of the sample rock has a strong influence on the erodibility coefficient. Based on the result of the linear equation between the critical shear stress and the erodibility coefficient shows a negative correlation, this means that the increases of critical shear stress of rock made decreasing of erodibility coefficient.

IV. ACKNOWLEDGMENT

The author would like to thank PT. Bukit Asam Muara Enim, South Sumatra, has accepted and facilitated our presence for observation and is willing to provide data related to this research.

REFERENCES

[1] Briaud J.-L., C. H.-C.-A. (2011). *THE SRICOS - EFA METHOD*. Texas: Texas A & M university.

[2] Clark, L., & Wynn, T. (2007). Methode For Determining Streambank Critical Shear Stress and Soil Erodibility: Implications For Erosion Rate Predictions. *American Society Of Agricultural and Biological Engineers*, 95 - 106.

[3] Hanson, G. J., & Simon, A. (2001). Erodibility of cohesive streambeds in the loess area of the. *Hydrological Processes*, 23 - 38.

[4] Jason P. Julian, R. R. (2006). Hydraulic Erosion of Cohesive Riverbanks. *Geomorphology*, 193-206.

[5] Kimiaghalam, D., Clark, S. P., & Ahmari, H. (2015). Experimental Study on the Effects of Physical, Mechanical, and Electrochemical Properties of Natural Cohesive Soils on Critical Shear Stress and Erosion Rate. *International Journal of Sediment Research* , 1-14.

[6] L.A. Clark, T. M. (2007). Methods For Determining Streambank Critical Shear Stress and Soil Erodibility: Implications For Erosion Rate Predictions. *American Society of Agricultural and Biological Engineers* , 95 - 106.
[7] Liu, X., Wu, J., Conrad, P., S. Dun, C. T., McNeamy, R., Elliot, W. J., et al. (2015). Impact of surface coal mining on soil hydraulic properties. *Society For Mining, Metallurgy, & Exploration*, 381-392.
[8] Miscevic, P., & Vlastelica, G. (2014). impact of weathering on slope stability in soft rosck mass. (6).
[9] Muttaqin, T. (2017). Laju Erosi Terhadap Perubahan Tata Guna Lahan Kawasan Hutan Lindung Pada Area Pertanian Desa Sumber Brantas, Kecamatan Bumiaji, Kota Batu. *Jurnal Daun*, 119-125.
[10] Pei Zhao, M. A. (2011). Effects Of Erosion And Deposition On Particle Size Distribution Of Deposited Farmland Soils On The Chinese Loess Plateau. *Revista Brasiela de Ciencia de Solo Vol 35*, 2135 - 2144.
[11] Shasta M Marrero, A. S. (2018). Controls On Subaerial Erosion Rates in Antartica. *Earth and Planetary Science Letters*, 56-66.
[12] Small, E. E., Blom, T., Hancock, G. S., Hynek, B. M., & Wobus, C. W. (2015). Variability of Rock Erodibility in Bedrock-Floored Stream Channels Based on Abrasion Mill Experiments. *Journal of Geopysical Research: Earth Surface*, 1455-1469.
[13] Smerdon, E. T., & Beasley, R. (1959). The Tractive Force Theory Applied to Stability of Open Channels in Cohesive Soils. *Research Bulletin 715, University Missouri, Agricultural Research*.
[14] Sri Sarminah, D. K. (2017). Analisis Tingkat Bahaya Erosi Pada Kawasan Reklamasi Tambang Batubara PT. Jembayan Marabara Kalimantan Timur. *Ulin*, 154-162.
[15] Stacey, T.-K., & Karim, M. Z. (2017). *Characterizing Soil Erosion Potential Using Electrical Resistivity Imaging*. Kansas: Kansas Department of Transportation.
[16] Stephen F. Mueller, J. W. (2015). Variability of Natural Dust Erosion fron Coal Pile. *Journal of Applied Meteorology and Climatology*, 3 - 14.
[17] Sugiyono. (2012). *Metode Penelitian Kuantitatif Kualitatif dan R & D*. Bandung: Alfabeta.
[18] W. J. Elliot, W. Q. (1993). Aplication Of The WEPP Model to Surface Mine Reclamation. *The Challenge of Integrating Diverse Perspectives in Reclamation, 10 th National Meeting of ASSMR* (pp. 116 - 126). Spokane: America Society of Mining and Reclamation.
[19] Yellishetty, M. M. (2013). Prediction of Soil Erosion From Waste Dumps of Opencast Mines and Evaluation of Their Impacts on The Environmet. *International Journal of Mining, Reclamation and Environment*, 88-102.
[20] Zhao, P., Shao, M. a., Omran, W., & Amer, A. M. (2011). effect of erosion and deposition on particle size distribution of deposited farmland soils on the chinese loess plateau. *35*(6).

The Effect Of Physical and Mechanical Properties of Rock on Erosion Potential in Coal Mine Disposal

ORIGINALITY REPORT

16%	10%	14%	6%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

MATCH ALL SOURCES (ONLY SELECTED SOURCE PRINTED)

1%

★ Kory M. Konsoer, Bruce L. Rhoads, Eddy J. Langendoen, James L. Best, Mick E. Ursic, Jorge D. Abad, Marcelo H. Garcia. "Spatial variability in bank resistance to erosion on a large meandering, mixed bedrock-alluvial river", Geomorphology, 2016

Publication

Exclude quotes	Off	Exclude matches	Off
Exclude bibliography	Off		