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Reviewer A:
This paper already has novelty, but the contribution is not well
illustrated. Improve sentence writing and title selection so that this
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effective sentences. Writing introductions and paragraphs with efficient and
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based on accurate data. Improve references with primary references that
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sentence of the last paragraph Introduction.
In the method section, there are still deficiencies in the clear and
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done is to add a flow chart to the method. Strengthen your method by using
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Kepada: restu_juniah@yahoo.co.id; ttoha@unsri.ac.id

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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 mine is carried out in an open pit mine using a shovel-dump truck system as the main tool. The condition of the overburden material consists of top soil and claystone with a strength of 0.2 - 3 MPa. The digging force of the Komatsu PC 2000 excavator is 697 kN or 0.697 MPa, so for overburden excavation, the Komatsu D375A ripper support tool is used to feed the material. With the specifications of the tools used and the physical and mechanical characteristics of the overburden, it turns out that the productivity of the Komatsu PC 2000 excavator is not optimal because the bucket width is larger, namely 2.5 m, while the average depth of the material being stripped is only 1.2 m. To optimize the excavator's productivity, blasting activities must be carried out to deliver the material. Considering that the pit limit in the western part is close to residential buildings, it is necessary to design a blasting technique to reduce ground vibrations which have an effect on slope stability and residential areas around the mine. Based on the results of the analysis of overburden blasting at the Banko Pit 2 mine on static and pseudostatic slope stability with the optimal berm simulation, 12 m with a safety factor (SF) of 1.5, while the amount of safe explosives for prediction of PVS 3 value, 5 mm / sec is 50 Kg / Delay with a minimum distance of 500 m from the residential area. The results of the analysis of the area to be blasted are 112.59 hectares and the area that remains ripped is 134.04 hectares.

Kata-kata kunci: *blasting, soil vibration, pseudo-static slope stability, PPV, PPA*

I. INTRODUCTION

The coal mining system at the West Banko Pit 1 Mine is strip mining using a shovel-dump truck system. Mining activities include land clearing, stripping and transportation of top soil 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 (0.4-1 MPa). and very low strength rock (1-5 MPa) according to Broch & Franklin 1972 [1] so that it cannot be excavated directly by an excavator. To support the excavator's performance, the overburden removal is carried out using the Komatsu D375A-5 ripper. 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. To increase the productivity of the shovel-dump truck system, it is necessary to carry out blasting activities to deliver the material. 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 and overcome ground vibrations due to blasting and to increase slope stability, it is necessary to design blasting geometry, use of explosives, and delay systems [2].

Soil vibrations caused by blasting activities if it has exceeded a certain level can cause disturbance to slope stability and damage to the environment around the mine [3]. 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. [4].

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.

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

Conditions Pit 1 West Banko 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 Pit 1 West Banko area tends to follow the intrusion zone to form a dome with the intrusion zone as the central point. So that 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 existing pit PIT 1 WEST BANKO (Fig 3) has an area of 120 hectares, extending following the direction of coal strike from north to south with a dip to west. The northern part is bordered by coal cropline boundaries, the eastern part is bordered by settlements, the western part is limited by the andesite intrusion zone, the southern part is the direction of the pit continuity.

The stratigraphy of the Pit 1 West Banko area was obtained from the correlation of the drill data of PT Bukit Asam Tbk in the Pit 1 West Banko area. The stratigraphy of Pit 1 West Banko (Fig 3) is as follows.

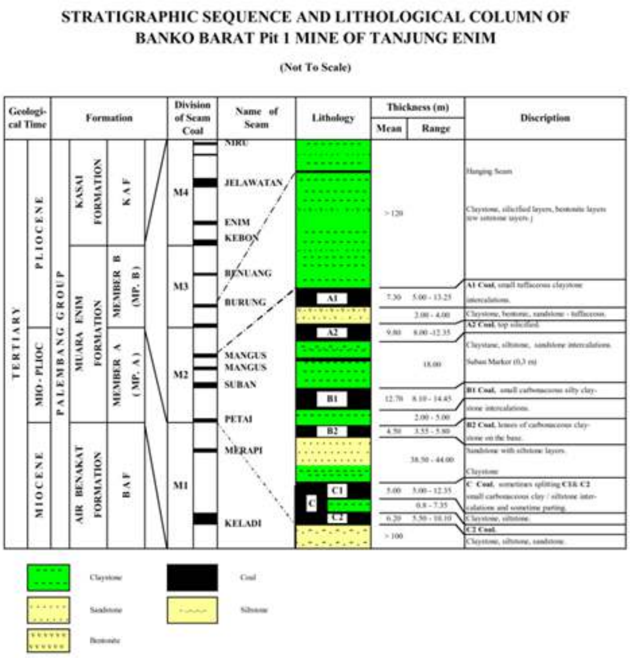

Fig 1. Stratigraphy Area Pit 1 West Banko

B. Geotechnical Conditions

The layer of material in the North West Banko Pit 1 area is divided into layers of overburden, coal seam, and interburden between seams. The dominant overburden layer is silty claystone. The coal seams consist of A1, A2, B, 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 1). Geotechnical parameter data was obtained based on the physical and mechanical properties of the rock by PT Bukit Asam Tbk.

TABLE 1
GEOTECHNICAL PARAMETER PIT 1 WEST BANKO

No	Material	D (ton m3)		UCS	τ	C	Ø
		In-Situ	Bulk	(MPa)	(MPa)	(KPa)	(°)
1	Top Soil	1,005 - 1,63	1,53 - 1,88	0,066 - 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

C. Hydrogeological Conditions

Groundwater around the Pit 1 West Banko area is assumed to come from surface infiltration water. Ground water sources were not found in the pit openings. The groundwater flow in the Pit 1 West Banko area is assumed to only follow the layer of the top soil layer. Top soil types tend to be loose material with a thickness of 1 - 3 m. The next layer has a type of silty claystone material which is more impermeable. Hence the water level effect was not considered in the analysis. It can be seen based on the state of rainfall in the area in Table 2.

TABLE 2
WEST BANKO RAINFALL DATA 2019

Month	Rainfall (mm)	Rainy Time (Jam)	Rainy Day	Rain Frequency
January	491,8	52,5	27	69
February	445,2	78	27	69
March	257,8	27,6	21	40
April	404,8	47,2	23	57
Mey	110,9	18,2	15	31
June	61,1	13	18	29
July	90,8	7,4	11	19
August	117,4	10,6	2	9
September	19,3	1,5	4	6
October	47,4	4,4	9	12
November	158,3	20	16	30
December	326,5	58,1	18	64
Total	2531,1	338,5	191	433

II. MATERIAL AND METHOD

The location of 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 Mine Pit 1.

The stages in this research started from the stage of literature study, field observation, data processing and analysis, as well as conclusions and suggestions.

Literature study is carried out to obtain a theoretical basis. The theoretical basis used in the pseudo-static slope stability analysis is to take into account the ground vibration variables due to overburden blasting [4], [5], [8], [9]. In each section, the forces acting in the arc avalanche plane are as illustrated in Fig 3.

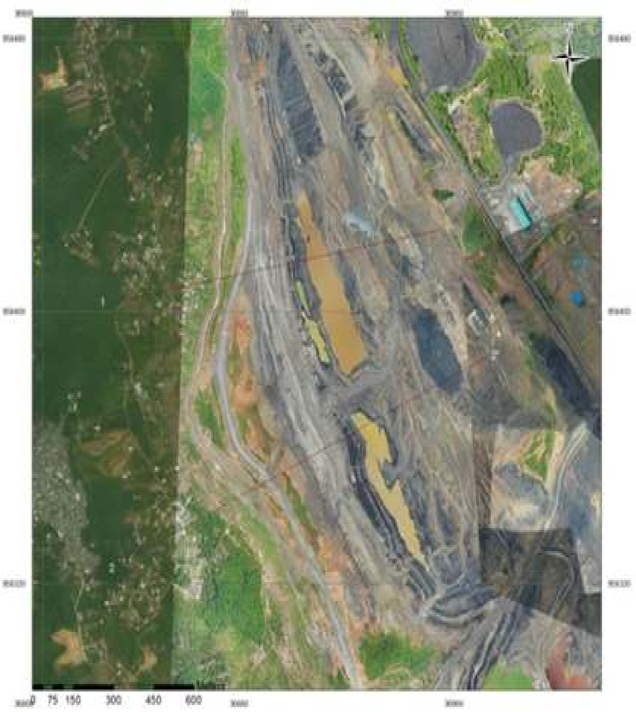

Fig 2. Map of Orthophoto Pit 1 West Banko

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

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

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 blastmate. 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) [5], [6], [11]. The seismic coefficient (Kh) is obtained by the following equation:

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) [12].

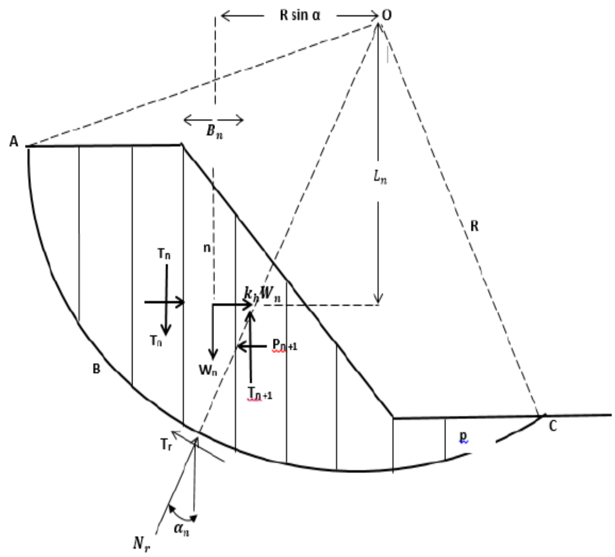

Fig 3. Slope Model With Surface Sliding

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. By inputting data on geological, geotechnical, geohydrological / hydrological conditions, and acceleration of ground vibration safety factor for mine slopes (single slope, intermediate slope, and overall slope) [1]. The results of the pseudo-static slope stability analysis 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 sections which are critical and safe slope conditions. Also discussed how to technically minimize ground vibration from overburden blasting effect.

The conclusions and suggestions are to know 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.

III. Results and Discussion

A. Blasting Activity

The overburden blasting system at Pit 1 West Banko uses a non-electric detonator (nonel) combined with an initiation system using a poweradet electric detonator which is connected to a blasting machine using 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 (Table 3). As well as the reference to the use of explosives in pit 1 will follow the reference to the use of explosives in 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 (Fig 4). If the type of blasting is double deck, it uses a 500 ms inhole detonator and a 6000 ms inhole detonator to minimize the impact of blasting in the form of vibrations generated in the blasting.

TABLE 3
BLASTING GEOMETRY

S (m)	B (m)	PC (m)	T (m)	H (m)	PPV (mm/s)			PVS (mm/s)
					Tran	Vert	Long	
9,23	8,12	1,89	6,41	8,50	7,62	5,84	4,57	7,81
9,01	8,20	1,89	6,22	8,41	1,14	0,889	1,4	2,01
9,14	8,03	1,89	6,15	8,44	4,70	7,49	2,54	7,63
9,05	8,17	1,89	6,31	8,52	1,78	1,02	1,4	2,13

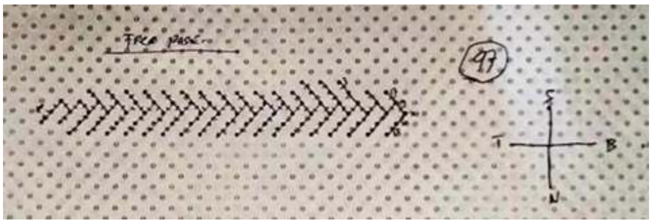

Fig 4. Delay System

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 for the April - July 2019 period as shown in Table 4.

TABLE 4
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 June 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 x 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 [10], [7].

B. Analysis of Effect of Soil Vibration

1. Analysis of Final Slope Stability

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 pit 1 West Banko. Seismic slope stability analysis can be determined using the pseudo-static method approach.

Potential factors causing mine slope landslides include slope geometric 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 pit 1 West Banko is still in the process of 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 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, and 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 (Table 5).

The location of the cross section for the berm simulation analysis is chosen in an area that has been determined by the mining boundary (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).

TABLE 5
FINAL SLOPE GEOMETRY SIMULATION

Geometry		
Width (m)	Height (m)	Slope Angle (°)
10	8	45
12	8	45
15	8	45

Slopes of section 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 mine 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.

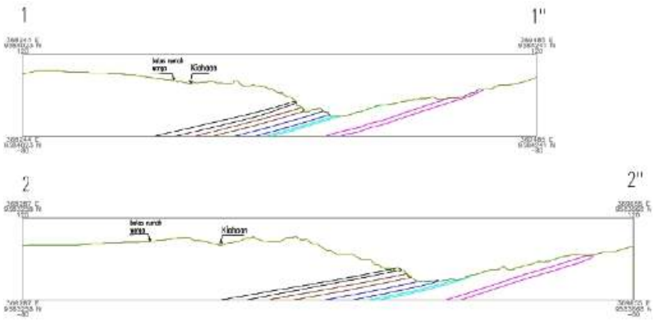

Fig 5. Section of Geometry Bench Pit 1 West Banko

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 pit 1 West Banko consist of transverse, vertical, and longitudinal accelerations. In the analysis, the transverse and vertical accelerations are assumed to 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. Based on the blasting activity plan at the West Banko pit 1 mine, it 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. Approach is done by using the static arc and pseudo static equilibrium limit method.

The analysis stage was carried out by testing 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 m m 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 slope, intermediate slope, and single slope. Slope stability analysis used rocscience slide v6.0 software with the bishop arc equilibrium limit method.

Slope stability simulation is carried out on modeling with variable berms of 10 m, 12 m, 15 m. The results of slope stability analysis under static and pseudo-static conditions (Appendix,).

TABLE 6
FS OVERALL SLOPE SECTION 1

	Overall Slope				
Single Berm (m)	Width (m)	Height (m)	Slope Angle (°)	FK Statik	FK Pseudo - Statik
10	296	132	24	1.712	1.517
12	308	128	23	1.842	1.615
15	353	128	19	2.102	1.813

TABLE 7
FS OVERALL SLOPE SECTION 2

	Overall Slope				
Single Berm (m)	Width (m)	Height (m)	Slope Angle (°)	FK Statik	FK Pseudo - Statik
10	296	136	25	1.608	1.428
12	326	134	22	1.693	1.481
15	376	136	20	1.908	1.646

TABLE 8
FS OVERALL SLOPE AT LOW WALL

	Overall Slope				
Single Berm (m)	Width (m)	Height (m)	Slope Angle (°)	FK Statik	FK Pseudo - Statik
Lowwall 1	484	143	17	2.585	2.213
Lowwall 2	425	132	17	2.631	2.247

Based on the results shown in (Appendix, Tables 6, 7 and 8) the value of the safety factor increases directly proportional to the increase in 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. As in section 2 with a 10 m diameter SF value of 1.428 in a pseudo-static slope condition shows a much smaller safety factor compared to 1.5 which is the standard of safety factors that have been set in the pseudo-static condition. Whereas with a 12 m diameter, the SF result in a static condition = 1.693 (Table 4.10), while the SF result in a pseudo-static condition = 1.481 (Table 4.10) 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, the 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.

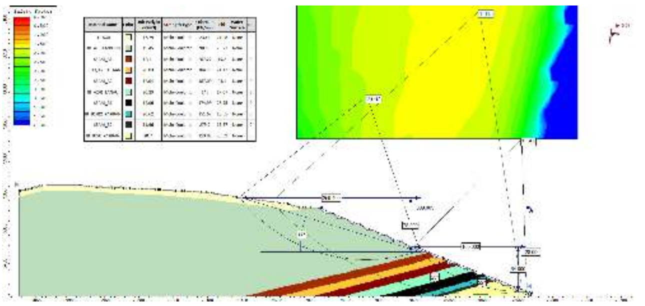

Fig 6. Pseudo - Static Analysis FS Section 1 Berm 12 m

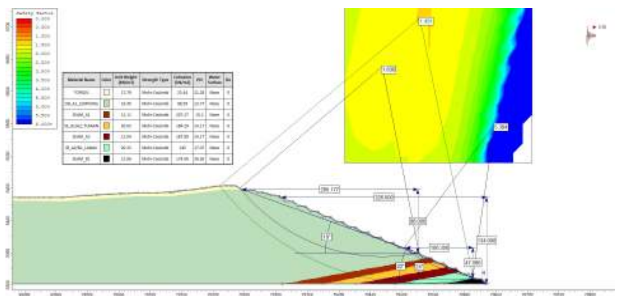

Fig 7. Pseudo - Static Analysis FS Section 2 Berm 12 m

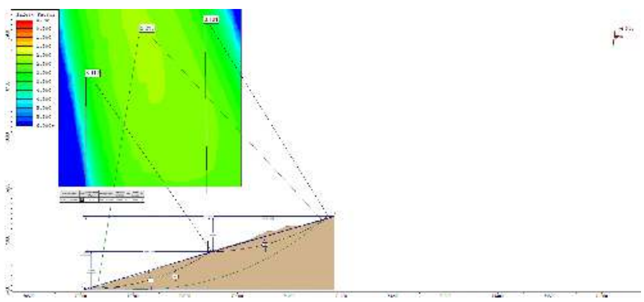

Fig 8. Pseudo - Static Analysis FS Low wall Section 1 Berm 12 m

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 SF scope of the final slopes is divided into two, the upper intermediate (Appendix) and the lower intermediate.

The results shown in (Appendix) show the SF 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 very small, both in static conditions and in pseudo static conditions. This is due to the material on the slope.

The upper intermediate SF had a smaller SF when compared to the lower intermediate SF. It is also influenced by the forming material. The upper intermediate is formed by the type of sandy siltstone material, while the lower intermediate material is formed from several types of harder materials, namely Sandy silty claystone, coal, and sandy siltstone. This is what causes the lower intermediate SF to be much higher.

To apply slope stability, both 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 of 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 1 pit mine.

2. Analisis Pengaruh Peledakan Terhadap Pemukiman

Scaled distance (SD) is a factor that affects ground vibrations, namely the measurement distance divided by the root of the amount 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 so that it can predict the safe distance to carry out blasting activities at pit 1 West Banko. 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 filling of 50 kg per hole, the scaled distance is 98.994 (Table 9), while showing a PVS value of 0 , 57 with a distance of 1935 meters with a hole filling of 52.91 kg per hole obtained a scaled distance of 266.02 (Table 10). So it can be concluded also 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 that will occur in the next detonation can be predicted in a non-linear regression equation. The equation is obtained from the analysis of the value of the scaled distance and peak vector sum. Based on Table 9 and Table 10, 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), that is, 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 9
SCALE DISTANCE AND PEAK VECTOR SUM (PVS)
ELEKTRIC BLASTING

Distance (m)	Charge/ Delay (kg)	Scaled 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
500	150	70,7106781	4,70	7,49	2,54	7,63
1160	50	164,048773	1,78	1,02	1,4	2,13

TABLE 10
ANALYSIS SCALE DISTANCE AND PEAK
VECTOR SUM (PVS)

Distance (m)	PPV (mm/s)	Charge/ hole (kg)	Scaled 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	247,46
1500	0,473	57,14	198,43
1800	0,262	42,33	276,67
1500	0,609	52,91	206,22

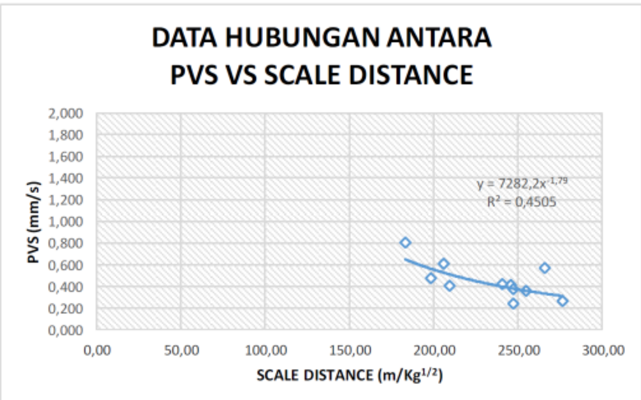

Fig 9. Relationship Peak Velocity Sum dan Scaled Distance

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 certain distance (Table 11). So that we get the following equation.

$$PVS = 7282{,}2 \times SD^{-1{,}79} \qquad (2)$$

Ground Vibration Control

Based on the blasting analysis that has been carried out, it is found that the more filling 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.

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 filling is obtained for one blasting hole. (Table 11).

TABLE 10
NUMBER OF SAFE USE OF EXPLOSIVES

PVS (mm/s)	Distance (m)	Scaled 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 11, it can be seen that at a distance of 300 m and 400 m the charge / hole that can be filled is 17.65 kg and 31.5 kg, respectively, which indicates that the filling 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 filling of 49.03 Kg is able to fulfill the filling in the blasting plan, as well as the vibrations generated by the safe blasting effect on the surrounding settlements, namely 3.5 mm / s With these provisions, at pit 1 West Banko 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 pit 1 West Banko, it is necessary to plan an area that can be blown up. 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 pit 1 West Banko, 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 9). The ripping area and the blasting area are 246.63 hectares.

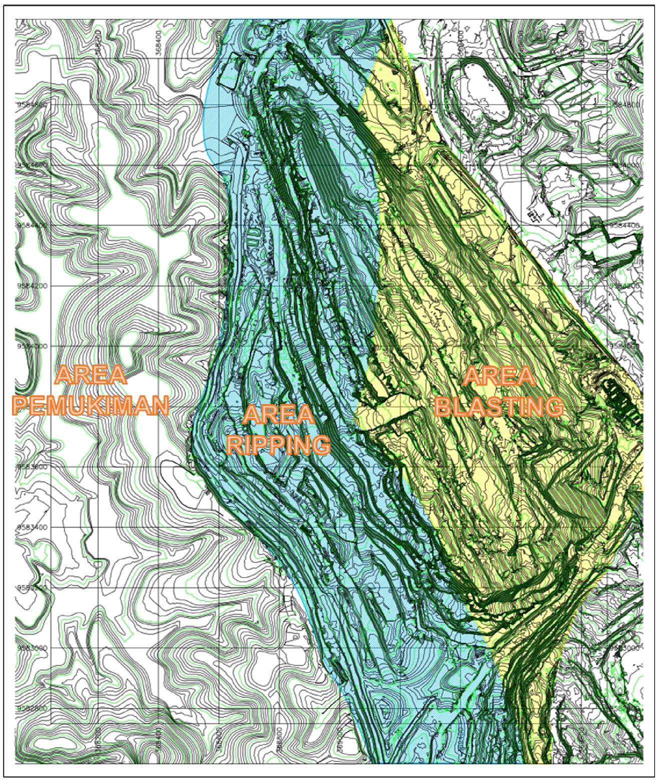

Fig 9. Ripping - Blasting Overburden Area

The ripping area shows the areas that are blue. The area has a distance from the settlement of less 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. Whereas 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 that blasting activities can be carried out by adjusting the delay when blasting is carried out so that it can minimize ground vibrations which can have a bad impact on 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.

IV. CONCLUSION

Based on the results of this study, it can be concluded (1) The Blasting Design will apply the blasting technique applied to the West Banko Pit 2 mine because the lithology of the coal deposition material is relatively the same and the location is adjacent to the Banko Pit 1 mine, the blasting geometry used is 200 mm in diameter, 8 m Burden, 9 m space, Depth 8 m, loading density 26.5 kg/ m (2) Simulations with 10 m, 12 m and 15 m for analysis of static and pseudo static slope stability 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 striping ratio. (3 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. (4) Soil 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. (5) The area to be blown up 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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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. Overburden consists of top soil 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 pseudostatic slopes with the simulation of the optimal berm, the maximum berm is 12 m with a safety factor (SF) of 1.5, while the amount 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 results of the analysis of the area to be blast are 112.59 Ha and the area that remains ripped is 134.04 Ha.

Keyword: *blasting, ground vibration, pseudo-static slope stability, PPV, PPA*

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 transportation of top soil 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 (0.4-1 MPa). and very low strength rock (2-20 MPa) according to Bienawski [1] so that it cannot be excavated directly by an excavator. To support the excavator's performance, the overburden removal is carried out using the Komatsu D375A-5 ripper. 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], [3]. To increase the productivity of the shovel-dump truck system, it is necessary to carry out blasting activities to deliver the material. 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 and overcome ground vibrations due to blasting and to increase slope stability, it is necessary to design blasting geometry, use of explosives, and delay systems [4], [5].

Soil vibrations caused by blasting activities if it has exceeded a certain level can cause disturbance to slope stability and damage to the environment around the mine [6]. 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 [6].

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.

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

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. So that 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 existing pit West Banko Pit 1 North (Fig. 3) has an area of 120 hectares, extending following the direction of coal strike from north to south with a dip to west. The northern part is bordered by coal cropline boundaries, the eastern part is bordered by settlements, the western part is limited by the andesite intrusion zone, the southern part is the direction of the pit continuity.

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. 3) is as follows.

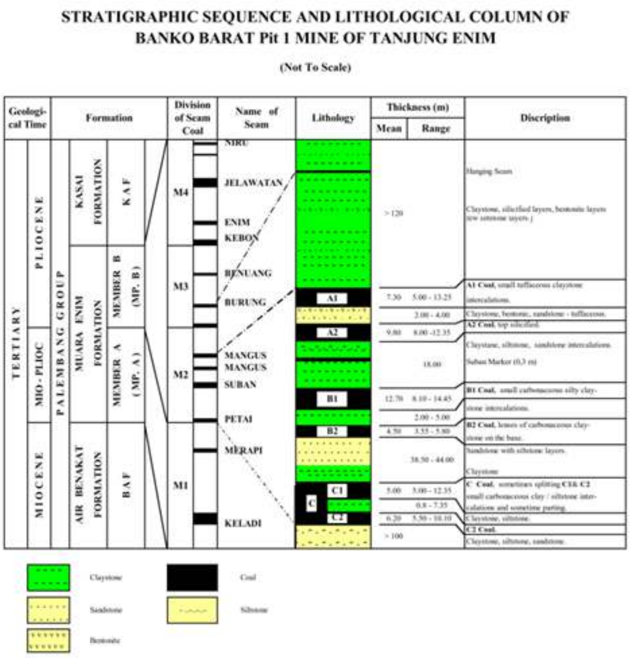

Fig. 1 Stratigraphy Area Pit 1 West Banko

B. Geotechnical Conditions

The layer of material in the West Banko Pit 1 North area is divided into layers of overburden, coal seam, and interburden 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 1). Geotechnical parameter data was obtained based on the physical and mechanical properties of the rock by PT Bukit Asam Tbk.

TABLE 1
GEOTECHNICAL PARAMETER PIT 1 WEST BANKO

No	Material	D (ton/m3)		UCS	τ	C	ϕ
		In-Situ	Bulk	(MPa)	(MPa)	(KPa)	(°)
1	Top Soil	1,005 - 1,63	1,53 - 1,88	0,066 - 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

C. Hydrogeological Conditions

Groundwater around the West Banko Pit 1 North area is assumed to come from surface infiltration water. Ground water sources were not found in the pit openings. The groundwater flow in the West Banko Pit 1 North area is assumed to only follow the layer of the top soil layer. Top soil types tend to be loose material with a thickness of 1 - 3 m. The next layer has a type of silty claystone material which is more impermeable. Hence the water level effect was not considered in the analysis. It can be seen based on the state of rainfall in the area in Table 2.

TABLE 2
WEST BANKO RAINFALL DATA 2019

Month	Rainfall (mm)	Rainy Time (Jam)	Rainy Day	Rain Frequency
January	491,8	52,5	27	69
February	445,2	78	27	69
March	257,8	27,6	21	40
April	404,8	47,2	23	57
Mey	110,9	18,2	15	31
June	61,1	13	18	29
July	90,8	7,4	11	19
August	117,4	10,6	2	9
September	19,3	1,5	4	6
October	47,4	4,4	9	12
November	158,3	20	16	30
December	326,5	58,1	18	64
Total	2531,1	338,5	191	433

II. MATERIAL AND METHOD

The location of 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 and analysis, as well as conclusions and suggestions.

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 take into account the ground vibration variables due to overburden blasting [6]–[11]. In each section, the forces acting in the arc avalanche plane are as illustrated in Fig. 3.

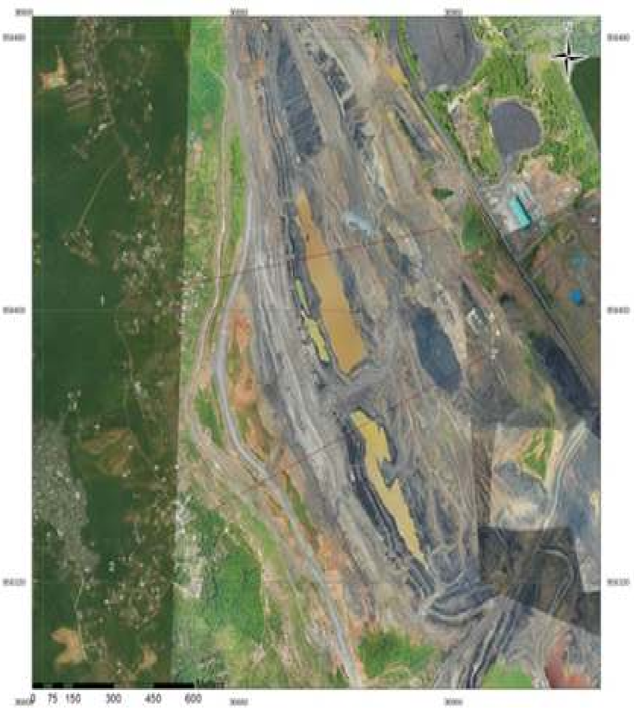

Fig. 2 Map of Orthophoto Pit 1 West Banko

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

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

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 blastmate. 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) [7], [8]. The seismic coefficient (Kh) is obtained by the following equation:

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) [12].

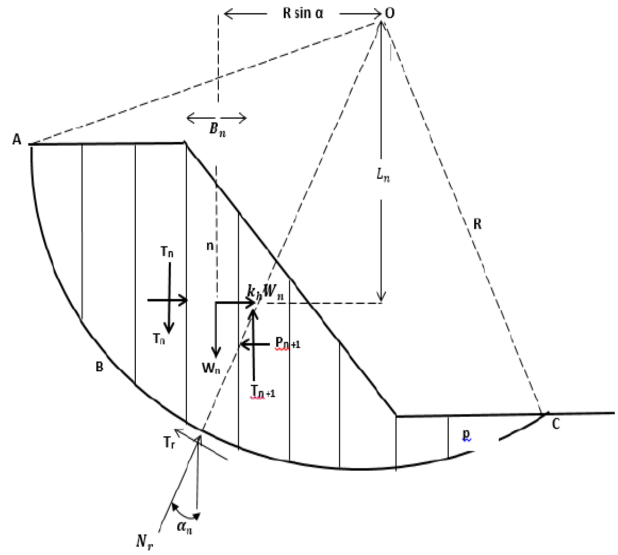

Fig. 3 Slope Model With Surface Sliding

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. By inputting data on geological, geotechnical, geohydrological / hydrological conditions, and acceleration of ground vibration safety factor for mine slopes (single slope, intermediate slope, and overall slope) [1]. The results of the pseudo-static slope stability analysis 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 sections which are critical and safe slope conditions. Also discussed how to technically minimize ground vibration from overburden blasting effect.

The conclusions and suggestions are to know 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 [10], [11].

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 poweradet electric detonator which is connected to a blasting machine using 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 (Table 3). 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 (Fig. 4). If the type of blasting is double deck, it uses a 500 ms inhole detonator and a 6000 ms inhole detonator to minimize the impact of blasting in the form of vibrations generated in the blasting.

TABLE 3
BLASTING GEOMETRY

S (m)	B (m)	PC (m)	T (m)	H (m)	PPV (mm/s)			PVS (mm/s)
					Tran	Vert	Long	
9,23	8,12	1,89	6,41	8,50	7,62	5,84	4,57	7,81
9,01	8,20	1,89	6,22	8,41	1,14	0,889	1,4	2,01
9,14	8,03	1,89	6,15	8,44	4,70	7,49	2,54	7,63
9,05	8,17	1,89	6,31	8,52	1,78	1,02	1,4	2,13

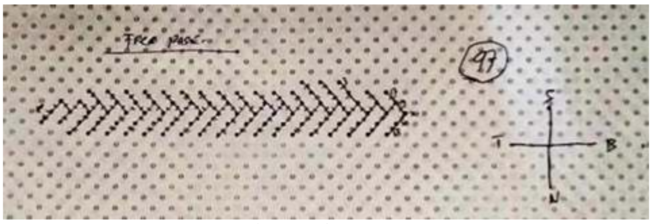

Fig. 4 Delay System

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 4.

TABLE 4
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 x 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 [10], [11].

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 slope geometric 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 in the process of 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 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, and 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 (Table 5).

The location of the cross section for the berm simulation analysis is chosen in an area that has been determined by the mining boundary (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).

TABLE 5
FINAL SLOPE GEOMETRY SIMULATION

Geometry		
Width (m)	Height (m)	Slope Angle (°)
10	8	45
12	8	45
15	8	45

Slopes of section 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.

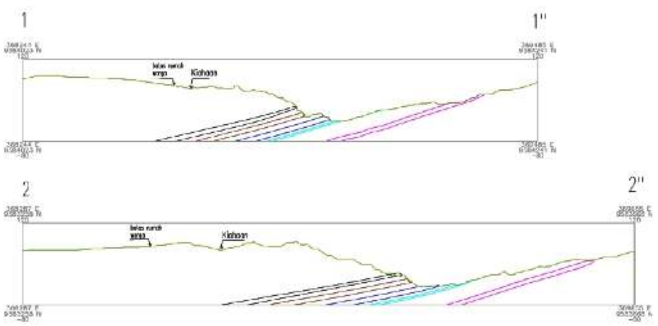

Fig. 5 Section of Geometry Bench Pit 1 West Banko

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. In the analysis, the transverse and vertical accelerations are assumed to 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. Based on the blasting activity plan at the West Banko Pit 1 North, it 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. Approach is done by using the static arc and pseudo static equilibrium limit method.

The analysis stage was carried out by testing 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 m m 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 slope, intermediate slope, and single slope. Slope stability analysis used rocscience slide v 6.0 software with the bishop arc equilibrium limit method.

Slope stability simulation is carried out on modeling with variable berms of 10 m, 12 m, 15 m. The results of slope stability analysis under static and pseudo-static.

TABLE 6
FS OVERALL SLOPE SECTION 1

	Overall Slope				
Single Berm (m)	**Width (m)**	**Height (m)**	**Slope Angle (*)**	**FS Static**	**FS Pseudostatic**
10	296	132	24	1.712	1.517
12	308	128	23	1.842	1.615
15	353	128	19	2.102	1.813

TABLE 7
FS OVERALL SLOPE SECTION 2

	Overall Slope				
Single Berm (m)	**Width (m)**	**Height (m)**	**Slope Angle (*)**	**FS Static**	**FS Pseudostatic**
10	296	136	25	1.608	1.428
12	326	134	22	1.693	1.481
15	376	136	20	1.908	1.646

TABLE 8
FS OVERALL SLOPE AT LOW WALL

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

Based on the results shown in (Tables 6, 7 and 8) the value of the safety factor increases directly proportional to the increase in 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. As in section 2 with a 10 m diameter SF value of

1.428 in a pseudo-static slope condition shows a much smaller safety factor compared to 1.5 which is the standard of safety factors that have been set in the pseudo-static condition. Whereas with a 12 m diameter, the SF result in a static condition = 1.693 (Table 4.10), while the SF result in a pseudo-static condition = 1.481 (Table 4.10) 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, the 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.

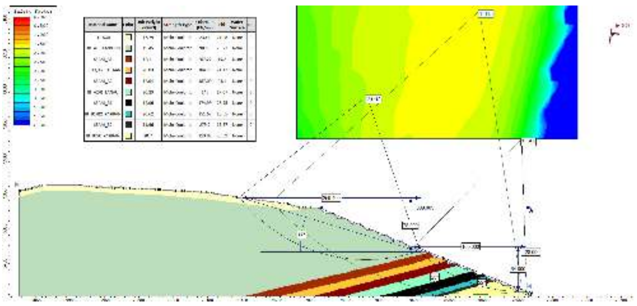

Fig. 6 Pseudo - Static Analysis FS HW Section 1 Berm 12 m

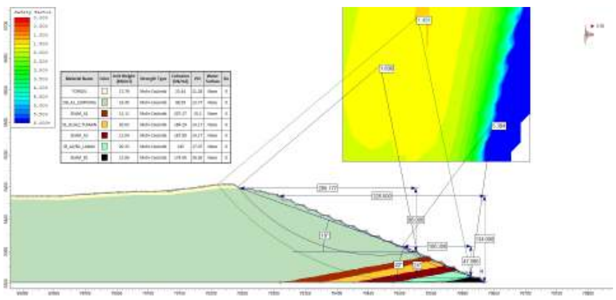

Fig. 7 Pseudo - Static Analysis FS HW Section 2 Berm 12 m

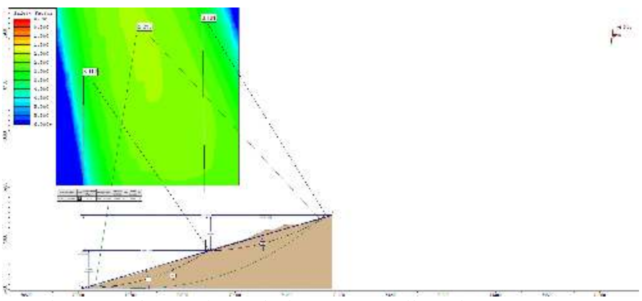

Fig. 8 Pseudo - Static Analysis FS Low wall Section 1 Berm 12 m

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.

The results 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 very small, both in static conditions and in 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 . It is also influenced by the forming material. The upper intermediate is formed by the type of sandy siltstone material, while the lower intermediate material is formed from several types of 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, both 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 of 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 amount 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 so that it can 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 9), 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 10). So it can be concluded also 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 that will occur in the next detonation can be predicted in a non-linear regression equation. The equation is obtained from the analysis of the value of the scaled distance and peak vector sum. Based on Table 9 and Table 10, 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), that is, 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 9
SCALE DISTANCE AND PEAK VECTOR SUM (PVS)
ELEKTRIC BLASTING

Distance (m)	Charge/ Delay (kg)	Scaled 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
500	150	70,7106781	4,70	7,49	2,54	7,63
1160	50	164,048773	1,78	1,02	1,4	2,13

TABLE 10
ANALYSIS SCALE DISTANCE AND PEAK
VECTOR SUM (PVS)

Distance (m)	PPV (mm/s)	Charge/ hole (kg)	Scaled 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	247,46
1500	0,473	57,14	198,43
1800	0,262	42,33	276,67
1500	0,609	52,91	206,22

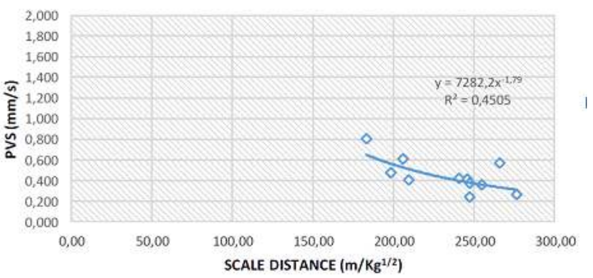

Fig. 9 Relationship Peak Vector Sum and Scaled Distance

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 certain distance (Table 11). So that we get the following equation.

$$PVS = 7282{,}2 \times SD^{-1{,}79} \quad (2)$$

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.

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 11).

TABLE 11
NUMBER OF SAFE USE OF EXPLOSIVES

PVS (mm/s)	Distance (m)	Scaled 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 11, it can be seen that at a distance of 300 m and 400 m 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 is able to fulfill the charge in the blasting plan, as well as 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, it is necessary to plan an area that can be blown up. 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.

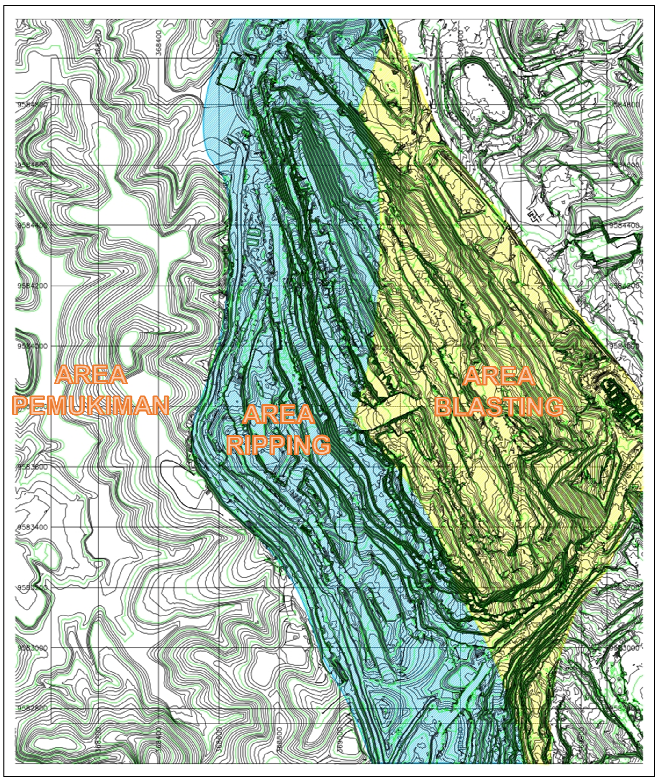

Fig. 10 Ripping - Blasting Overburden Area

The ripping area shows the areas that are blue. The area has a distance from the settlement of less 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. Whereas 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 that blasting activities can be carried out by adjusting the delay when blasting is carried out so that it can minimize ground vibrations which can have a bad impact on 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.

IV. CONCLUSION

Based on the results of this study, it can be concluded (1) 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 Banko Pit 1 mine, the blasting geometry used is 200 mm in diameter, 8 m Burden, 9 m space, Depth 8 m, loading density 26.5 kg / m.. (2) Simulations with 10 m, 12 m and 15 m for analysis of static and pseudo static slope stability 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 striping ratio. (3) 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. (4) 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. (5) The area to be blast 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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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. Overburden consists of top soil 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 pseudostatic 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 amount 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 results of the analysis of the area to be blast are 112.59 Ha and the area that remains ripped is 134.04 Ha.

Keyword: *blasting, ground vibration, pseudo-static slope stability, PPV, PPA*

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 transportation of top soil 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 (0.4-1 MPa). and very low strength rock (2-20 MPa) according to Bienawski [1] so that it cannot be excavated directly by an excavator. To support the excavator's performance, the overburden removal is carried out using the Komatsu D375A-5 ripper. 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], [3], [4]. To increase the productivity of the shovel-dump truck system, it is necessary to carry out blasting activities to deliver the material [5], [6], [7], [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 and overcome ground vibrations due to blasting and to increase slope stability, it is necessary to design blasting geometry, use of explosives, and delay systems [9], [10], [11].

Soil vibrations caused by blasting activities if it has exceeded a certain level can cause disturbance to slope stability and damage to 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], [13], [14], [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

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. So that 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 existing pit West Banko Pit 1 North (Fig. 3) has an area of 120 hectares, extending following the direction of coal strike from north to south with a dip to west. The northern part is bordered by coal cropline boundaries, the eastern part is bordered by settlements, the western part is limited by the andesite intrusion zone, the southern part is the direction of the pit continuity.

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. 3) is as follows.

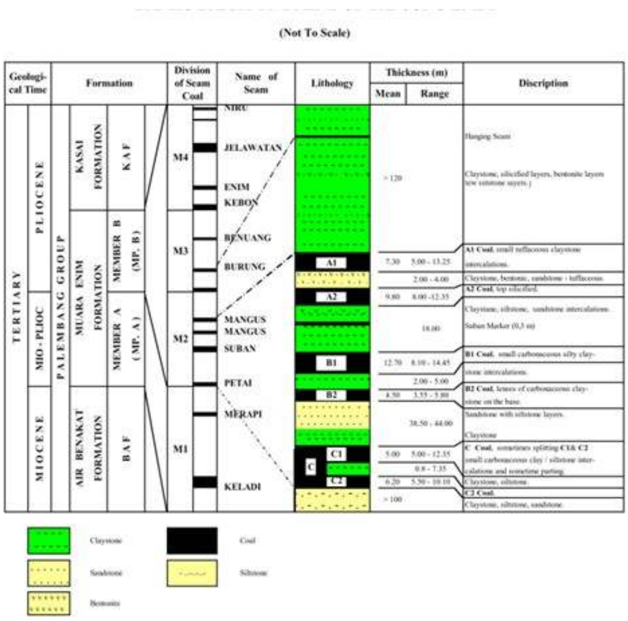

Fig. 1 Stratigraphy Area Pit 1 West Banko

B. Geotechnical Conditions

The layer of material in the West Banko Pit 1 North area is divided into layers of overburden, coal seam, and interburden 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 1). Geotechnical parameter data was obtained

TABLE 1
GEOTECHNICAL PARAMETER PIT 1 WEST BANKO

No	Material	D (ton/m3)		UCS	τ	C	Ø
		In-Situ	Bulk	(MPa)	(MPa)	(KPa)	(°)
1	Top Soil	1,005 - 1,63	1,53 - 1,88	0,066 - 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

C. Hydrogeological Conditions

Groundwater around the West Banko Pit 1 North area is assumed to come from surface infiltration water. Ground water sources were not found in the pit openings. The groundwater flow in the West Banko Pit 1 North area is assumed to only follow the layer of the top soil layer. Top soil types tend to be loose material with a thickness of 1 - 3 m. The next layer has a type of silty claystone material which is more impermeable. Hence the water level effect was not considered in the analysis. It can be seen based on the state of rainfall in the area in Table 2.

TABLE 2
WEST BANKO RAINFALL DATA 2019

Month	Rainfall (mm)	Rainy Time (Jam)	Rainy Day	Rain Frequency
January	491,8	52,5	27	69
February	445,2	78	27	69
March	257,8	27,6	21	40
April	404,8	47,2	23	57
Mey	110,9	18,2	15	31
June	61,1	13	18	29
July	90,8	7,4	11	19
August	117,4	10,6	2	9
September	19,3	1,5	4	6
October	47,4	4,4	9	12
November	158,3	20	16	30
December	326,5	58,1	18	64
Total	2531,1	338,5	191	433

II. MATERIAL AND METHOD

The location of 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 and analysis, as well as conclusions and suggestions.

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 take into account the ground vibration variables due to overburden blasting systems [17], [18], [19], [20]. 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.

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

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 blastmate. 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) [21]. The seismic coefficient (Kh) is obtained by the following equation:

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) [22].

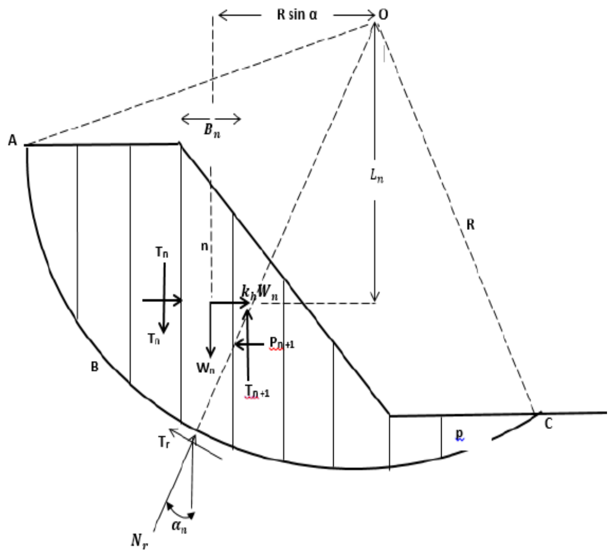

Fig. 3 Slope Model With Surface Sliding

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. By inputting data on geological, geotechnical, geohydrological / hydrological conditions, and acceleration of ground vibration safety factor for mine slopes (single slope, intermediate slope, and overall slope [1]. The results of the pseudo-static slope stability analysis 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 sections which are critical and safe slope conditions. Also discussed how to technically minimize ground vibration from overburden blasting effect.

The conclusions and suggestions are to know 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.

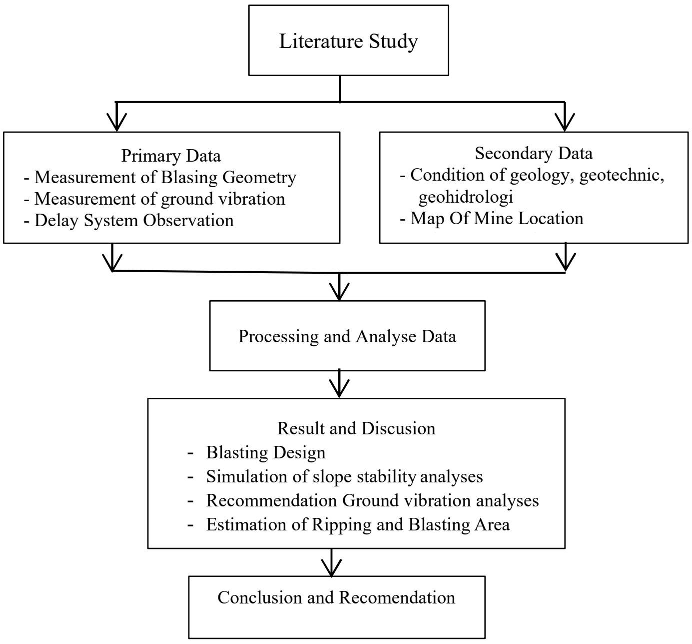

Fig. 4 Flow Chart of Research

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 poweradet electric detonator which is connected to a blasting machine using 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 (Table 3). 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 (Fig. 5). If the type of blasting is double deck, it uses a 500 ms inhole detonator and a 6000 ms inhole detonator to minimize the impact of blasting in the form of vibrations generated in the blasting.

TABLE 3
BLASTING GEOMETRY

S (m)	B (m)	PC (m)	T (m)	H (m)	PPV (mm/s)			PVS (mm/s)
					Tran	Vert	Long	
9,23	8,12	1,89	6,41	8,50	7,62	5,84	4,57	7,81
9,01	8,20	1,89	6,22	8,41	1,14	0,889	1,4	2,01
9,14	8,03	1,89	6,15	8,44	4,70	7,49	2,54	7,63
9,05	8,17	1,89	6,31	8,52	1,78	1,02	1,4	2,13

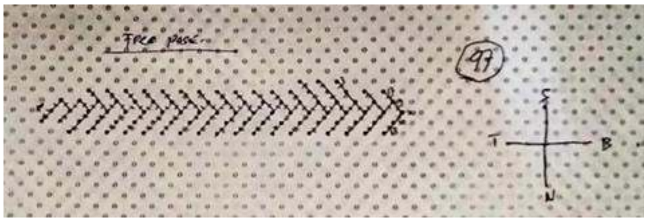

Fig. 5 Delay System

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 4.

TABLE 4
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 x 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 slope geometric 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 in the process of 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 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, and 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 (Table 5).

The location of the cross section for the berm simulation analysis is chosen in an area that has been determined by the mining boundary (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 6).

TABLE 5
FINAL SLOPE GEOMETRY SIMULATION

Geometry		
Width (m)	Height (m)	Slope Angle (°)
10	8	45
12	8	45
15	8	45

Slopes of section 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.

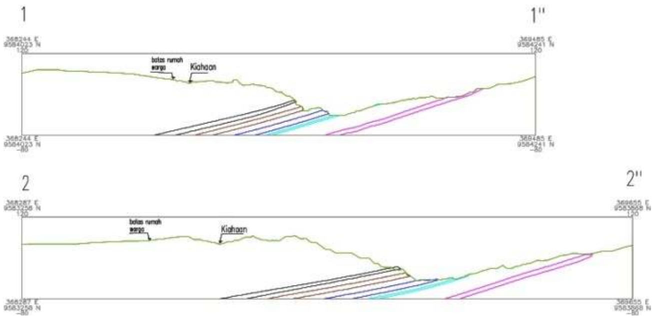

Fig. 6 Section of Geometry Bench Pit 1 West Banko

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. In the analysis, the transverse and vertical accelerations are assumed to 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. Based on the blasting activity plan at the West Banko Pit 1 North, it 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. Approach is done by using the static arc and pseudo static equilibrium limit method.

The analysis stage was carried out by testing 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 m m 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 slope, intermediate slope, and single slope. Slope stability analysis used rocscience slide v 6.0 software with the bishop arc equilibrium limit method.

Slope stability simulation is carried out on modeling with variable berms of 10 m, 12 m, 15 m. The results of slope stability analysis under static and pseudo-static.

TABLE 6
FS OVERALL SLOPE SECTION 1

	Overall Slope				
Single Berm (m)	**Width (m)**	**Height (m)**	**Slope Angle (*)**	**FS Static**	**FS Pseudostatic**
10	296	132	24	1.712	1.517
12	308	128	23	1.842	1.615
15	353	128	19	2.102	1.813

TABLE 7
FS OVERALL SLOPE SECTION 2

	Overall Slope				
Single Berm (m)	**Width (m)**	**Height (m)**	**Slope Angle (*)**	**FS Static**	**FS Pseudostatic**
10	296	136	25	1.608	1.428
12	326	134	22	1.693	1.481
15	376	136	20	1.908	1.646

TABLE 8
FS OVERALL SLOPE AT LOW WALL

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

Based on the results shown in Tables 6, 7 and 8 (Fig. 7,8,9) the value of the safety factor increases directly proportional to the increase in 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. As in section 2 with a 10 m diameter SF value of 1.428 in a pseudo-static slope condition shows a much smaller safety factor compared to 1.5 which is the standard of safety factors that have been set in the pseudo-static condition. Whereas with a 12 m diameter, the SF result in a static condition = 1.693 (Table 4.10), while the SF result in a pseudo-static condition = 1.481 (Table 4.10) 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, the 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.

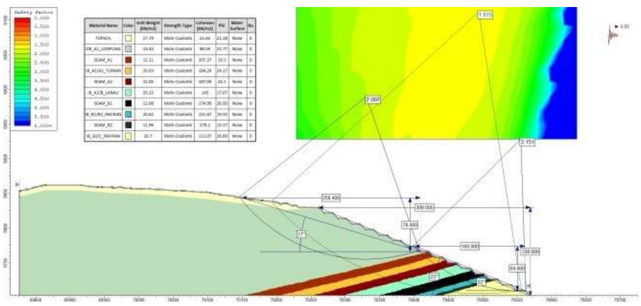

Fig. 7 Pseudo - Static Analysis FS HW Section 1 Berm 12 m

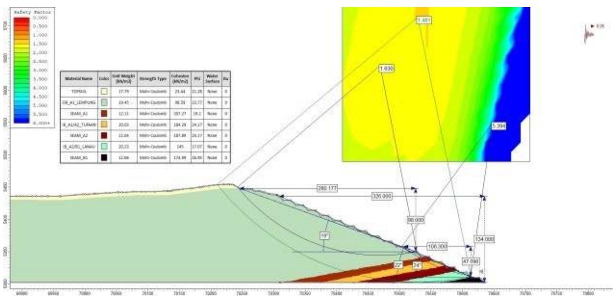

Fig. 8 Pseudo - Static Analysis FS HW Section 2 Berm 12 m

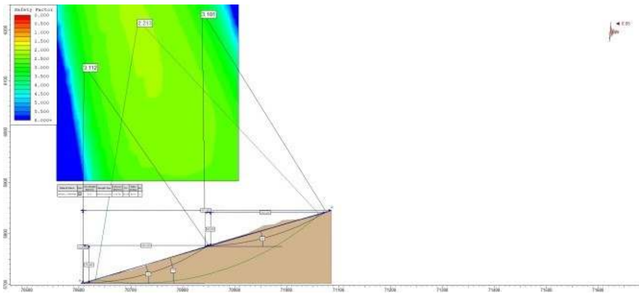

Fig. 9 Pseudo - Static Analysis FS Low wall Section 1 Berm 12 m

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.

The results 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 very small, both in static conditions and in 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. It is also influenced by the forming material. The upper intermediate is formed by the type of sandy siltstone material, while the lower intermediate material is formed from several types of 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, both 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 of 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 amount 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 so that it can 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 9), 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 10). So it can be concluded also 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 that will occur in the next detonation can be predicted in a non-linear regression equation. The equation is obtained from the analysis of the value of the scaled distance and peak vector sum. Based on Table 9 and Table 10, a graph of the relationship between scaled distance and peak vector sum is obtained (Fig. 10). 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), that is, 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 9
SCALE DISTANCE AND PEAK VECTOR SUM (PVS)
ELEKTRIC BLASTING

Distance (m)	Charge/ Delay (kg)	Scaled 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
500	150	70,7106781	4,70	7,49	2,54	7,63
1160	50	164,048773	1,78	1,02	1,4	2,13

TABLE 10
ANALYSIS SCALE DISTANCE AND PEAK
VECTOR SUM (PVS)

Distance (m)	PPV (mm/s)	Charge/ hole (kg)	Scaled 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	247,46
1500	0,473	57,14	198,43
1800	0,262	42,33	276,67
1500	0,609	52,91	206,22

Fig. 10. 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 certain distance (Table 11). So that we get the following equation.

$$PVS = 7282{,}2 \times SD^{-1{,}79} \quad (2)$$

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.

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 11).

TABLE 11
NUMBER OF SAFE USE OF EXPLOSIVES

PVS (mm/s)	Distance (m)	Scaled 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 11, it can be seen that at a distance of 300 m and 400 m 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 is able to fulfill the charge in the blasting plan, as well as 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, it is necessary to plan an area that can be blown up. 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. 11). The ripping area and the blasting area are 246.63 hectares.

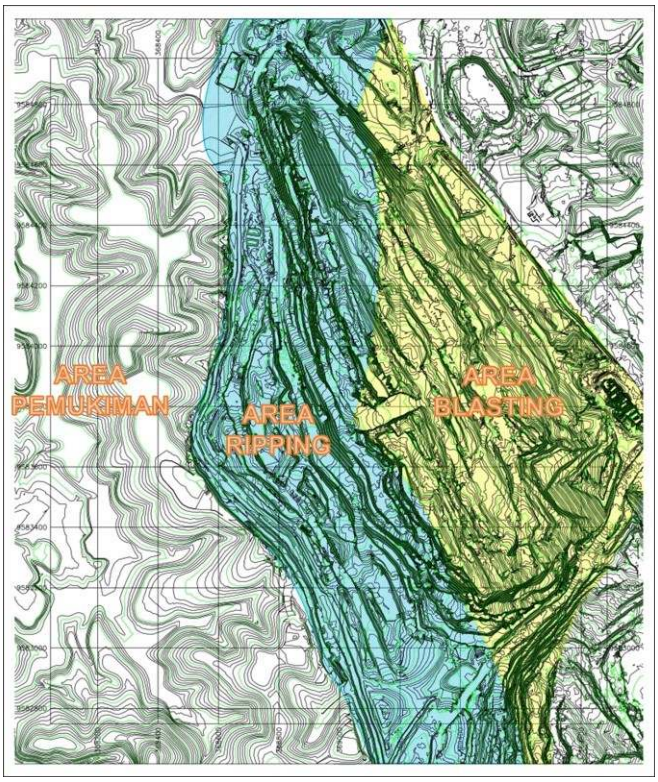

Fig. 11. Ripping - Blasting Overburden Area

The ripping area shows the areas that are blue. The area has a distance from the settlement of less 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. Whereas 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 that blasting activities can be carried out by adjusting the delay when blasting is carried out so that it can minimize ground vibrations which can have a bad impact on 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.

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 analysis of static and pseudo static slope stability 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 striping 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 $\leq$ 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 blast 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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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 Pit 1 North West Banko is carried out in an open pit using a shovel-dump truck system. Overburden consists of top soil 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 Pit 1 North West Banko on the stability of static and pseudostatic 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 amount 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 results of the analysis of the area to be blast 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 Pit 1 North West Banko is strip mining using a shovel-dump truck system. Mining activities include land clearing, stripping and transportation of top soil 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 (0.4-1 MPa). and very low strength rock (2-20 MPa) according to Bienawski [1], [2] so that it cannot be excavated directly by an excavator. To support the excavator's performance, the overburden removal is carried out using the Komatsu D375A-5 ripper. The excavation of overburden on the material that has been dug is not optimal because the specifications of the Komatsu PC 2000 excavator and the Komatsu D375A-5 ripper used are not yet optimal [3]. To increase the productivity of the shovel-dump truck system, it is necessary to carry out blasting activities to deliver the material [4], [5]. The West and Southwest area of the pit limit of the Pit 1 North West Banko coal mine are close to residential areas. In order to increase the efficiency of overburden excavation and overcome ground vibrations due to blasting and to increase slope stability, it is necessary to design blasting geometry, use of explosives, and delay systems [6], [7].

Soil vibrations caused by blasting activities if it has exceeded a certain level can cause disturbance to slope stability and damage to 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 [8]–[13].

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.

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

Conditions Pit 1 North West Banko 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 Pit 1 North West Banko area tends to follow the intrusion zone to form a dome with the intrusion zone as the central point. So that 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 existing pit Pit 1 North West Banko has an area of 120 hectares, extending following the direction of coal strike from north to south with a dip to west. The northern part is bordered by coal cropline boundaries, the eastern part is bordered by settlements, the western part is limited by the andesite intrusion zone, the southern part is the direction of the pit continuity.

The stratigraphy of the Pit 1 North West Banko area was obtained from the correlation of the drill data of PT Bukit Asam Tbk in the Pit 1 North West Banko area. The stratigraphy of Pit 1 North West Banko (Fig. 1) is as follows.

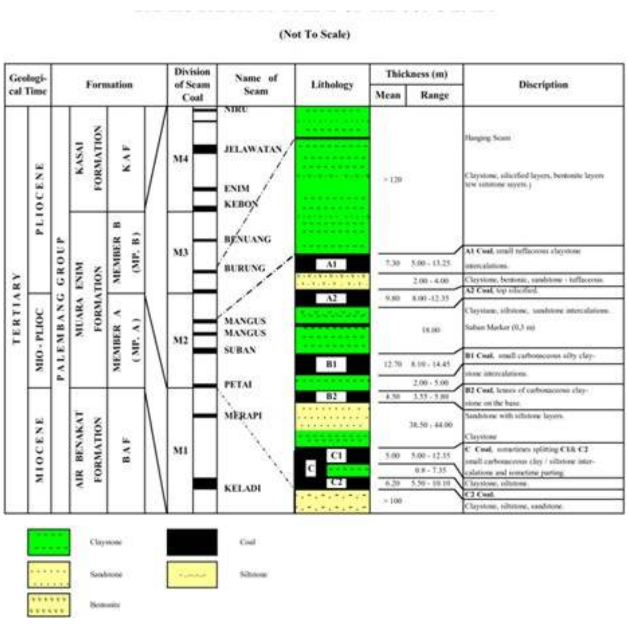

Fig. 1 Stratigraphy Area Pit 1 West Banko

B. Geotechnical Conditions

The layer of material in the Pit 1 North West Banko area is divided into layers of overburden, coal seam, and interburden 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 angle of friction in the water-saturated material. Geotechnical parameter data was obtained (Table I).

TABLE I
GEOTECHNICAL PARAMETER PIT 1 NORTH WEST BANKO

No	Material	D (ton/m^3)		UCS	σ	C	Φ
		In-Situ	Bulk	(Mpa)	(MPa)	(KPa)	(°)
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

C. Hydrogeological Conditions

Groundwater around the Pit 1 North West Banko area is assumed to come from surface infiltration water. Ground water sources were not found in the pit openings. The groundwater flow in the Pit 1 North West Banko area is assumed to only follow the layer of the top soil layer. Top soil types tend to be loose material with a thickness of 1 - 3 m. The next layer has a type of silty claystone material which is more impermeable.

II. MATERIAL AND METHOD

The location of 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 and analysis, as well as conclusions and recomendations.

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 take into account the ground vibration variables due to overburden blasting systems [14]–[16]. In each section, the forces acting in the arc avalanche plane are as illustrated in Fig. 3.

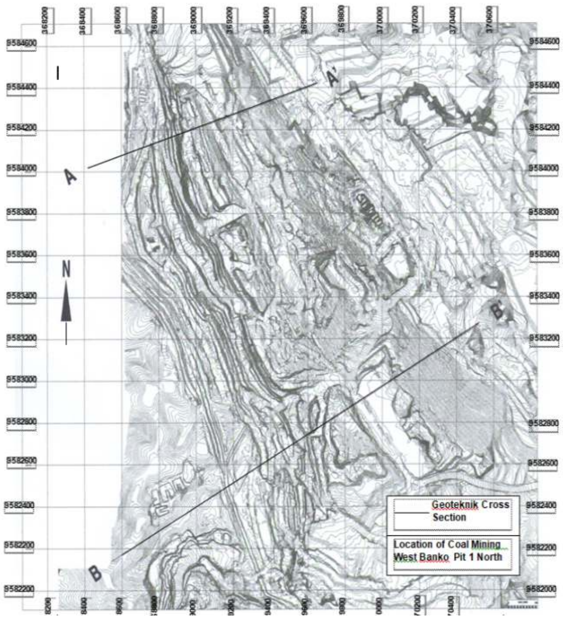

Fig. 2 Location of coal mining West Banko 1 North

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

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

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 blastmate. 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) [17], [18]. The seismic coefficient (Kh) is obtained by the following equation:

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

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

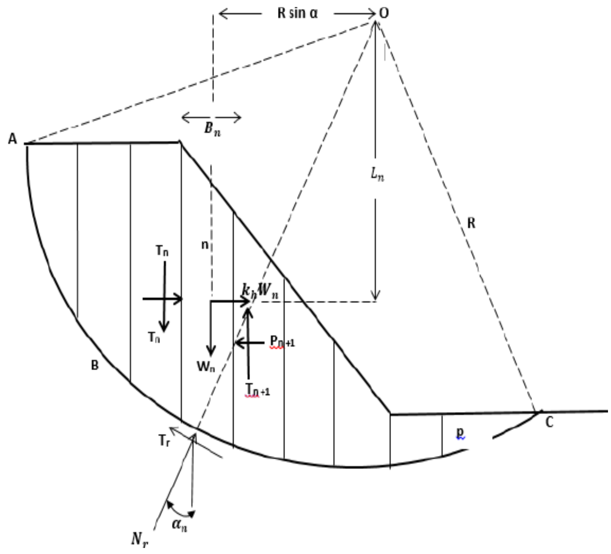

Fig 3. Slope Model With Surface Sliding

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. By inputting data on geological, geotechnical, geohydrological / hydrological conditions, and acceleration of ground vibration, safety factor for mine slopes (single slope, intermediate slope, and overall slope [1]. The results of the pseudo-static slope stability analysis 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 four cross sections which are critical and safe slope conditions. Also discussed how to technically minimize ground vibration from overburden blasting effect.

The conclusions and recomendations are to know 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 (delay system, use of explosives, and application of controlled blasting methods) in order to improve slope stability [9], [19], [20].

Flow chart of research as shown in figure 4.

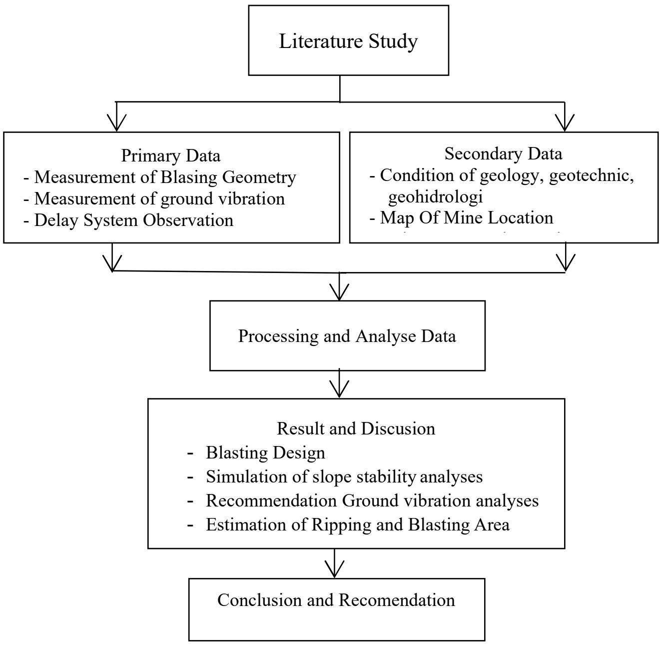

Fig. 4 Flow Chart of Research

III. RESULTS AND DISCUSSION

A. Blasting Activity

The overburden blasting system at Pit 1 North West Banko uses a non-electric detonator (nonel) combined with an initiation system using a poweradet electric detonator which is connected to a blasting machine using 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 0 , 09 Kg / bcm. The blasting geometry used at the Pit 1 North West Banko location is the same as the blasting geometry for West Banko 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 (Fig. 5). If the type of blasting is double deck, it uses a 500 ms inhole 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 x 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 [21].

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 Pit 1 North West Banko. Seismic slope stability analysis can be determined using the pseudo-static method approach.

Potential factors causing mine slope landslides include slope geometric 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 [19], [20], [22], [23]. These parameters must be known in analyzing the stability of the final slope.

The geometry of the slope of the existing Pit 1 North West Banko is still in the process of 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 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 slope follow the parameters of the existing pit with a height of 8 m, single slope angle of 45°, and a height of 8 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 has been determined by the mining boundary (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. 2 and Fig. 5).

Slopes of cross section 1 and 2 are simulated against tiered slopes (overall slope, intermediate slope and single slope) following floor B2. Based on the simulation of each variable, slope geometry, stratigraphic, geotechnical data and hydrogeological data were used to analyze the slope stability of the static method. Overburden material removal activities at the Pit 1 North West Banko 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.

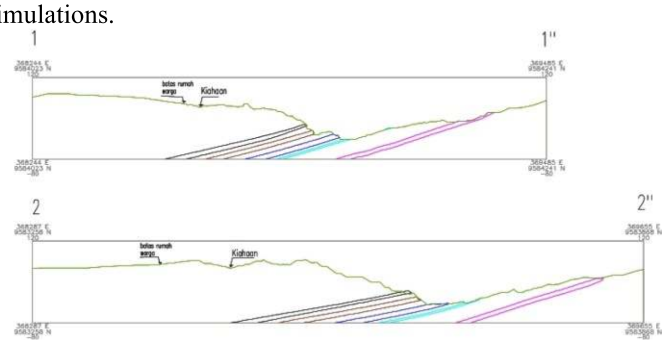

Fig. 5 Section of Geometry Bench Pit 1 West Banko

The seismic acceleration value (Seismic coefficient) of blasting activity at Pit 1 North West Banko is determined by selecting the peak acceleration (g) which has the highest effect. The seismic acceleration data for Pit 1 North West Banko consist of transverse, vertical, and longitudinal accelerations. In the analysis, the transverse and vertical accelerations are assumed to 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 slope stability analysis are the highest ground vibrations, with a longitudinal acceleration of 0.106 g and a PVS of 6.110 mm / s with a distance of 300 m (Table I), 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. Based on the blasting activity plan at the Pit 1 North West Banko, it 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. Approach is done by using the static arc and pseudo static equilibrium limit method.

The analysis stage was carried out by testing 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 m 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 cross section 1 and Low Wall cross section 2. The safety factor (SF) analyses scale was carried out on the overall slope, intermediate slope, and single slope. Slope stability analysis used rocscience slide v 6.0 software with the bishop arc equilibrium limit method.

Slope stability simulation is carried out on modeling with variable berms of 10 m, 12 m, 15 m. The results of slope stability analysis under static and pseudo-static, as shown on Table III.

TABLE III
SECTION FS OVERALL SLOPE 1

Overall Slope					
Single Berm (m)	Width (m)	Height (m)	Slope Angle (^{0})	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 (^{0})	FS Static	FS Pseudostatic
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 (^{o})	FS Static	FS Pseudostatic
Lowwall 1	484	143	17	2.585	2.213
Lowwall 2	425	132	17	2.631	2.247

Based on the results shown in Tables III-V and Fig. 6 the value of the safety factor increases directly proportional to the increase in berm, either in static or pseudo- static conditions. In addition, it can be observed that in sections with the same , there is a decrease in the safety factor (SF) between the slopes with static and pseudo- static conditions. As in cross section 2 on a berm 10 m SF value of 1.428 (Table IV) in a pseudo-static slope condition shows a much smaller safety factor compared to 1.5 which is the standard of safety factors that have been set in the pseudo- static condition. Whereas with a 12 m diameter, the SF result in a static condition = 1.693 (Table IV), while the SF result in a pseudo-static condition = 1.481 (Table IV) 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, the optimal safety factor is on a berm of 12 m which is closest to the SF of 1.5. Therefore, the optimal slope modeling is used based on safety factor both in static conditions and in pseudo static conditions, namely by using a berm of 12 m.

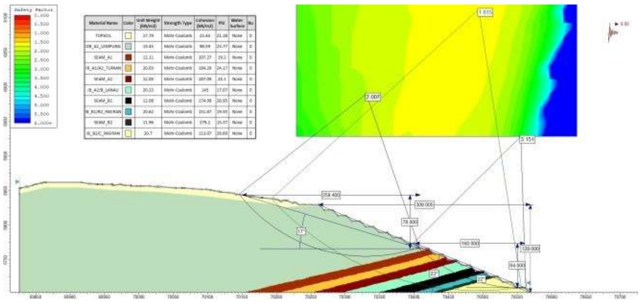

Fig. 6 Pseudo - Static Analysis FS HW Section 1 Berm 12 m

Unstability slope also has the potential on 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 slope of the final slopes is divided into two, the upper intermediate and the lower intermediate.

The results 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 very small, both in static conditions and in 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. It is also influenced by the forming material. The upper intermediate is formed by the type of sandy siltstone material, while the lower intermediate material is formed from several types of 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, both 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 of 12 m, it will be safe to do blasting without worrying about the impact of the disturbance on the slope stability of the Pit 1 NorthWest Banko .

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 amount 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 so that it can 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 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. So it can be concluded also 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 that will occur in the next detonation can be predicted in a non-linear regression equation. The equation is obtained from the analysis of the value of the scaled distance and peak vector sum. Based on a graph of the relationship between scaled distance and peak vector sum is obtained. 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), that is, 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) ELEKTRIC 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

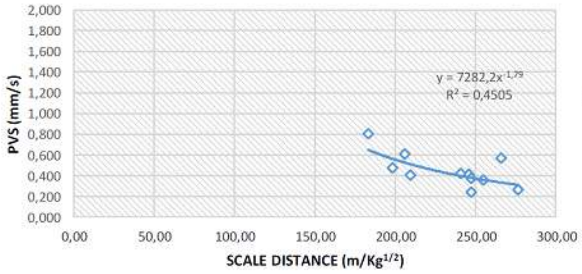

Fig. 7 Relationship Peak Vector Sum and Scaled Distance

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 certain distance. So that we get the following equation.

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

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.

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 400 m 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 is able to fulfill the charge in the blasting plan, as well as the vibrations generated by the safe blasting effect on the surrounding settlements, namely 3.5 mm / s With these provisions, at Pit 1 North West Banko 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, it is necessary to plan an area that can be blown up. 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 Pit 1 North West Banko 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. 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 less 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. Whereas 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 that blasting activities can be carried out by adjusting the delay when blasting is carried out so that it can minimize ground vibrations which can have a bad impact on 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.

IV. CONCLUSION

The Blasting Design will apply the blasting technique applied to the Pit 1 North West Banko 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 analysis of static and pseudo static slope stability 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 striping 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 cross 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 $\leq$ 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 blast 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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