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Relationship of Rock Geomechanics and Coal Mine Slope Safety Factor in South Sumatra Region, Indonesia

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Abstract

The research location is in the coal mine area South Sumatera region, Indonesia. This study aims to determine the geomechanics relationship of the rock which includes the physical properties of the rock: bulk density, and mechanical properties of the rock (shear strength), cohesion and internal shear angle to the safety factor of the coal mine slopes in the study area. Field research is carried out by observing and measuring directly in the field in the following ways: (a) Measuring slope azimuth, slope, dip direction and slope height and width using a measuring tape and geological compass. (b) Rock description based on physical characteristics (megascopic) and rock sampling for testing the physical and mechanical properties of the rock in the laboratory. (c) Observing the general condition of water from rock slopes (dry, moist, watery, wet or flowing) and slope vegetation. 2. Cohesion values and internal shear angles are secondary data obtained from PT. X which has been analyzed in the laboratory. 3. Slope modeling was carried out using Rocscience Slide software. This shows that the smaller the rock density value, the greater the rock cohesion value. The greater the cohesion value of the rock, the smaller the value of the shear angle on the rock. The smaller the value of the shear angle in the rock, the greater the value of the safety factor of the rock slope.

1. Introduction

Mining activities can cause changes in the earth's surface to be tilted at a certain angle to the horizontal plane which is called slope. Slopes are divided into 2, namely slopes formed due to natural processes and artificial slopes formed due to human activities [1]. Slopes can be formed naturally or man-made. Slopes that are formed naturally, for example hillsides and river cliffs, while man-made slopes include excavations and embankments, embankments and open pit mine walls [2] and [3]. In the operation of mining activities, slope stability problems will be found in open pit excavations, disposal sites, ore stockyards, dams and other infrastructure such as roads, bridges and slopes around facilities such as housing [4]. Stability of slopes is a very important factor in work related to excavation and stockpiling of soil, rock and excavated materials, because it involves issues of human safety (workers), equipment safety and smooth production. Even though a slope has been stable for a long time, the slope can become unstable due to several factors such as external and internal rocks [4].

Table 1. Relationship between slope safety factor values and landslide intensity [13]

No	Safety Factor Value (SF)	Landslide Occurrence / Intensity
1	FK < 1,07	Frequent landslides (labile class)
2	FK 1,07 – 1,25	Avalanche ever happened (critical class)
3	FK > 1,25	Landslides are rare (stabile class)

Slope conditions that do not meet safety criteria and are not monitored will be a threat to the surrounding conditions [5]. A high and stable safety factor can be influenced by low levels of rock weathering, low joint intensity, and fairly resistant lithology, and is dominated by massive rock structures as external controllers [6]. The values of Density, cohesion and internal shear angle also have an effect as internal factors on the value of the safety factor of the slope [4]. In the rock slope model there are various input parameters that can affect the safety factor, for example rock density, rock material strength and joint strength [7]. The magnitude of the shear strength value is influenced by the presence of cohesion and internal shear angle, the greater the cohesion and internal shear angle, the greater the value of shear strength in the rock [8]. The value of the factor of safety on the slope will increase along with the increase in the value of cohesion and internal shear angle. The greater the value of internal cohesion and shear angle, the greater the factor of safety (the more stable the slope) as an internal controller [9]. In the stability of a slope, the cohesion value and internal shear angle greatly affect the ability to withstand external loads [10].The presence of water can cause a decrease in the cohesion value, and the rock shear angle (mechanical properties). This is influenced by the nature of clastic sedimentary rocks which are highly reactive and easily absorb water, causing the bonds between grains in the rock to become weak when the water is saturated [11]. Physical properties and mechanical properties are one of the parameters that affect rock engineering requirements and slope stability [12]. Parameters of the physical properties of the rock such as bulk density and mechanical properties (shear strength), namely cohesion and shear angle of the rock are used for modeling and identification of problems on coal mine slopes. Parameters of rock physical properties as a basis for geomechanical modeling and geological engineering design [11], this is because physically and mechanically have a close relationship and can affect the stability of open slopes and mine pits. This study aims to determine the geomechanical relationship of the rock which includes the physical properties of the rock: bulk density, and the mechanical properties of the rock (shear strength), cohesion and internal shear angle on the safety factor of the coal mine slopes in the study area. The slope safety factor is divided into 3 groups in terms of landslide intensity [13] (Table 1). Therefore, it is important to know the relationship between rock geomechanics and the safety factor of mine slopes, especially in coal mines in South Sumatra, Indonesia.

Table 2. Value of slope height, slope, lithology layer, physical properties (density), mechanical properties (cohesion, and internal shear angle) the research area 1

Slope Height and Slope	Lithology layer	Density (kN/m2)	Cohesion (kPa = kN/m3)	Internal Shear Angle (θ)
115 m and 15°	Claystone	19,03	144,35	17,42
	Coal	11,03	277,18	25,25
	Tuffaceous Sandstone	18,79	123,09	18,44
	coal	11,93	536,48	23,91
	Siltstone	19,86	72,88	13,62
	Sandstone	19,66	128,12	28,61

Table 3. Value of slope height, slope, lithology layer, physical properties (density), mechanical properties (cohesion, and internal shear angle) the research area

Slope Height and Slope	Lithology layer	Density (kN/m2)	Cohesion (kPa = kN/m3)	Internal Shear Angle (θ)
125 and 80°	Tuffaceous Sandstone	18,79	123,09	18,44
	Siltstone	19,86	72,88	13,62
	Sandstone	19,66	128,12	28,61
	Sandstone	21,54	164,61	15,25

2. Methodology

Field research is carried out by observing and measuring directly in the field in the following ways: (a) Measuring slope azimuth, slope, dip direction and slope height and width using a measuring tape and geological compass. (b) Rock description based on physical characteristics (megascopic) and rock sampling for testing the physical and mechanical properties of the rock in the laboratory. (c) Observing the general condition of water from rock slopes (dry, moist, watery, wet or flowing) and slope vegetation. 2. Cohesion values and internal shear angles are secondary data obtained from PT. X which has been analyzed in the laboratory. 3. Slope modeling was carried out using Rocscience Slide software with data in the form of slope geometry, cohesion values, internal shear angles, and rock density. Slope modeling uses color based on the lithology of the slope. Next is to analyze the stability of the slope to obtain the value of the slope safety factor, and the rock geomechanical relationship to the slope safety factor.

Field research is an intricate process that involves a comprehensive approach to data collection and analysis. It entails on-site observation and direct measurements in order to gather accurate data. Specifically, this research adopted the following methods:

(a) Determining the slope's orientation, angle, and dimensions by measuring the azimuth, slope height, width, dip direction, and slope itself. This was achieved using advanced instruments like a geological compass and a measuring tape, ensuring precision and reliability.

(b) A meticulous description of the rock was carried out based on its physical attributes. This description, which is largely megascopic in nature, involved the careful examination of the rock's texture, color, and other distinguishing features. Furthermore, rock samples were systematically collected. These samples later underwent rigorous testing in the laboratory to ascertain their physical and mechanical properties.

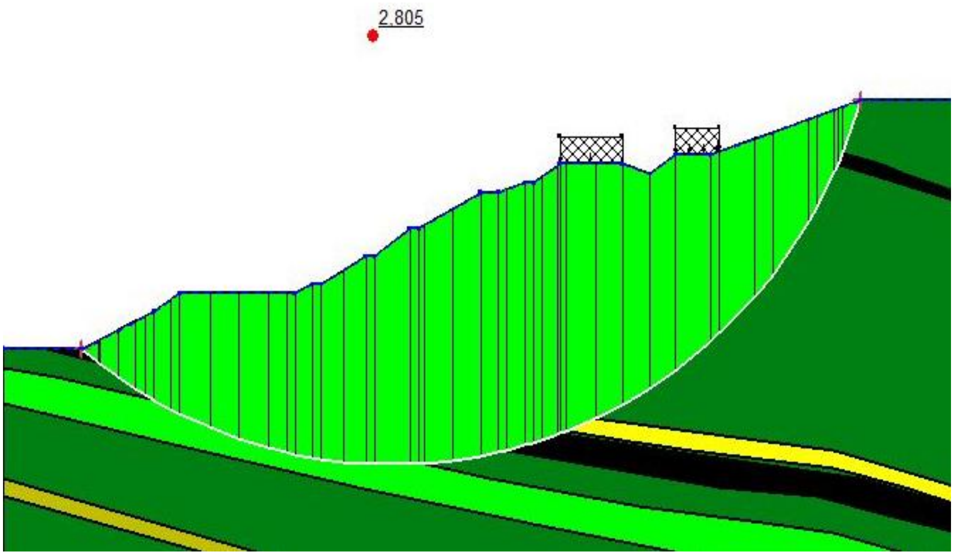

Figure 1. Model and safety factor of coal mine slope 1

(c) A keen observation was conducted on the state of water emanating from the rock slopes. The conditions were classified into various categories, such as dry, moist, watery, damp, or having a steady flow. Additionally, the vegetation on the slope was carefully studied to gauge its type and density, as this can influence slope stability.

Secondary data, which included cohesion values and internal shear angles, was procured from PT. X. This data had already undergone thorough laboratory analysis, ensuring its validity and reliability.

In terms of slope modeling, the sophisticated Rocscience Slide software was employed. The software effectively utilized the collected data, which comprised slope geometry, cohesion values, internal shear angles, and the density of the rock. An innovative feature of this modeling technique is its use of color coding based on the lithology of the slope. This visual representation aids in understanding the geological composition of the slope.

The final phase of the research involved an in-depth analysis of slope stability. This was done to derive the safety factor value of the slope. The interplay between rock geomechanics and this safety factor was then critically examined, paving the way for a thorough understanding of the slope's structural integrity.

3. Results and discussions

Based on field observations, and laboratory analysis obtained slope geometry, lithology layers, physical properties (density), mechanical properties (cohesion, and internal shear angle) which are used to model the stability of coal mine slopes in the study area (Tables 2 and 3).

Slope of the coal mine road which is at an elevation of +65 m to - 50 m which has 6 layers of rock and the safety factor of the slope of the coal mine road is 2,805 based on [13] the results of the safety factor analysis above show that the safety factor is 2,805 > 1,25, which means that the slope is safe overall landslides are rare (Figure 1). Safety factor of 2,805 > 1,25 which is large because the study area is composed of fine-medium grained clastic sedimentary rocks which have a tendency to bond between grains very tightly, so that the cohesion value is relatively higher compared to large grains [14], and the cohesion and a sufficiently large internal shear angle with sign density can affect the cohesion value and internal shear angle. Therefore, the greater the value of the cohesion and the internal shear angle, the greater the value of the factor of safety (the more stable the slope) [15] and [16]. The density value in the study area is quite low and increases the value of the safety factor because the increase in water content causes a decrease in the cohesion value and internal friction angle [17].

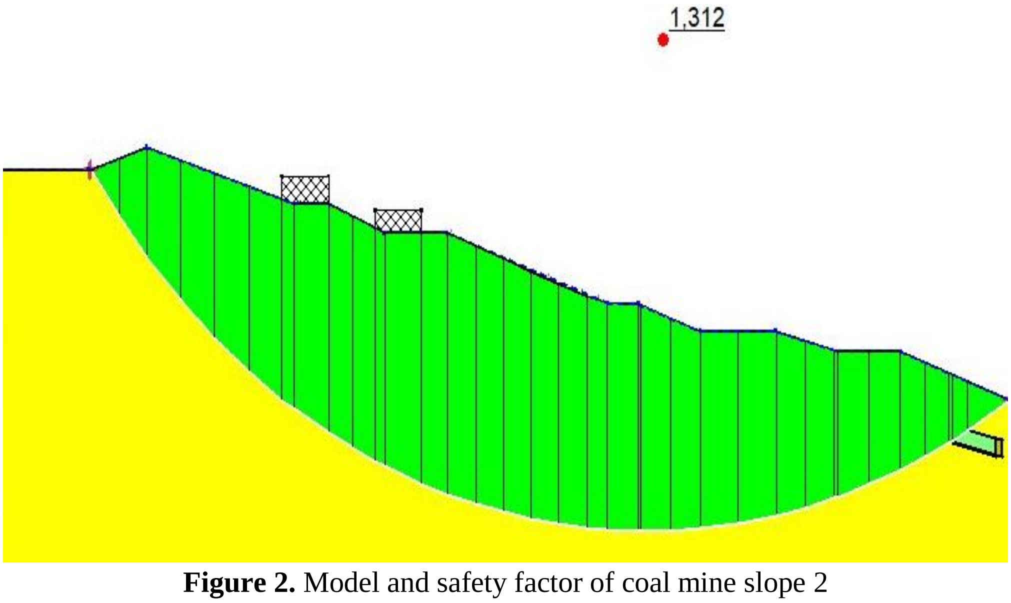

Figure 2. Model and safety factor of coal mine slope 2

The slope of the coal mine road which is at an elevation of +65 m to - 50 m which has 4 layers of rock and the safety factor for the slope of the coal mine road is 1,312 based on [13] the results of the safety factor. The analysis above shows the safety factor is 1,312 > 1,25 which means that the slope is safe as a whole, landslides rarely occur (Figure 2). Safety factor of 1,312 > 1,25 which is large because the study area is composed of fine-medium grained clastic sedimentary rocks which have a tendency to bond between grains very tightly, so that the cohesion value is relatively higher compared to large grains [14], and the cohesion and a sufficiently large internal shear angle with sign density can affect the cohesion value and internal shear angle. Therefore, the greater the value of the cohesion and the internal shear angle, the greater the value of the factor of safety (the more stable the slope) [15] and [16]. The density value in the study area is quite low and increases the value of the safety factor because the increase in water content causes a decrease in the cohesion value and internal friction angle [17].

4. Conclusion

In a comprehensive study spanning two distinct research locations within the specified area, it has been conclusively established that rock geomechanics is intricately linked with the value of the coal mine slope safety factor.

Detailed analysis reveals that for location 1, the safety factor stands at 2.805, which is notably greater than the threshold of 1.25. Similarly, location 2 presents a safety factor of 1.312, also surpassing the 1.25 benchmark. These numbers, at their core, signify that the slopes in these locations are structurally sound and safe overall. It's noteworthy that instances of landslides are infrequent, further underscoring the stability of these areas.

When one delves deeper into the specific parameters contributing to this stability, a pattern emerges. Location 1 showcases an average rock density value of 16.72 kN/m^2, whereas location 2 records a slightly higher average density of 19.92 kN/m^2. Concurrently, the average cohesion value in location 1 is marked at 213.68 kPa or kN/m^3, whereas location 2 exhibits a cohesion value of 122.17 kPa or kN/m^3. Furthermore, there's a noteworthy observation concerning the internal shear angles. In location 1, the average shear angle measures 21.20° (theta), while in location 2, it averages at 18.98° (theta). These measurements lead to an intriguing correlation: as the rock density diminishes, the rock's cohesion value ascends. This means that rocks with higher cohesion values generally manifest reduced shear angles. Consequently, when the shear angle in a rock is at a lower value, it results in an elevated safety factor for the rock slope, ensuring heightened stability and safety. This interconnected relationship between rock properties and slope stability is pivotal for understanding and predicting the long-term performance of these slopes.

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