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The Wave Effect Analysis Caused By Blasting Toward Highwall Slope Stability At Coal Mining, Pit 3000 Block 05 Sb 1, PT Trubaindo Coal Mining, Kutai Western District, East Kalimantan Province

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Abstract

PT Trubaindo Coal Mining (PT TCM) is a coal mining company located in West Kutai, East Kalimantan. Demolition of overburden layer is done by drilling and blasting can effect results primarily blasting ground vibration for highwall slope stability. Controlled blasting activities undertaken in 3000 Pit Block 05 using linedrill. Vibration measurement data obtained from the reading apparatus is not necessarily a factor affecting vibration highwall slope stability, but with the direction of propagation horizontal vibrations that cause the decrease highwall slope stability. The maximum horizontal acceleration arising from blasting activities as parameters that play a role in the stability of the slope obtained by linking the PPA with the equation Amax = 0.5167 x PPA. Therefore, to determine the effect of ground vibration due to blasting for highwall slope stability modeling needs to be done cross-section A-A ', B-B', C-C ', D-D' and E-E '. Results of prediction equations safety factor value of each cross-section as follows:

- *Section of A-A', FK =* $5,1489\, a_{max}{}^{6} – 32,719\, a_{max}{}^{5} + 79,933\, a_{max}{}^{4} – 93,928\, a_{max}{}^{3} + 54,189\, a_{max}{}^{2} – 13,898\, a_{max} + 1,30852$
- *Section of B-B', FK =* $0,4838\, a_{max}{}^{6} – 3,0058\, a_{max}{}^{5} + 7,0149\, a_{max}{}^{4} – 7,6767\, a_{max}{}^{3} + 4,4953\, a_{max}{}^{2} – 2,4997\, a_{max} + 1,44549$
- *Section of C-C', FK =* $1,2021\, a_{max}{}^{6} – 7,4203\, a_{max}{}^{5} + 16,907\, a_{max}{}^{4} – 17,239\, a_{max}{}^{3} + 8,0429\, a_{max}{}^{2} – 2,8212\, a_{max} + 1,3628$
- *Section of D-D', FK =* $5,279a\, a_{max}{}^{6} – 33,941\, a_{max}{}^{5} + 84,105\, a_{max}{}^{4} – 100,68\, a_{max}{}^{3} + 59,648\, a_{max}{}^{2} – 15,946\, a_{max} + 1,57907$
- *Section of E-E', FK =* $-1,9442\, a_{max}{}^{6} + 11,453\, a_{max}{}^{5} – 24,289\, a_{max}{}^{4} + 20,677\, a_{max}{}^{3} – 2,7313\, a_{max}{}^{2} – 4,8741\, a_{max} + 1,65573$

The calculation results of critical maximum horizontal acceleration for every cross-section varies as the follows:

- *Section of A-A',* a_{max}*-critical = 0,007 g*
- *Section of B-B',* a_{max}*-critical = 0,118 g*
- *Section of C-C',* a_{max}*-critical = 0,062 g*
- *Section of D-D',* a_{max}*-critical = 0,025 g*
- *Section of E-E',* a_{max}*-critical = 0,09 g*

Variation is influenced by the thickness of the layer of top soil (top soil) and any cross-sectional geometry highwall slope.

Keywords: Blasting, Ground Vibration, Peak Particle Velocity (PPV), Peak Particle Acceleration (PPA), Horizontal Maximum Acceleration (a_{max}*)*

1. Preleminary

PT. Trubaindo Coal Mining (PT. TCM) is a private company engaged in coal mining. Mining system applied by PT. TCM is a system of open-pit mining (surface mining). Overburden demolition activities in PT. TCM is done today is with drilling and blasting. Such activities may cause effects such as stone fly (flying rock), the sound of explosions (air blast), and in particular the vibration ground (ground vibration). The impact of ground vibrations emerging from the blasting activities also affect the stability of the walls of highwall that could potentially lead to the occurrence of avalanches due to horizontal acceleration that appears mainly to Pit 3000 Block 05 which every day perform blasting activities.

This research was conducted by analyzing the factors that influence the magnitude of ground vibrations due to blasting of the highwall slope

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stability is like blasting geometry, the nature of the explosives used and the distance to the vibration monitoring sites. This study is thus expected to generate design blasting geometry which suitable in Pit 3000 Block 05 with a max which secure against highwall slope stability.

The Observation Aims

1. Determine the factors that influence the results of blasting ground vibration for highwall slope stability.
2. Determining the value equation of PPV, PPA, $a_{max}$and appropriate FK in Pit 3000 Block 05 SB 1 PT. TCM.
3. Determine the value limit of a_{max}that affect the value of the safety factor for highwall slope.

Scope of Problem

1. Approach PPA prediction using method of determining a scaled distance on the longitudinal wave.
2. Fragmentation is a concern in the design geometry blasting of PT. TCM.
3. Do not give recommendations slope geometry.
4. The safety factor equation for value prediction is derived from the design of the final pit in 2014.

The Observation Benefits

1. The results of this study are expected to be used as research material for comparative studies related to ground vibrations due to blasting of the highwall slope stability.
2. To be the basis for determining the company's policy in preparing planning design of blasting geometry and geometry of the slopes.

2. Observation

The Research Location

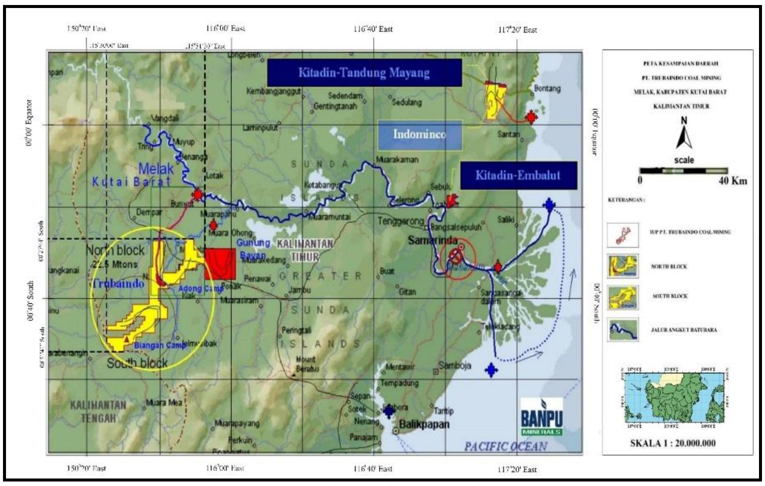
PT. TCM managing coal mining region by permission PKP2B (Perjanjian Kerjasama Pengusahaan Pertambangan Batubara/in english: Coal Cooperation Agreement) with a total area of 23,650 hectares is now divided into North Block and South Block. PT. TCM is astronomically located at position $115^0$30'00 "BT – $115^0$51'30" BT and $0^0$27'44 "LS – $0^0$51'41" LS includes Muara Lawa, Muara Pahu, District of Peace, District and Sub-District Bentian Great Melak, Kutai Barat - East Kalimantan (see Picture 1).

Coal mining location in PT. TCM can be reached through three channels, namely:

1. Air Strip, using aircraft from Yogyakarta route Yogyakarta - Balikpapan - Melak. Air line from Balikpapan - Melak can be reached within 30 minutes,
2. Strip land, from Samarinda at a distance of 300 km are reached within approximately 7 hours. The condition of the road is paved up to Kota Bangun, then through the streets of hardening up to the location of the mining activities of PT. TCM,
3. Transport water, is through the Mahakam river takes about 14 hours by boat river.

Geology and Stratigraphy

The main structure in the concession area of PT. TCM is dominated by folds associated with the main shear fault. Two major syncline separating coal carrier formation into two main areas, namely North Block and South Block. The main geological structures in the project area Trubaindo is syncline in the eastern part of the ocean known as the Cold syncline. The main carrier of coal formation on the top of the formation Pamaluan formed around the syncline axis. All parts of southeast syncline Cold is to be cut by a pair of major normal fault which limits Jembungan Anticline.



Picture 1. The Observation Map

3. The Result Of Observation

Measuring Ground Vibration

Ground vibration measurements performed by Instantel Blastmate III. Instantel Blastmate Instantel III is a product of Canada. This tool has three channels consisting of first channel is channel vibration recorder (geophones) are generated from the detonation of three components of the rock movement in the transverse direction, vertical and longitudinal. The second channel is the channel used to record water blast (microphone) generated during the blasting process, a third channel is a channel to connect the device to a computer or laptop (output recording data either from the vibrations and the results sound of an explosion) then the data is included in Blastware software.

Data Processing

Blasting Data

The data processing of the results of ground vibration measurements performed on Microsoft Excel software. The data used for this study is the measurement data of ground vibration at 3000 Pit Block 05 SB 1 with a total data 32 field measurement data. The data is then analyzed using non-linear regression models of geometric (power) to obtain formula of relationship between the peak particle velocity (PPV), peak particle acceleration (PPA) with the scaled distance (SD). Linear regression for a maximum horizontal acceleration **(**a_{max})with PPA and regression polynomial for correlation value of safety factor with the maximum horizontal acceleration **(**a_{max}).

Geotechnical Data

Manufacture of modeling a cross section A-A ', B-B', C-C ', D-D' and E-E 'which is based on differences in Pit slope design gemoetri 3000 Block 05. From the modeling analyzed every cross-section with safety factor use software version 5.0 slide.

4. Discussion

Prediction Equations of Vibration Monitoring Land Result

Of the 32 monitoring data obtained blasting prediction equation to determine the relationship of the ground shaking following highwall slope stability

1. Prediction of the equation PPV. Of the 32 vibration monitoring data obtained PPV formulation with SD method using non-linear regression analysis of power in Pit 3000 Block 05 and the formulation of the PPV = $90{,}896(SD)^{-0896}$
2. Prediction equations of PPA. Approach to get a prediction of PPA longitudinal wave with an SD of 32 Data obtained formulation PPA =$0{,}4835(SD)^{-768}$.

The Relationship between the value of Slope Safety Factor witha_{max}

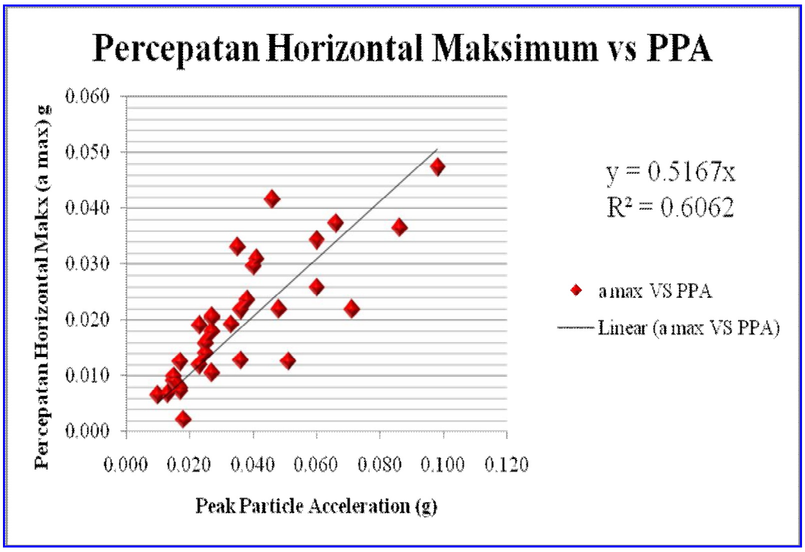
Pit sectional modeling in 3000 Block 05 is done 5 times a modeling analysis because there are differences in slope geometry and thickness of the layer of top soil that makes the relationshipapproach with a_{max} safety factor value varies with equations in Table 1.

Table 1.The relationship between the value of the safety factora_{max}

No.	Sectional	The relationship equation of a max with Factor Security
1	A-A'	$FK= 5.1489(a_{max})^6 - 32.719(a_{max})^5 + 79.933(a_{max})^4 - 93.928(a_{max})^3 + 54.189(a_{max})^2 - 13.898(a_{max}) + 1.30874$
2	B-B'	$FK = 0.4838(a_{max})^6 - 3.0058(a_{max})^5 + 7.0149(a_{max})^4 - 7.6767(a_{max})^3 + 4.4953(a_{max})^2 - 2.4997(a_{max}) + 1.44549$
3	C-C'	$FK = 1.2021(a_{max})^6 - 7.4203(a_{max})^5 + 16.907(a_{max})^4 - 17.239(a_{max})^3 + 8.0429(a_{max})^2 - 2.8212(a_{max}) + 1.3628$
4	D-D'	$FK = 5.279(a_{max})^6 - 33.941(a_{max})^5 + 84.105(a_{max})^4 - 100.68(a_{max})^3 + 59.648(a_{max})^2 - 15.946(a_{max}) + 1.57907$
5	E-E'	$FK = -1.9442(a_{max})^6 + 11.453(a_{max})^5 - 24.289(a_{max})^4 + 20.677(a_{max})^3 - 2.7313(a_{max})^2 - 4.8741(a_{max}) + 1.65573$

The Relationship of$a_{max}$with PPA

Equation of calculation coefficient a_{max} as a result blasting ground vibration affecting slope stability which obtained from the analysis coefficient of the relation of $a_{max}$with PPA (Wong, 1992) using linear regression.a_{max} = 0,5167xPPA equation. See Picture 1.



Picture 2.The Relationship of$a_{max}$with PPA

The Relationship of Distance and Explosives Actual Stuffingwith B-B' Highwall Slope

Equation formula that has been obtained is used to analyze the influence of blasting activities in Pit 3000 Block 05 slope stability with studies B-B '. Results of the effect of ground vibration blasting activity of the highwall slope stability can be seen in Table 2.

Table 2. Recapitulation ofa_{max}on B-B' sectional

No.	Date of Observation	Location	Distance (m)	IsianBahan Peledak/17 ms	Prediksi			
					PPV (mm/s)	PPA (g)	a max (g)	FK
1	Mei6th 2015	Interburden East	567	628,08	5,557	0,044	0,023	1,389
2	15 Mei 2015	Interburden	87	104,68	13,355	0,093	0,050	1,331
3	19 Mei 2015	Expose Seam 3000	115	314,04	17,014	0,115	0,061	1,308
4	22 Mei 2015	Interburden West	391	209,36	4,739	0,038	0,020	1,396
5	27 Mei 2015	Expose Seam 3000 East	711	209,36	2,774	0,024	0,013	1,414
6	29 Mei 2015	Extend 3000 West	247	209,36	7,152	0,055	0,029	1,376
7	1 Juni 2015	Extend 3000 East	889	314,06	2,723	0,024	0,013	1,414
8	2 Juni 2015	Expose Seam 3000 West	223	104,68	5,746	0,045	0,024	1,388
9	4 Juni 2015	Bench Blasting	9,5	209,36	132,515	0,668	0,345	0,888

Comparison of Standard Calculation a_{max} between Seed (1972), Wong (1992), and the CDMG (1997) against Score Predicition of Factor Security

Election prediction calculation a_{max} value is determined based on conditions on the ground so that the approach according to Wong further demonstrate the results of the effect of vibration on the stability of highwall slopes in the pit 3000 Block 05 SB 1 PT. TCM because the coefficients are determined to predict the value of a_{max} is based on the actual analysis coefficients in the field. See Table 3.

Table 3. Recapitulation ofa_{max}towardSafety Factor Value

No.	Tanggal Pengamatan	Lokasi	Jarak (m)	Isian Bahan Peledak / 17 ms (kg)	Prediksi									
					PPV USBM (mm/s)	PPA Wong (g)	PPA CDMG (g)	PPA Seed (g)	a max Wong (g)	a max CDMG (g)	a max Seed (g)	FK Wong	FK CDMG	FK Seed
1	6 Mei 2015	Interburden East	567	628,08	5,557	0,044	0,036	0,036	0,023	0,018	0,007	1,391	1,402	1,428
2	15 Mei 2015	Interburden	87	104,68	13,355	0,093	0,068	0,068	0,048	0,034	0,014	1,334	1,366	1,412
3	19 Mei 2015	Expose Seam 3000	115	314,04	17,014	0,115	0,120	0,120	0,059	0,060	0,024	1,311	1,310	1,388
4	22 Mei 2015	Interburden West	391	209,36	4,739	0,038	0,018	0,018	0,020	0,009	0,004	1,398	1,423	1,436
5	27 Mei 2015	Expose Seam 3000 East	711	209,36	2,774	0,024	0,021	0,021	0,013	0,011	0,004	1,415	1,419	1,435
6	29 Mei 2015	Extend 3000 West	247	209,36	7,152	0,055	0,050	0,050	0,028	0,025	0,010	1,378	1,385	1,421
7	1 Juni 2015	Extend 3000 East	889	314,06	2,723	0,024	0,026	0,026	0,012	0,013	0,005	1,415	1,414	1,433
8	2 Juni 2015	Expose Seam 3000 West	223	104,68	5,746	0,045	0,016	0,016	0,023	0,008	0,003	1,389	1,426	1,438
9	4 Juni 2015	Bench Blasting	9,5	209,36	132,515	0,668	0,697	0,697	0,345	0,348	0,139	0,888	0,885	1,166

The value ofa_{max}-criticalevery Highwall Slope Sectional Modeling Pit 3000 Block 05

Slope geometry difference produces different a_{max} value for each modeling a cross section in Pit 3000 Block 05. From the results of the predictive value of the safety factor can be concluded that optimal slope geometry on the geometry of highwall slopes B-B' caused by a_{max}-biggest critical. Can be seen in Table 4.

Table 4. Recapitulation ofa_{max}-criticaleverysectional modeling

No.	Operasi Peledakan	Penampang									
		A-A'		B-B'		C-C'		D-D'		E-E'	
		a max-pemantauan	a max-kritis	a max-pemantauan	a max-kritis	a max-pemantaua	a max-kritis	a max-pemantauan	a max-kritis	a max-pemantauan	a max-kritis
1	6 Mei 2015	0,023	**0,0070**	0,023	**0,1180**	0,023	**0,0620**	0,023	**0,0250**	0,023	**0,0900**
2	15 Mei 2015	0,048		0,048		0,048		0,048		0,048	
3	19 Mei 2015	0,059		0,059		0,059		0,059		0,059	
4	22 Mei 2015	0,020		0,020		0,020		0,020		0,020	
5	27 Mei 2015	0,013		0,013		0,013		0,013		0,013	
6	29 Mei 2015	0,028		0,028		0,028		0,028		0,028	
7	1 Juni 2015	0,012		0,012		0,012		0,012		0,012	
8	2 Juni 2015	0,023		0,023		0,023		0,023		0,023	
9	4 Juni 2015	0,345		0,345		0,345		0,345		0,345	

Comparison of Distance and Field Hole Blasting Explosive End Actual Study and Recommendations to the classification of land as a result of Blasting Vibration on the Slope Stability

Controlled blasting for blasting levels using line hole drill conducted at PT. TCM particularly in Pit 3000 Block 05 have not in accordance to the theoretical. Especially in the field of explosive end of the pit area the greatest influence on the value of a_{max} that can affect the stability of the highwall slopes. Recommendations and their predictive value a_{max} can be seen in Table 5.

Table 5. Recapitulation ofthe effect of ground vibration blasting results

No.	Keterangan	Parameter				PPV (mm/s)	a max (g)	Klasifikasi			
		Burden Linedrill (m)	Burden Lubang Ledak (m)	*Powder Charge* (m)	Isian Bahan Peledak (kg)			Dyno Nobel	Langefors, Westerberg dan Kihlstron (1958)	Call and Nicholas	Index a max
1	Aktual	4	9,5	4,3	209,36	132,515	0,358	Kerusakan Ringan	Retakan Sedang	Sedikit Kerusakan	Mengganggu Kestabilan
2	Rekomendasi	4	12	2	54,294	68,63	0,161	Ambang Kerusakan	Tidak Ada Kerusakan	Sedikit Kerusakan	Mengganggu Kestabilan

5. Discussion Conclusion And Suggestion

Conclusion

1. Based on the calculations predicted a a_{max} received slope of blasting levels at 0358 g classified destabilize the slopes with a value of Safety Factor into 0873, it is influenced by several factors such as the reduction hole spacing explosive end to toe level of influence in the form of a narrowing burden holes linedrill 9 m to 4 m and the width of the formation of the design level of 5 m to 4 m, and 2 locations overburden blasting operations carried out at the same time.
2. Application of controlled blasting using drill hole line drill have not in accordance, especially in the field of stuffing explosives of final explosive hole.
3. The equation to determine the maximum horizontal acceleration in Pit 3000 Block 05 PT. TCM is a a_{max} = 0.5167 x PPA.
4. Differences slope geometry will affect the great value of a a_{max}-critical of modeling cross section made in Pit 3000 Block 05 can be seen as follows :
   a. Sectional of A-A' a_{max}-critical = 0,007 g
   b. Sectional of B-B' a_{max}-critical = 0,118 g
   c. Sectional of C-C' a_{max}-critical = 0,062 g
   d. Sectional of D-D' a_{max}-critical = 0,025 g
   e. Sectional of E-E' a_{max}-critical = 0,09 g

Suggestions

1. Improvements to the formation width of the level become 5 m in accordance with the design, increasing the distance burden linedrill hole 9 m from toe levels of influence, reducing field by 50% for final explosive hole , and change in hole delay becomes 2 differences between location 1 to location 2 of 400 ms to 500 ms (in accordance to blasting accessories provided by PT.TCM) which aims to avoid two or more holes exploded simultaneously in the same delay so it can produce a reduction in the value of a prediction of actual a_{max} 0.358

g to 0.161 g with Safety Factor value = 0.873 into 1,131.

2. From the research, the optimal highwall slopes geometry in Pit 3000 Block 05 on modeling a cross section of B-B' 'caused by being able to accept a biggest *a* $_{max}$-critical compared to other cross-sectional modeling..
3. Calculation and recommendation of *a* $_{max}$ value have not calculated the value of reduction at the ground vibration result from blasting operations with the using of linedrill hole that conducted by company as the blasting controller so recommendation must be analyzed further more in field application.

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