SLOPE STABILITY ANALYSIS USING FINITE ELEMENT METHOD (FEM) IN WARA OPEN PIT COAL MINE, PT ADARO INDONESIA, TABALONG, SOUTH KALIMANTAN

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ABSTRACT

The stability of slope is impacted by Rock Mass Rating, material properties, and slope geometry. Furthermore, the slope stability analysis was needed to know the slope stability condition. This research aims to know the Strength Reduction Factor (SRF) value by using Finite Element Method (FEM) using Hu=1 and Hu=Auto. The geotechnical mapping that is Rock Mass Rating (RMR) and Measured Section were done to get the Geological Strength Index (GSI) and profile of layer rocks in highwall slope SCT_J1 and SCT_J2. From the FEM analysis, actual slope SCT_J1 has the SRF=1.25 with Hu=1 and SRF=1.4 with Hu=Auto. SCT_J2 has SRF=1.21 with Hu=1 and SRF=1.3 with Hu=Auto. From the slope stability analysis, SCT_J1 and SCT_J2 were classified into stable slope due to the SRF value higher than 1.2.

Keyword: Geological Strength Index, Finite Element Method, Rock Mass Rating, Slope Stability Analysis

INTRODUCTION

In mining operation, stabilty of slope is the main issue that has to be concerned. Due to the economical aspect in mining, the corporate will widing dan deeping of excavation. Wider and deeper the excavation will effect the stability of slope. The way to measure the stability is reflected by calculating the Strength Reduction Factor (SRF). This factor equals as the resisting force (τ) devided by driving force (s).

The open pit mine slope of Highwall Pit Wara, which is organized by PT. Adaro Indonesia, is chosen by considering the potential of failure due to the strength of rocks and water seepage issue. This issue has to be the main concern in coal mining corporate to analyse the factor of safety and prevent any disadvantages.

The condition of slope stability in open pit mine can be analysed through several methods such as RMR (Rock Mass Rating) and safety factor calculation by using Morgenstern-Price. This research was done in 2 section that are SCT_J1 and SCT_J2 (Figure 1).Through the methods, stability of slope in open pit mine of Highwall Pit Wara can be measured.

RESEARCH METHOD

The research method was done by doing geotechnical mapping that is RMR (Rock Mass Rating), Measured Section (MS), and slope stability analysis using Limit Equilibrium Method (LEM) as the primary data.

The classification of GSI is combining 2 major parameters that are block characteristic (Structure Rating) and (SRC) Surface Condition Rating (Hoek, 1994). There are several discontinuity parameters such as length of discontinuity, spacing of discontinuity, roughness of discontinuity, aperture of discontinuity, filling of discontinuity, orientation of discontinuity, and rating of weathering of discontinuity (Bell, 2007). The secondary data was material and engineering properties of rock and soil; external boundary; and PIT Wara Map.

GEOLOGICAL CONDITION

One of the basin in South Kalimantan is Barito Basin and Asam-asam Basin. These basin is separated by Meratus Mountain. In the nothern is confined by Kutai Basin which is separated by Sesar Andang. In the Western, this basin is confined Sunda Shelf. In the beginning, Barito Basin and Asam-Asam Basin is a same Basin, till in Early Miocene, these basin was separated by the uplift of Meratus Mountain (Satyana, 1995). The stratigraphy of South Kalimantan consists of several formations (Heryanto & Sanyoto, 1994) and (Adaro Resource Report, 1999), such as Tanjung Fm, Berai Fm, Warukin Fm, nad Dahor Fm. These formation ages ranging from Eocene – Pliocene (Figure 2).

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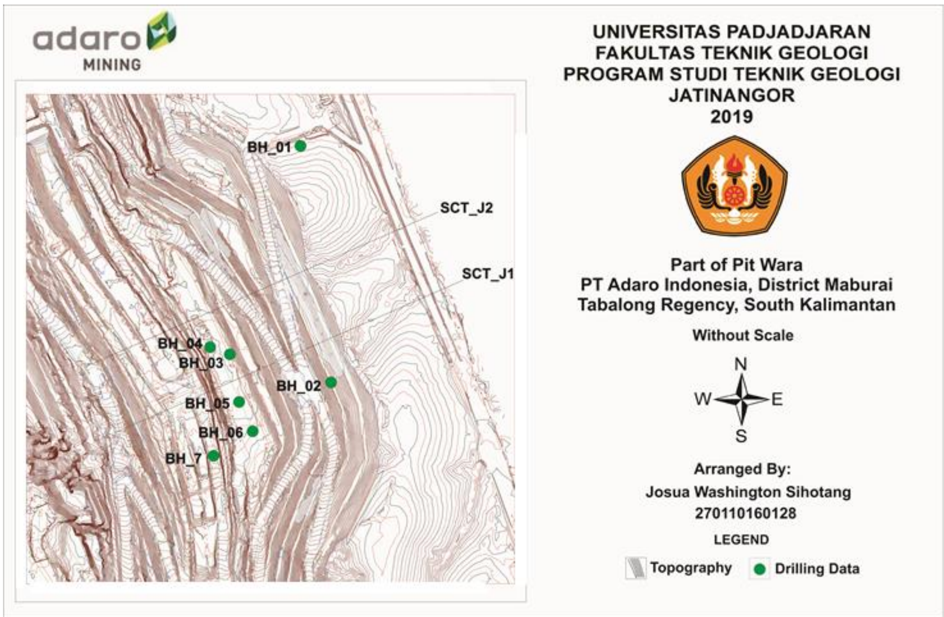

Figure 1. Map of Highwall Slope and Drillings Data in Pit Wara

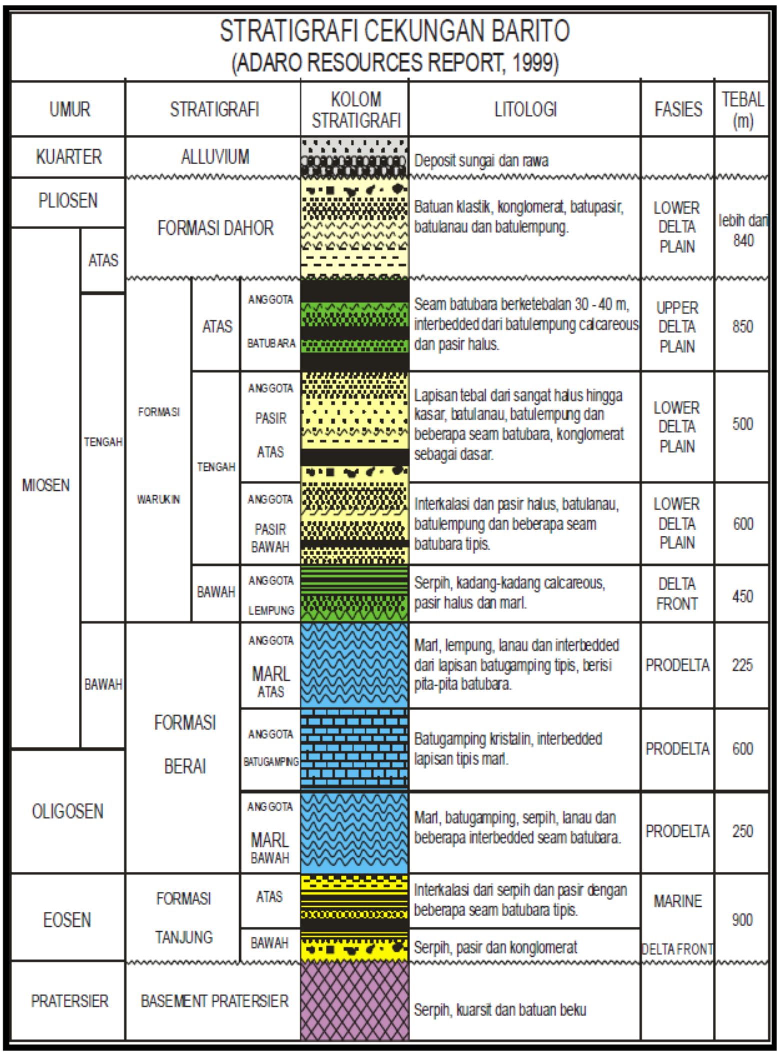

Figure 2. Stratigraphy of Barito Basin (Adaro Resource Report, 1999

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Several Geological Formations in research location, that are:

- TANJUNG FORMATION

  Tanjung Fm is characterized by lithological of quartz sandstone and claystone with insertion of coal and limestone. Sedimented in fluviatil facies to shallow marine with the thickness 750 m. the carbonate sedimentation is found in the upper part of this formation which is the begining phase to Berai Fm be sedimented.

- BERAI FORMATION

  Berai Fm is characterized by lithological of Limestone with Oligocene - Early Miocene aged and insertion of chert, sedimented in neritic facies with the thickness 1000 m. This formation is conformity with the Tanjung Fm in the upper part, but shows unconformity in some area.

- WARUKIN FORMATION

  Warukin Fm is consist of quartz sandstone and claystone with coal insertion, sedimented in fluviatil facies with the thickness 400 m and Middle Miocene – Late Miocene aged. This formation shows conformity to Berai Fm in the upper part.

- DAHOR FORMATION

  Dahor Fm is consist of loose quartz sandstone with the grainsize medium sandstone, poorly sorted, loose conglomerate with the component quarts 1-3 cm, soft claystone, lignite and limonite in some area, sedimented in fluviatil facies with the thickness 250 m and Plio-Plistocene aged. This formation shows consformity in the upper part of Warukin Fm.

RESULT

Geotechnical mapping was done through Rock Mass Rating (RMR) from (Bieniawaski, 1989) to get the Geological Strength Index (GSI) value. GSI is a classification of rock mass based on the structure observation (geometry and shape of block) and the condition of discontinuity surface (weathering, roughness degree, and alteration). The GSI value equals to RMR – 5 (Hoek & Brown, 1997).

The assessment of RMR was done in 2 section that are SCT_J1 and SCT_J2. The Measured Section (MS) was also done to measure the orientation and thickness of rock layers. From the mapping result, the lithology in research area is consist of sandstone, siltstone, claystone, and carbonaceous mudstone, and coal (Wentworth, 1992).

- Sandstone

  Fresh colour is light grey, weathered colour is brown, grain size very fine – fine sandstone, open fabric, well-sorted, flacer structure, low cemented. The maximum thickness is 6.7 m. Sandstone could be the failure bedding because of the rock strength is below the extremely weak rock, which is 160 KN/m^2.

- Siltstone

  Fresh colour is light grey, weathered colour is brown, grain size silt, open fabric, well sorted, massive. Siltstone is classified to very weak rocks (Deere & Miller, 1968) with the highest UCS value is 1440 KN/m^2. The maximum thickness is 13.7 m.

- Claystone

  Fresh colour is light grey, weathered colour is dark grey, grain size is clay, lenticular structure. Claystone is classified into very weak rock (Deere & Miller, 1968) with the highest UCS value is 2499.48 KN/m^2. The maximum thickness is 31.8 m.

- Carbonaceous Mudstone

  Carbonaceous Mudstone is a sedimentary rocks with the grain size is clay, sedimented from the terrestrial plant that is buried in reduction condition that makes rich in organic materials (Tucker, 2001). This rock could be the bedding failure and decrease the Strength Reduction Factor of slope. The maximum thickness is 3.9 m.

MODELED OF HIGHWALL SLOPE

In modelling the slope, the input data to the software are actual axternal boundary,

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type and thickness of rocks, and the material properties. SCT_J1 is a highwall slope with overall slope 14°, slope height 111,11 m, and single slope 24°. In behind the crest, ponded water was created with the elevation 68.102 m which is used to analyse the impact to the slope stability. The water surface was assumed in 3 m below the surface.

Rocks material properties data such as internal friction, Young's Modulus, wet unit weight, cohession, Uniaxial Compressive Strength, and constanta mi were needed to analyse the slope stability. The data was collected from the geotechnical drilling. The rock layers model was done by correlating the measured section data to the geological drilling and coal seam near the SCT_J1 dan ST_J2 (Table 1). The geotechnical drilling is done to identify the rock material properties, both from in situ and laboratory testing. The geological drilling is done to know the orientation and description of rock layers.

Table 1. Geological and geotechnical drillings data

Borehole Code	Elevation (m)	Borehole Type
BH_01	71.69	Geotechnic
BH_02	67.957	Geology
BH_03	81.694	Geology
BH_04	82.01	Geology
BH_05	69.093	Geology
BH_06	67.431	Geology
BH_07	52.617	Geotechnic

SLOPE STABILITY ANALYSIS

In Finite Element Method, slope stability can be showed by Strength Reduction (SRF) value. Slope stability was analysed using failure criterion Generalized Hoek-Brown, groundwater method using Water Surface, and Type Surface is non-circular with Auto Refine Search. Groundwater condition in slope stability analysis was in 2 condition that are H_u coefficient = 1 and H_u=Auto. H_u=1 assumes that the groundwater is in steady state condition. Hu=Auto will calculate $H_u = \cos^2 \alpha$ (Figure 3).

The analyse of Strength Reduction Factor of SCT_J1 has the SRF=1.25 with Hu=1 (Figure 4) and SRF=1.4 with Hu=Auto (Figure 5). SCT_J2 has SRF=1.21 with Hu=1 (Figure 6) and SRF=1.3 with Hu=Auto (Figure 7). From the slope stability analysis, SCT_J1 and SCT_J2 were classified into stable slope due to the SRF value higher than 1.2.

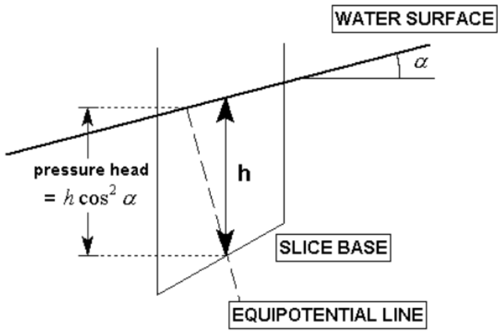

Figure 3. Calculation of H_u=Auto

The failure bedding can be showed by the delineation of shear strain value. It can be seen clearly in (figure 6 and figure 7), the shear strain value showed the inter-ramp failure. Higher the shear strain value determines the higher total displacement. From the analysis result, the Hu=Auto groundwater condition showed the higher SRF value. This caused by the H_u=1 assumed that the groundwater is in hydrostatic condition, whereas H_u=Auto will calculate the inclination of groundwater line.

CONCLUSION

From the research, the conclusion can be described as:

1. The actual slope stability in SCT_J1 and SCT_J2 in highwall slope was classified into stable slope with the most critical Strength Reduction Factor 1.25 and 1.21 respectively
2. The coefficient value H_u=1 shows the critical value rather than H_u=Auto.

The actual groundwater line should be identified to know the actual slope stability.

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REFERENCES

E-ISSN : 2579 – 3136

Adaro Resources Report, 1999. Stratigrafi Cekungan Barito. PT. Adaro Indonesia, Tabalong.

Bieniawski, Z. T., 1989. Engineering Rock Mass Classifications. New York: John Wiley & Sons.

Deere, D. U. and Miller, R.P., 1966. Engineering classification and index properties of rock. Tech. Report Air Force Weapons Lab., New Mexico, 65-116.

Heryanto, R., & Sanyoto, P., 1994. Geological Map of Amuntai Sheet, South Kalimantan, scale 1: 250.000. Pusat Penelitian dan Pengembangan Geologi, Bandung.

Hoek, E., 1994. Strength of rock and rock masses. ISRM News Journal, 2, 4-16.

Hoek, E., and Brown, E.T., 1997. Practical estimates of rock mass strength. International Journal of Rock Mechanics and Mining Sciences, 34 (8), 1165-1186.

Satyana, A.H., 1995. Paleogene Unconformities in The Barito Basin, Southeast Kalimantan. Indonesian Petroleum Association, Proceedings 24th Annual Convention, Jakarta, Vol 1.1-230.

Tucker, M.E., 2001. Sedimentary Petrology, 3 ed. Blackwell Publishing, Oxford.

Wentworth, C.K., 1992. A scale of grade and class terms for clastic sediments. Journal of Geology, 30, 377–392

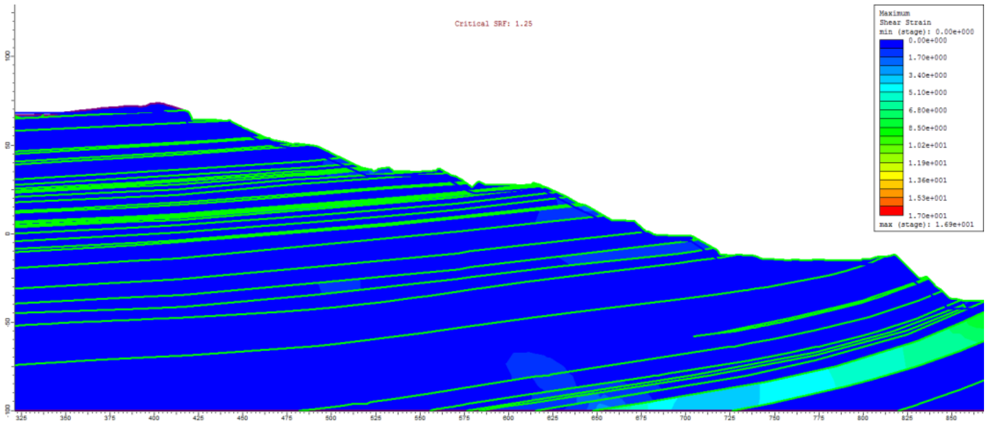

Figure 4. Slope Stability Analysis of SCT_J1 with H_u = 1

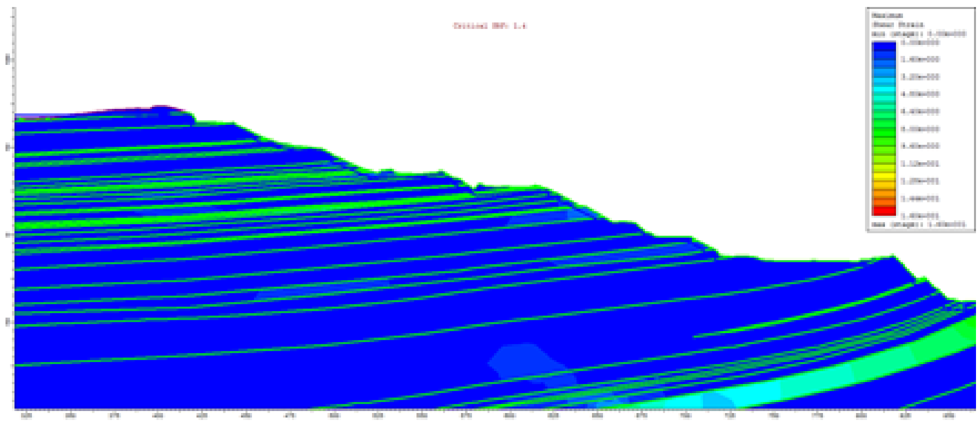

Figure 5. Slope Stability Analysis of SCT_J1 with H_u = Auto

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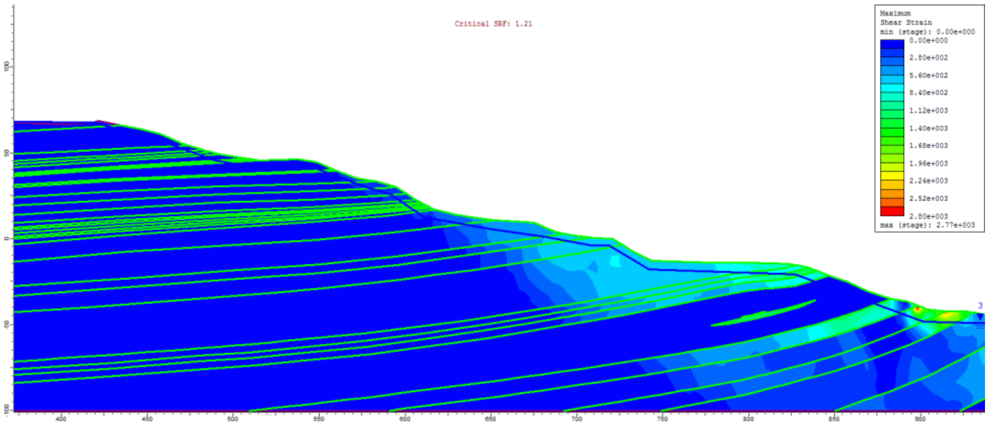

Figure 6. Slope Stability Analysis of SCT_J2 with Hu =1

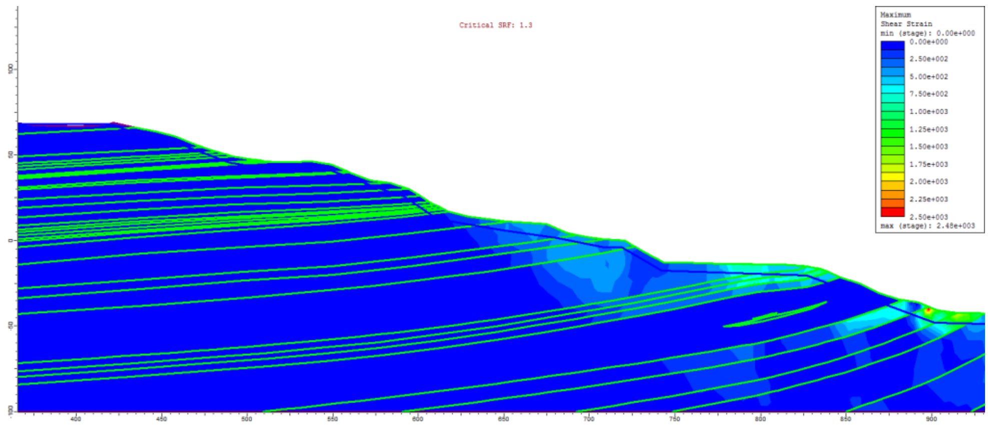

Figure 7. Slope Stability Analysis of SCT_J2 with H_u =Auto

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