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Technical Blasting and Ripping of Overburden to Reduce the Effect of Ground Vibration on Slope Stability and Residence around Coal Mine

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***Abstract*—The coal mining method at the West Banko Pit 1 North is carried out in an open pit using a shovel-dump truck system. The overburden consists of topsoil and claystone with a strength of 0.2 – 3 MPa. The digging force of the Komatsu PC 2000 excavator is 0.697 MPa, so to optimize the productivity of the excavator, it must be carried out using a Komatsu D375A ripper and blasting. Considering that the pit limit in the west is close to residential buildings, it is necessary to design the mining area to be ripping and the area to be blasted as well as blasting technical design to reduce the impact of ground vibration on slope stability and damage to buildings in residential areas around the mine. Based on the results of the analysis of overburden blasting at the West Banko Pit 1 North on the stability of static and pseudo-static slopes with the simulation of the optimal Berm, the maximum Berm is 12 m with a safety factor (SF) of 1.5, while the overburden blasting was based on research at West Banko pit 2 because the material conditions were relatively the same. The number of safe explosives for predicting the Peak Vector Sump (PVS) value 3.5 mm/second is 50 Kg/ Delay with a minimum distance of 500 m from residential areas. The analysis results of the area to be blasted are 112.59 Ha, and the area that remains ripped is 134.04 Ha.**

***Keywords*— Blasting; ground vibration; pseudo-static slope stability; PPV; PPA.**

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I. INTRODUCTION

The coal mining system at the West Banko Pit 1 North is strip mining using a shovel-dump truck system. Mining activities include land clearing, stripping and transporting topsoil and overburden, excavating and transporting coal, and mine reclamation/revegetation. In overburden excavation, the Komatsu PC 2000 backhoe excavator was used with a digging force of 626 kN = 0.626 MPa, while the overburden material in the form of claystone with compressive strength values ranging from 0.2 to 3.0 MPa was classified as extremely low strength rock (0.1-1 MPa). It is a very low-strength rock (2-20 MPa) [1], so it cannot be excavated directly by an excavator. The overburden removal is carried out using the Komatsu D375A-5 ripper to support the excavator's performance. The excavation of overburden on the material that has been milled is not optimal because the specifications of the Komatsu PC 2000 excavator and the Komatsu D375A-5 ripper used are not yet optimal [2]–[4]. To increase the productivity of the shovel-dump truck system, it is necessary to carry out blasting activities to deliver the material [5]–[8]. The West and Southwest sections of the pit limit of the West Banko Pit 1 North coal mine are close to residential areas (Fig. 2). In order to increase the efficiency of overburden excavation, overcome ground vibrations due to blasting, and increase slope stability, it is necessary to design blasting geometry, use of explosives, and delay systems [9]–[11].

Soil vibrations caused by blasting activities, if it has exceeded a certain level, can cause disturbance to slope stability and damage the environment around the mine. Ground vibrations are usually expressed in terms of peak particle velocity (PPV), peak particle acceleration (PPA), displacement, and acceleration, which are strongly influenced by the maximum amount of explosives per delay and the distance from the measurement point to the blast site [12]–[15]. The purpose of this study will discuss the design of blasting geometry, use of explosives, and delay systems to reduce ground vibrations in residential areas where PPV values are below the quality standard threshold value based on SNI 7571: 2010 [16]. The results of this study are expected to be able to determine the minimum limit of material blasting by blasting and using ripping.

A. Geological Conditions

West Banko Pit 1 North area is situated with hilly morphology. The highest elevation of the hill at ev +135 masl and the lowest elevation of the valley at ev +55 masl. The geological structure condition of the surrounding area is influenced by igneous andesite intrusion in the eastern part of the existing pit. The contour of the layering structure of the West Banko Pit 1 North area tends to follow the intrusion zone to form a dome with the intrusion zone as the central point. Thus, the direction of the sediment continues to the south then slides to the east following the intrusion zone. Fault structures tend to be found in areas bordering the andesite intrusion zone.

The stratigraphy of the West Banko Pit 1 North area was obtained from the correlation of the drill data of PT Bukit Asam Tbk in the West Banko Pit 1 North area. The stratigraphy of West Banko Pit 1 North (Fig. 1). The existing pit West Banko Pit 1 North (Fig. 2), has an area of 120 hectares, extending following the direction of coal strike from north to south with a dip to the west. Coal crop line boundaries border on the northern part. Settlements border on the eastern part. The andesite intrusion zone limits the western part. The southern part is the direction of the pit continuity.

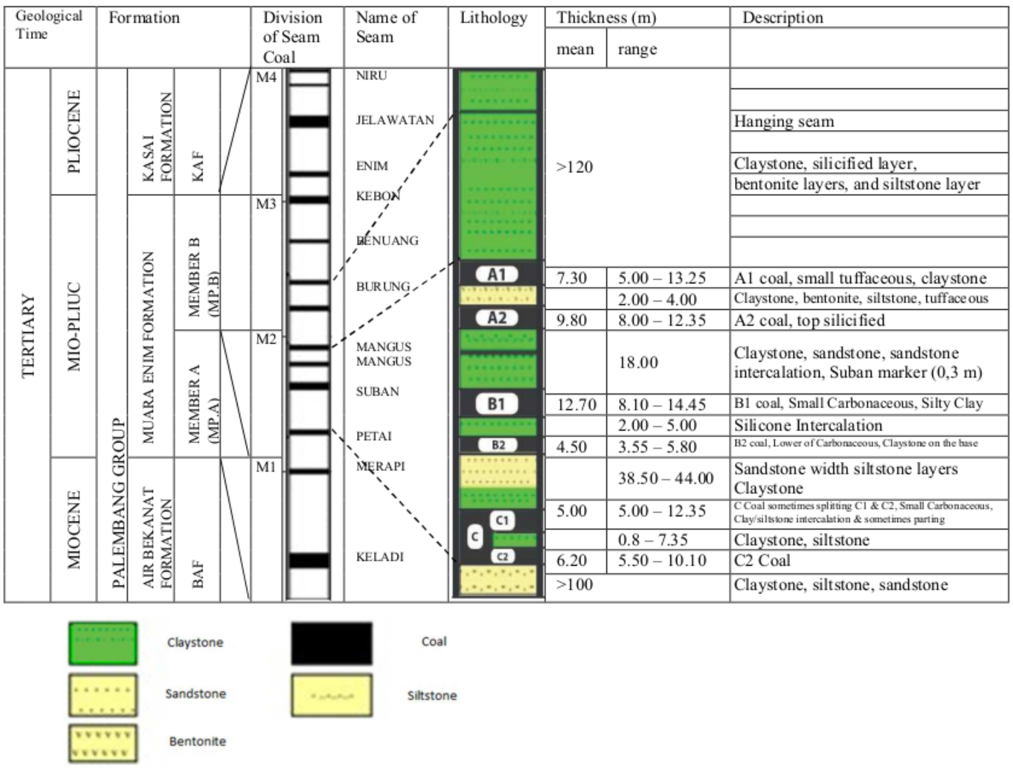

Fig. 1 Stratigraphy Area Pit 1 West Banko

TABLE I
GEOTECHNICAL PARAMETER PIT 1 WEST

No	Material	D (ton/m³) In-Situ	D (ton/m³) Bulk	UCS (Mpa)	σ (MPa)	C (KPa)	Φ (°)
1	Top Soil	1.005-1.63	1.53-1.88	0.06-0,199	-	32.81	11.2-24.36
2	OB A1	1.13-2.03	1.35-2.27	1,32	0.47	77.14	3.24-27.16
3	Seam A1	0.83-0.90	1.18-1.28	7.46	0.18	176.14	15.38-44.18
4	IB A1-A2	1.34-2.001	1.76-2.17	5.75	0.17	142.41	6.1-30.77
5	Seam A2	0.89-1.10	1.15-1.35	9.1	0.26	229.86	7.64-40.45
6	IB A2-B1	0.98-1.92	1.59-2.16	2.02	0.28	107.23	5.6-30
7	Seam B1	0.80-1.01	1.13-1.32	10.2	0.29	203.07	11.31-38.85
8	IB B1-B2	1.65-2.24	1.94-2.42	0.4	0.14	126.84	7.64-25.9
9	Seam B2	0.84-1.03	1.17-1.42	7.23	0.23	254.77	15.37-29.64
10	IB B2-C	0.93-2.30	1.2-2.46	3.29	0.25	118.2	2.86-127.4
11	Seam C	0.83-1.89	1.15-2.14	4.64	0.16	201.43	22.79-37.11
12	Lower C	1.70-2.08	1.96-2.27	2.66	1.27	139.59	9.1-24.39

B. Geotechnical Conditions

The layer of material in the West Banko Pit 1 North area is divided into overburden, coal seam, and inter burden between seams. The dominant overburden layer is silty claystone. The coal seams consist of A1, A2, B1, B2 and C seams. The interburden layer consists of sandy silty claystone, silty claystone, and sandy siltstone types. The geotechnical parameters used in this study were data on density, cohesion, and shear angle in the water-saturated material (Table I). Geotechnical parameter data was obtained.

C. Hydrogeological Conditions

Groundwater around the West Banko Pit 1 North area is assumed to come from surface infiltration water. Groundwater sources were not found in the pit openings. The groundwater flow in the West Banko Pit 1 North area is assumed to follow the topsoil layer. Topsoil types tend to be loose material thickness 1-3 m. The next layer has a silty claystone material that is more impermeable.

II. MATERIAL AND METHOD

This research is the coal mining company PT Bukit Asam Tbk which is located in Tanjung Enim, Muara Enim Regency, South Sumatra Province. The location of measurements and observations is in the coal mining area of the West Banko Pit 1 North. The stages in this research started from the stage of literature study, field observation, data processing, analysis, and conclusions and suggestions. A literature study is carried out to obtain a theoretical basis. The theoretical basis used in the static and pseudo-static slope stability analysis is to consider the ground vibration variables due to overburden blasting systems [17]–[19]. In each section, the forces acting in the arc avalanche plane are as illustrated in Fig. 3.

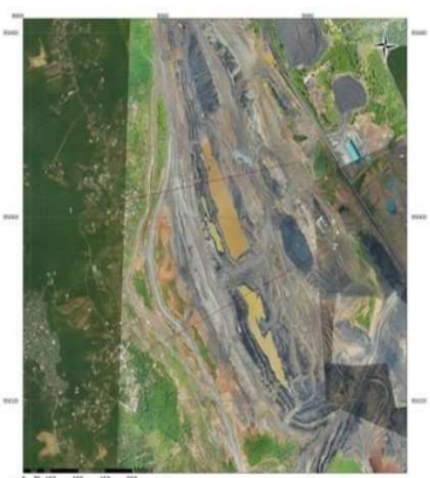

Fig. 2 Map of Orthophoto Pit 1 West Banko

To calculate the safety factor (SF) of pseudo-static slope stability, a seismic coefficient or horizontal earthquake coefficient (Kh) is required.

$$SF = \frac{\sum_{n=1}^{p}(c.B_n.Sec\,\alpha + W_n\cos\alpha_n\tan\varphi)}{\sum_{n=1}^{p}[W_n\,Sin\,\alpha_n + k_h W_n(\frac{L_n}{R})]} \quad (1)$$

Where: SF = Safety factor, Kh = horizontal earthquake coefficient; W = area of each slice; c = cohesion; R = landslide radius; h = average height of the slices; b = width of the slice; x = the horizontal distance from the center of mass of the slice to the center of the moment; α = angle of inclination of the slope. The seismic coefficient is obtained from measuring ground vibrations using a blast mate. This horizontal vibration will control the pseudo-static force acting on the slope. Seismic acceleration (Kh) is equal to 50% of peak ground acceleration (PGA) (ie Kh = 0.5 x a max / g) [20]. The following equation obtains the seismic coefficient (Kh):

$$Kh = 0{,}5\,\frac{ad}{g} \quad (2)$$

Where: Kh = horizontal seismic coefficient.
ad = seismic acceleration corrected (gal); g = gal

The result of the correlation between the value of the calculation of the minimum distance of the rock that is safe from rock damage with the graph of the speed of propagation of the blasting wave, it is known that the PPV value that causes rock damage is 17.20 mm / second (PT. KJA), 18.41 mm / second (PTBA), 16.70 mm / sec (PT. BBE) and 16.80 mm / sec (PT. MSJ) [21].

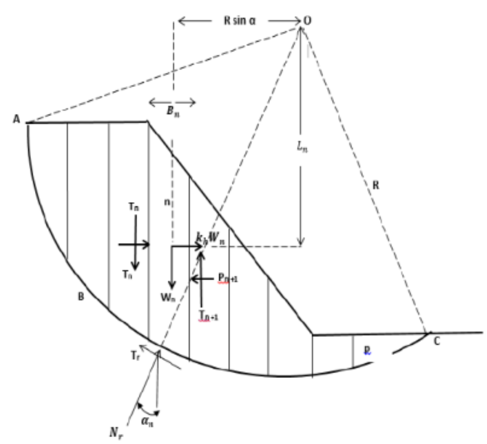

Fig. 3 Slope Model with Surface Sliding

The second stage of the field study was collecting primary data as well as secondary data as follows: Primary data includes direct measurement of ground vibrations (during blasting activities at a certain distance, data collection on the delay system pattern applied, and the amount of explosives used); blasting geometry measurements; observe geological structures. Secondary data required include maps of research locations, as well as geological data; geotechnical (physical characteristics and mechanical characteristics) of rocks at the study site; previous data on ground vibrations (including PPV, PPA, seismic acceleration, distance, number of holes, and number of explosives); map of the mining block sequence plan.

The third stage is processing and analyzing data. The analysis used to determine the effect of ground vibrations due to blasting of overburden on slope stability is to use the pseudo-static analysis method with the help of Slide version 6 and Geostudio 2012 software. The authors inputted data on geological, geotechnical, geohydrological/hydrological conditions, and acceleration of ground vibration safety factors for mine slopes (single slope, intermediate slope, and overall slope [1]. The pseudo-static slope stability analysis results were obtained by performing a berm simulation on the final slope to determine the final slope stability conditions of the three simulations. Slope stability analysis is discussed for five critical and safe slope conditions. Also discussed is how to technically minimize ground vibration from the overburden blasting effect.

The conclusions and suggestions are subjected to find out the results of the berm simulation on the stability of the final slope as a company reference in optimizing the overall slope of the final slope. In addition, technical recommendations for blasting to reduce ground vibrations (system delay, use of explosives, and application of controlled blasting methods) in order to improve slope stability [14], [15]. Flow chart of research as shown in figure 4.

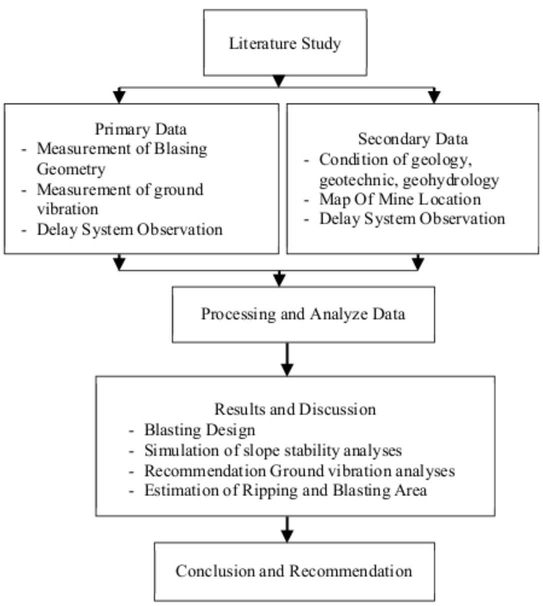

Fig. 4 Flow Chart of Research

III. Results and Discussion

A. Blasting Activity

The overburden blasting system at West Banko Pit 1 North uses a non-electric detonator (nonel) combined with an initiation system using a powered et electric detonator connected to a blasting machine a lead wire. Blasting geometry Diameter 6.75 inch (200 mm), Burden 8 meters, Space 9 meters, Depth 8 meters. The explosives used by ANFO consisted of 50 kg of Ammonium Nitrate (AN) and 3 liters of Fuel Oil (FO) for each blast hole, a loading density of 26.5 kg / m and a blasting powder factor of 53 kg / 576 bcm of 0, 09 Kg / bcm. The geometry used at the pit 1 location is the same as the blasting geometry for pit 2 for detonating the overburden. As well as the reference to the use of explosives in pit 1 will follow the reference to the use of explosives in West Banko pit 2, both non-air deck and air deck blasting.

The blasting delay system is divided into 5 groups, where 4 groups consist of 20 holes, and 1 group consists of 17 holes with a delay system for each group using a detonator delay of 0 ms, 42 ms, 67 ms, 109 ms, 3000 ms, and inhole. detonator 500 ms. If the type of blasting is double deck, it uses a 500 ms in-hole detonator and a 6000 ms inhole detonator to minimize the impact of blasting in the form of vibrations generated in the blasting. The results of measuring ground vibrations based on the amount of explosives and the delay system applied to the distance function obtained the largest PPV, PVS, and Seismic Acceleration as shown in Table II.

TABLE II
Ground Vibration Data

No	PPV (mm/s)	PVS (mm/s)	Acc (g)	Distance (m)	Holes (n)	Explosive (Kg)
1	7.990	7.990	0.058	200	117	31.75
2	0.434	0.629	0.040	1700	43	25.40
3	4.190	6.110	0.106	300	120	25.40
4	2.410	2.680	0.106	480	140	31.75
5	2.160	3.340	0.106	400	122	31.75

The seismic coefficient (Kh) used for the calculation of the safety factor based on the pseudo-static slope stability analysis used the data assumption where the seismic acceleration was 0.106 g and PVS 6.110 mm / s at a distance of 300 m, then: Kh = 0.50 x acceleration (g)

$$Kh = 0.50 \times 0.11\ g = 0.055\ g$$

When the blasting area approaches the final slope, it is necessary to reduce the number of explosives (number of explosive holes) per group delay and it is advisable to apply the blasting control system of line drilling [14].

B. Analysis of Effect of Ground Vibration

1) Analysis Stability of Final Slope: Static slope stability is determined by equilibrium limit analysis or pressure deformation analysis. In the analysis of the limit of the force equilibrium and or the moment of equilibrium for the soil mass above the potential landslide plane, it is considered and the soil mass above the plane is assumed to be in rigid conditions. The shear force is assumed to shift along the landslide surface, which results in a safety factor along the surface.

The effect of mine blasting vibrations spreads through the surrounding slopes causing dynamic shear forces that have the potential to cause slope landslides. The dynamic response of blasting activities needs to be known to determine the seismic acceleration which affects the dynamic shear force. The value of seismic acceleration is determined by selecting the greatest value of the peak acceleration of blasting activities around West Banko Pit 1 North. Seismic slope stability analysis can be determined using the pseudo-static method approach.

Potential factors causing mine slope landslides include geometric slope parameters, geotechnical parameters (physical and mechanical characteristics of slope forming materials), geological parameters (lithology and geological structures), hydrogeological parameters, ground vibration parameters (due to mining blasting and earthquake activities), stress parameters regional and time parameters. These parameters must be known in analyzing the stability of the final slope.

The geometry of the slope of the existing West Banko Pit 1 North is still expanding the pit. Mining slopes are still active working slopes with a width of 30 m, a height of 8 m, and a slope angle of 45 °. Especially in the North Low Wall area, the geometry used is a single slope following the bottom seam coal floor. The analysis is carried out by simulating the final level geometry of the existing pit, assuming the deepening of the pit is carried out to the lowest floor seam layer (floor seam B2).

The geometry parameters of the final stage follow the parameters of the existing pit with a height of 8 m, a single slope angle of 45 °, and a diameter of 15 m. Optimization of the overall slope pit limit will be simulated with 10 m, 12 m, and 15 m. The location of the cross-section for the berm simulation analysis is chosen in an area that the mining boundary has determined (pit limit) by the company, namely the Low Wall section 1 and Low Wall section 2. The highwall area will be made a single slope—sections created with the help of Minescape 5.7 software. There are two cross-sections for the Low Wall area, namely section 1 and section 2 (Fig. 5).

Slopes of sections 1 and 2 are simulated against tiered slopes (overall slope, intermediate slope, and single slope) following floor seam B2. Based on the simulation of each variable, level geometry, stratigraphic and geotechnical data, and hydrogeological data were used to analyze the slope stability of the static method.

Overburden material removal activities at the West Banko Pit 1 North were renewed using a ripper, and to optimize the removal activities, blasting activities were carried out against the overburden. The distribution of blasting vibrations that propagate on the walls of the mining slope causes seismic acceleration in the coating area. These factors have the potential to cause mining slope instability. The value of slope stability due to blasting activities can be determined by using the pseudo-static method approach. The pseudo-static method of slope stability analysis was performed with predetermined berm simulations.

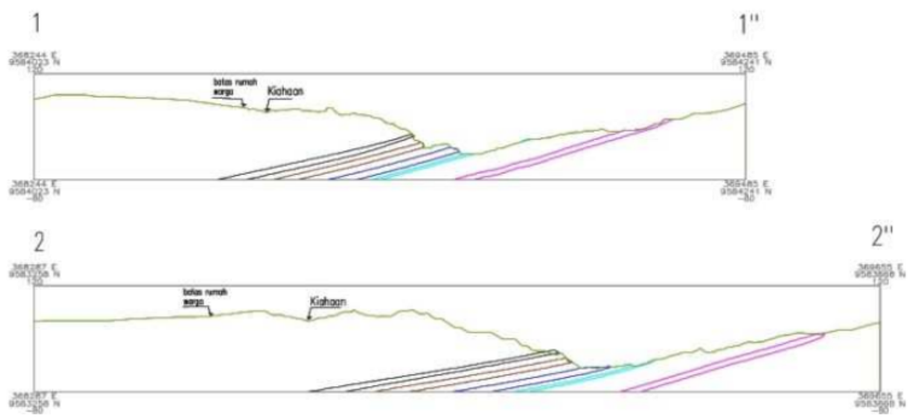

Fig. 5 Section of Geometry Bench Pit 1 West Banko

The seismic acceleration value (Seismic coefficient) of blasting activity at pit 1 West Banko is determined by selecting the peak acceleration (g) which has the highest effect. The seismic acceleration data for West Banko Pit 1 North consist of transverse, vertical, and longitudinal accelerations. The analysis assumes that the transverse and vertical accelerations have no major effect on slope instability. The value of the greatest longitudinal acceleration with the highest PVS value is determined as the seismic acceleration of the slope simulation. The seismic acceleration values used in the analysis are the highest ground vibrations, namely the blasting in June with a longitudinal acceleration of 0.106 g and a PVS of 6.110 mm / s with a distance of 300 m (Table 1), so the Kh value used in calculating the safety factor of pseudo-static slope stability is Kh = 0.50 x 0.11 = 0.055 g.

Slope stability in static conditions is influenced by geometric slope parameters, material geotechnical parameters, and hydrogeological parameters. The blasting activity plan at the West Banko Pit 1 North adds to the effect of seismic acceleration on slope stability. Slope stability analysis was conducted to determine the effect of these factors on the slope safety factor. The approach uses the static arc and pseudo-static equilibrium limit method. The analysis stage tested the slope safety factor (SF) on slope simulations in static and pseudo-static conditions. Slope modeling was made with 10 m, 12 m, and 15 mm variables. The geotechnical parameters of the slope constituent materials are assumed to be saturated with water because the hydrological parameters have a big influence in the slope stability analysis. The seismic acceleration value used in the pseudo-static slope stability analysis is the largest historical longitudinal acceleration, namely 0.055 g.

The areas analyzed were Low Wall section 1 and Low Wall section 2. The safety factor (SF) testing was carried out on the overall, intermediate, and single slopes. Slope stability analysis used rocscience slide v 6.0 software with the bishop arc equilibrium limit method. Slope stability simulation is performed on modeling with variable berms of 10 m, 12 m, 15 m. The results of slope stability analysis under static and pseudo-static.

TABLE III

SECTION FS OVERALL SLOPE 1

Overall Slope					
Single Berm (m)	Width (m)	Height (m)	Slope Angle (*)	FS Static	FS Pseudostatic
10	296	132	24	1712	1517
12	308	128	23	1842	1615
15	353	128	19	2102	1813

TABLE IV

FS OVERALL SLOPE SECTION 2

Overall Slope					
Single Berm (m)	Width (m)	Height (m)	Slope Angle (*)	FS Static	FS Pseudo static
10	296	136	25	1608	1428
12	326	134	22	1693	1481
15	376	136	20	1908	1646

TABLE V

FS OVERALL SLOPE AT LOW WALL

Overall Slope					
Single Berm (m)	Width (m)	Height (m)	Slope Angle (*)	FS Static	FS Pseudo static
Low wall 1	484	143	17	2.585	2.213
Low wall 2	425	132	17	2.631	2.247

Based on the results shown in Tables III-V (Fig. 6-8), the value of the safety factor increases directly proportional to the increase in the Berm, either in static or pseudo-static conditions.

In addition, it can be observed that in sections with the same diameter, there is a decrease in the safety factor (SF) between the slopes with static and pseudo-static conditions. Section 2 with a 10 m diameter SF value of 1.428 in a pseudo-static slope condition shows a much smaller safety factor than 1.5, which is the standard of safety factors set in the pseudo-static condition. Whereas with a 12 m diameter, the SF results in a static condition = 1.693, while the SF result in a pseudo-static condition = 1.481 with a decrease of about 12.5%. The decrease in SF in pseudo-static conditions is influenced by the value of the longitudinal seismic acceleration of 0.055 g due to blasting activities. For 15 m with static SF conditions and pseudo-static SF, the safety factor is far more than 1.5. Therefore, the optimal safety factor is with a diameter of 12 m which is closest to the SF of 1.5. Therefore, optimal slope modeling is used based on safety both in static conditions and in pseudo-static conditions, namely by using a diameter of 12 m. Slope instability also has the potential for intermediate slopes. This is influenced by the geotechnical conditions of the material composition (stratigraphy). The value of slope stability is determined in the same way as before. The Safety Factor scope of the final slopes is divided into two, the upper intermediate and the lower intermediate.

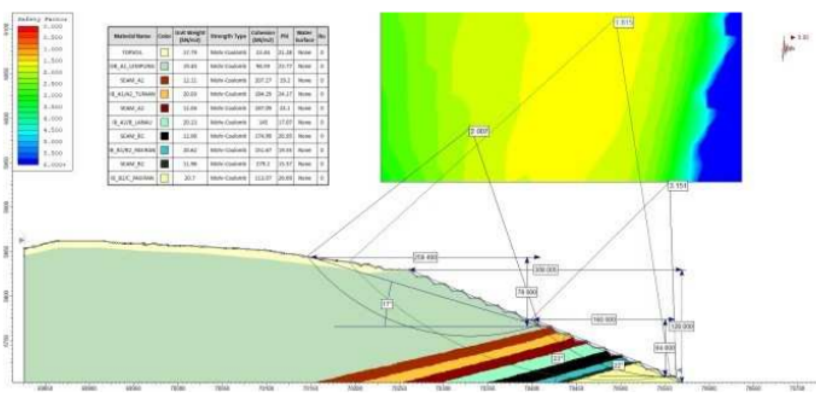

Fig. 6 Pseudo - Static Analysis FS HW Section 1 Berm 12 m

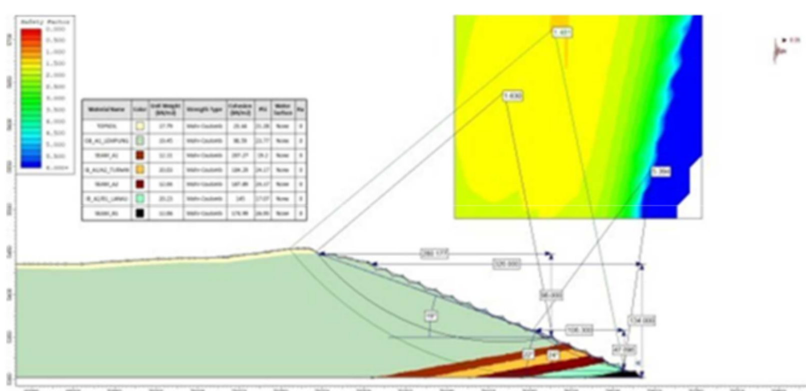

Fig. 7 Pseudo - Static Analysis FS HW Section 2 Berm 12 m

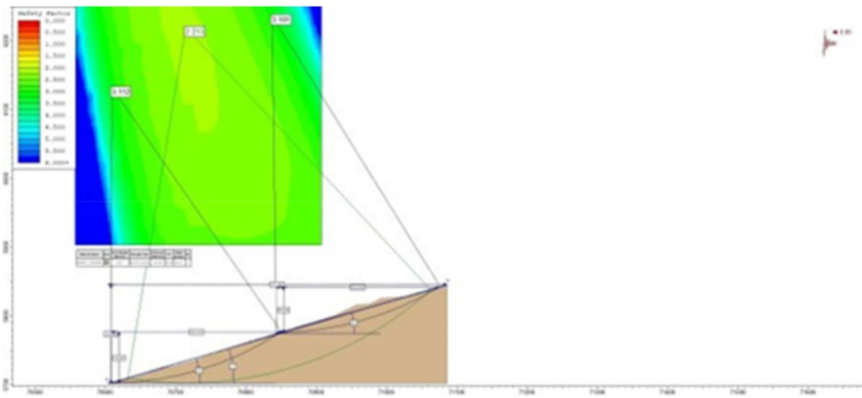

Fig. 8 Pseudo - Static Analysis FS Low wall Section 1 Berm 12 m

The results are shown in show the Safety Factor results on the final slope, both the upper intermediate and the lower intermediate, indicating that the safety factor has far exceeded the predetermined safety standards. So that the cause of disturbance in slope stability is exceedingly small, both in static and pseudo-static conditions. This is due to the material on the slope.

The upper intermediate Safety Factor had a smaller Safety Factor when compared to the lower intermediate Safety Factor. The forming material also influences it. The upper-intermediate is formed by sandy siltstone material, while the lower intermediate material is formed from several harder materials, namely Sandy silty claystone, coal, and sandy siltstone. This is what causes the lower intermediate Safety Factor to be much higher.

To apply slope stability in section 1 and section 2, the optimal Berm is determined, namely the overall slope, upper-intermediate, and lower intermediate 12 m. With a depth of 12 m, the slope will be safe in both static and pseudo-static conditions. By applying a berm 12 m, it will be safe to do blasting without worrying about the impact of the disturbance on the slope stability of the West Banko Pit 1 North.

2) Analysis of the Blast Effect on Residential Buildings: Scaled distance (SD) is a factor that affects ground vibrations, namely the measurement distance divided by the root of the number of explosives per time delay, the scaled distance affects the peak vector sum (PVS) value of ground vibrations produced by an explosion. This will affect the effect of ground vibrations on those caused by blasting activities. Efforts to minimize the effects of ground vibrations need to be taken measures to control ground vibrations so as not to cause danger to residential buildings at a certain distance. Therefore, it is necessary to measure the ground scraping and the activation of explosives to be carried out to predict the safe distance to carry out blasting activities at West Banko Pit 1 North. The PPV or PVS threshold value for residential buildings around the mine is ≤ 5 mm / second considering the building class, in the form of buildings with foundations, masonry, and cement mortar and tied with concrete slopes (SNI 7571: 2010).

The results of the measurement of the Peak Vector Sum (PVS) vs Scaled Distance vibration above can be seen that at the PVS value of 7.81 with a distance of 700 meters with a hole charge of 50 kg per hole, the scaled distance is 98.994 (Table VI), while showing a PVS value of 0.57 with a distance of 1935 meters with a hole charge of 52.91 kg per hole obtained a scaled distance of 266.02 (Table VII). So, it can also be concluded that the distance affects the level of ground vibrations. The farther the distance from the blasting area, the smaller the level of vibration that occurs and vice versa.

The value of ground vibrations in the next detonation can be predicted in a non-linear regression equation. The equation is obtained from analyzing the value of the scaled distance and peak vector sum. Based on Table VI and Table VII, a graph of the relationship between scaled distance and peak vector sum is obtained (Fig. 9). The results of the analysis of the relationship between the scaled distance and the actual PVS obtained from the results of measuring ground vibrations in the field show that there is a strong relationship between the scaled distance (SD) and the actual ground vibration (PVS). Each decrease in the scaled distance value is followed by an increase in the actual PVS value and conversely, any increase in the scaled distance value is followed by a decrease in the actual PVS value.

TABLE VI

SCALE DISTANCE AND PEAK VECTOR SUM (PVS) ELECTRIC BLASTING

Distance (m)	Charge/ (Delay (kg)	Scale Distance (m/kg^0.5	PPV (mm/s)			PVS (mm/s)
			Tran	Vert	Long	
700	150	98.9949494	7.62	5.84	4.57	7.81
500	50	70.7106781	1.14	0.889	1.4	2.01
600	150	70.7106781	4.70	7.49	2.54	7.63
1160	50	164.048773	1.78	1.02	1.4	2.13

TABLE VII

ANALYSIS SCALE DISTANCE AND PEAK VECTOR SUM (PVS)

Distance (m)	PPV (mm/s)	Charge/ hole (kg)	Scale Distance (m/kg^0.5)
1935	0.570	52.91	266.02
1876	0.413	58.20	245.91
1944	0.361	58.20	254.82
1750	0.421	52.91	240.59
1800	0.370	52.91	247.46
1400	0.808	58.20	183.51
1600	0.407	58.20	209.73
1800	0.241	52.91	247.76
1500	0.473	57,14	198.43
1800	0.262	42.33	276.67
1500	0.609	52.91	206.22

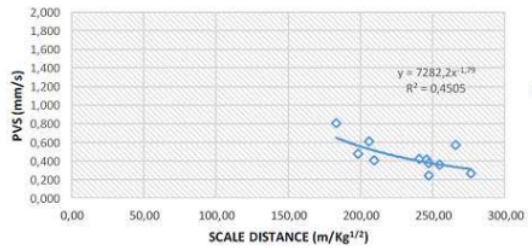

Fig. 9 Relationship Peak Vector Sum and Scaled Distance

The coefficient of determination (R2) from the data analysis shows that the R2 value is 0.4505, this indicates that the actual PVS is influenced by the scaled distance of 45.05%, while the rest is influenced by other factors such as physical and mechanical characteristics of the rock, lithology/rock bedding. The geological structure/discontinuity area in the form of a joint of the lining in the mine area, the influence of groundwater content, and others. The constants obtained in the equation to find the predictive PVS value are K = 7282.2 and M = -1.79. The constant values K and M are used to make calculations in predicting the peak vector sum amount at a certain scaled distance, to determine the blasting design simulation so that it can determine the safe vibration of an explosion based on explosives that can be used at a certain distance (Table VIII) so that we get the following equation.

$$PVS = 7282{,}2 \times SD\text{-}1{,}79$$

3) *Ground Vibration Control:* Based on the blasting analysis that has been carried out, it is found that the more charge weight is used over a certain distance, the greater the value of the resulting ground vibration. The resulting ground vibrations can be controlled by changing the load weight/delay and determining the appropriate circuit pattern according to the conditions of the blasting location. PT. Bukit Asam, Tbk.

The recommended range for getting PVS = 3.5 mm / s with a distance of 300 - 1500 m by using the equations that have been obtained from simple linear regression analysis, predictions can be made by adjusting the fill in the scaled distance formula so that the optimum charge is obtained for one blasting hole. (Table VIII).

TABLE VIII
NUMBER OF SAFE USE OF EXPLOSIVES

PVS (mm/s)	Distance (m)	Scale Distance (m/kg^0.5)	Charge/ hole (kg)
3	300	71.41	17.65
3	400	71.41	31.38
3	500	71.41	49.03
3	600	71.41	70.60
3	700	71.41	96.09
3	800	71.41	125.51
3	900	71.41	158.84
3	1000	71.41	196.10
3	1100	71.41	237.28
3	1200	71.41	282.39
3	1300	71.41	331.41
3	1400	71.41	384.36
3	1500	71.41	441.23

Based on Table VIII, it can be seen that at a distance of 300 m and 400m, the fill/hole that can be filled is 17.65 kg and 31.5 kg, respectively, which indicates that the charge cannot fill the explosive material with a diameter of 200 mm and a depth of 8 m. Therefore, blasting activities are not recommended at this distance. Meanwhile, at a distance of 500 m, the blast hole charge of 49.03 kg can fulfill the charge in the blasting plan and the vibrations generated by the safe blasting effect on the surrounding settlements, namely 3.5 mm / s. With these provisions, at West Banko Pit 1 North, blasting activities can be carried out with a minimum distance of 500 from residential areas.

C. Analysis of the Planned Area to be Blown up

By carrying out blasting activities in West Banko Pit 1 North, planning an area that can be blown up is necessary. It is necessary to consider the blasting activities that will be carried out because the effects of the vibrations caused can have an impact on residential areas. So, it is necessary to control blasting in a predetermined area so that the impact of blasting vibrations can be minimized and can also narrow the safe distance that can be detonated. Based on the results of the planned feed area carried out at West Banko Pit 1 North, it has been determined that the delivery area is divided into two areas, based on the treatment to be carried out, namely the ripping area and the blasting area (Fig. 10). The ripping area and the blasting area are 246.63 hectares.

The ripping area shows the areas that are blue. The area has a distance from the settlement of fewer than 500 m, so the use of blasting is not recommended in that area. The ripping area is located in the West highwall area, with an area of 134.04 Ha to be ripped. In comparison, the yellow area is an area where the reporting activities carried out in that area are carried out using the blasting method. The area is more than 500 m from the residential area, so blasting activities can be carried out by adjusting the delay when blasting is carried out to minimize ground vibrations, which can negatively impact residential buildings if the vibration effect exceeds the predetermined standard. The blasting area in the low wall area of the east is 112.59 hectares. With this arrangement, it will be safe to carry out activities without disturbing residential areas.

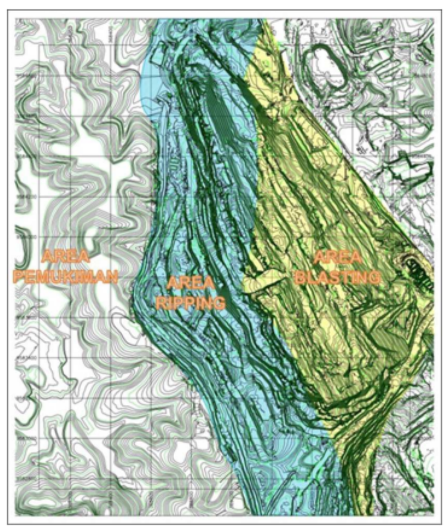

Fig. 10 Ripping - Blasting Overburden Area

IV. Conclusion

The Blasting Design will apply the blasting technique applied to the West Banko Pit 1 North because the lithology of the coal deposition material is relatively the same and the location is adjacent to the West Banko Pit 2, the blasting geometry used is 200 mm in diameter, 8 m Burden, 9 m space, Depth 8 m, loading density 26.5 kg / m. Simulations with 10 m, 12 m, and 15 m for static and pseudo-static slope stability analysis on the overall slope and intermediate slope, the wider the Berm, the higher the value of the slope safety factor and the sloping the overall slope and the greater the stripping ratio. The optimum Berm condition is 12 m with a pseudo-static safety factor of at least 1.50. The selection of the 12 m Berm is taken based on the value of the safety factor in section 2, almost close to 1.5 (long term) in accordance with the Ministerial Decree 1827 of 2018. Recommendation ground vibrations with blasting effects are planned for the scale distance for the PVS value set at ≤ 3.5 mm / s with the explosive charge per delay having an optimum value of 50 kg with a minimum distance of 500 m. The area to be blasted is 112.59 Ha, while the area to be ripped in the western pit limit area near residential areas with a radius of 500 m is 134.04 Ha.

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