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Application of Response Surface Methodology in Optimization of used Engine Oil for Burden Blasting and its Environmental Impact: A Case Study at the Sangatta Site of PT Kaltim Prima Coal

Revia Oktaviani[1]
[1]Mining Engineering of Mulawarman University Samarinda, Indonesia

Krishna Purnawan Candra[2]
[2]Magister Study Program of Mulawarman University, Samarinda, Indonesia

Asrul[3]
[3]PT. Kaltim Prima Coal Sangatta, Indonesia

Abstract:- PT. Kaltim Prima Coal Sangatta is a coal mining company that uses heavy equipment in Overburden removal activity. Heavy types of equipment use oil engines as engine lubricating fluid which is limited by its usage time, when the engine oil's useful life has been reached, the engine oil is drained and some of it is used as a mixture for explosives, a substitute for diesel fuel.

This study will analyze historical data on the impact of blasting activities using used engine oil from heavy equipment, on operations and the environment using Response Surface Methodology, in the form of Ground Vibration.

The result of historical data analysis that has been carried out using Response Surface Methodology, to obtain Ground vibration values that do not exceed 3,0 mm/sec, by maximizing the weight of explosive material by 907.46 Kilogram, then the percentage of explosives using used engine oil as a mixture of explosives is 43,98 %.

***Keywords**:- Used engine oil, Response Surface Methodology, Ground Vibration.*

I. INTRODUCTION

PT. Kaltim Prima Coal (KPC) is a company engaged in the mining and marketing of coal for industrial customers for both the export and domestic markets, located in Sangatta, East Kalimantan, Indonesia. This company applies the mining method using Open Pit Mining and manages a mining concession area with an area of 84,938 hectares. Supported by more than 4,199 employees and 21,000 personnel from contractors and related companies, KPC's coal production capacity reaches 70 million tons per year (PT. Kaltim Prima Coal, 2020).

One of the phenomena that are quite important and interesting to conduct more detailed research on is the practice of hazardous and toxic material waste management at this company, namely the use of used engine oil by mechanical equipment, which is also hazardous and toxic material waste, to be reused as a mixture for explosive. Efforts to utilize used engine oil from mining equipment that has reached its lifetime are of the 4R (Reduce, Reuse, Recycle, and Recovery) efforts.

This effort has been carried out in stages since 2010, the company's efforts have also become one of the assessment criteria for obtaining a Gold Proper Ranking in the 2020 Company Performance Rating Program in Environmental Management from the Ministry of Environment and Forestry (PT. Kaltim Prima Coal, 2020).

Fig. 1: Blasting Process in the open Pit Area

Blasting activity is still the cheapest way to destroy rock. The desired blasting results can only be obtained when the rock properties are properly known. Therefore, rock mass characteristics for each area are very important, to optimize the results of blasting activities. The character of the rock mass can also help in terms of selecting and using optimal explosives to increase the overall value of the project (Mohamed et al., 2015).

Blasting is considered an integrated component by the mining industry for successful mining operations. Taking into account the potential hazards that exist, explosives are needed in breaking or destroying hard material/rocks. The main objective of the excavation process is to remove rock material, either to bore a hole or to recover material of intrinsic value. To remove some parts of the rock mass, fracture induction and rock fragmentation are required. Rock fragmentation is very important for mining activities because this stage is the initial stage in the extraction process (John Wolstenholme CEng FIStrutE MICE, 2015).

Blasting activities have some negative impacts that can damage the surrounding environment and can even cause casualties, if not properly planned and controlled, including:

- Ground vibration
- Air blast
- Flying rocks
- Toxic fumes

In this paper, the author will focus on the analysis of ground vibration caused by blasting activities carried out at PT. Kaltim Prima Coal Sangatta.

Ground vibrations are waves that move in the ground caused by the presence of an energy source (Seismic Waves). The energy source can come from nature such as earthquakes or human activities, for example, blasting activities. Study of ground vibration reduction in coal mine overburden blasting at PT. Artamulia Tata Pratama Tanjung Belit Site, Jambi Province, which is located in materials in the form of Claystone with UCS test values above 20 MPa, and requires blasting activities to disperse these materials. Using an average of 20 Kilogram of explosives, it produces a vibration of 2,98 mm/sec, exceeding the threshold planned and agreed with the local government together with the surrounding community at a maximum of 1.4 mm/sec, whereas according to the Indonesian National Standard No. 7571 of 2010, the maximum permissible value of blasting vibration is 3.0 mm/sec, based on the condition of the buildings around the blasting location (Ridho Permana & Heriyadi, 2018).

In Table 1, a standard table of blasting vibration levels in open pit mines against buildings is presented according to the Indonesian National Standard Number 7571 of 2010, as follows:

Class	Building Type	Peak Vector Sum (mm/second)
1	Ancient buildings protected by the Law on Cultural Heritage Objects (Law No. 6 of 1992)	2
2	Buildings with foundations, masonry, and mortar only, including buildings with wooden foundations and floors covered with cement mortar	3
3	Building with foundation, masonry, and cement mortar tied to a concrete slope	5
4	Building with foundation, masonry, and concrete slope cement mortar, columns, and frames are tied with ring balk	7 - 20
5	Building with foundation, masonry, and mortar, concrete slope, column, and tied with steel frame	12 - 40

Table 1: Standard Level of Detonation Vibration in Open Mining Activities Against Buildings (SNI 7571: 2010)

Source: Indonesian National Standards Agency 2010.

The law of the charge weight scale predicts that the peak vibration of the explosion will always be directly proportional to the weight of the explosive charge. However, this estimate is inconsistent with an analytical model of the vibration of a blast hole in an infinite viscoelastic medium.

These models show that for a fixed diameter blast hole, there are near field and far field areas in the volume where the peak vibration is independent of the weight of the charge, provided the length of the explosive charge column is greater than + 0.25 times the blast hole diameter. For smaller lengths of explosive charge columns, the vibrations are close to zero as the charge lengths are close to zero, which is logical to be expected. The peak vibration of the detonation measured on the surface is highly dependent on the weight of the explosive loaded in the blast hole (Blair, 2014).

The conclusion from a study conducted in Manggis Village, Kelumpang Hulu District, is that the safe distance for blasting from ground vibrations is 1,037.84 meters from the point of explosion or the location of an active pit using safe blasting and air blasts for convenience. The environment is at a distance of 900 m from the point of explosion with an average depth of 15 m in the drill hole and an average explosive charge of 40,000 kilograms (Hidayat et al., 2014)

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Fig. 2: Blastmate III For Measuring

Ground Vibration Blasting

Other research was also conducted at PT. Bukit Asam (Persero), Tbk is a coal mining company whose mining area is located in Tanjung Enim, South Sumatra. The mining system applied is an open pit. With the help of PT. PAMA Persada Nusantara, this company dismantled the B2C inter burden rock of the Air Laya Mine Pit using the blasting method. Rock blasting causes ground vibrations which if it exceeds the safe limit of 5 mm/second at a distance of 500 meters causes damage to the surrounding benches and cracks in office buildings. With an actual blasting geometry of a 6-meter burden, spacing of 7 meters, and an average depth of 7.8 meters, vibration measurements were carried out using the Blastmate III tool 28 times. Measurement is divided into three stages. The first stage is measured without changes. The second stage was measured after reducing the explosive charge to 70 kilograms per hole. The third stage is after setting the delay time with the echelon cut and split patterns so that the final result is an average vibration of 3.4 mm/second at a distance of 500 meters. The success of blasting is very dependent on the accuracy of the implementation in the field and also several important factors including measuring distance, loading of explosives per delay with an ideal filling of 70 kilograms per hole, and proper delay settings using an echelon cut pattern. Coupled with the utilization of the pre-splitting method to protect the bench from vibration exposure.

Measurements must be taken periodically using Blastmate III and evaluated. Thus, it is hoped that the company's demand for a vibration of 5 mm/second at a distance of 500 meters can be achieved (Maryura et al., 2013).

II. RESEARCH METHODOLOGY

This study uses a quantitative research method, by analyzing historical data on several blasting activities that have been carried out from 2010 to 2021, using the Response Surface Methodology (RSM).

PT. Kaltim Prima Coal is located in Sangatta City, East Kutai Regency, East Kalimantan Province, which is at coordinates latitude 1^{0}52’39” North Latitude, 0^{0}20’10” South Latitude and longitude coordinates 118^{0}58’19” East Longitude, 115^{0}56’26”. Annual rainfall is between 2,000 mm - 3,000 mm, and a large number of tropical rainforest areas result in more dominant rainy days.

PT. Kaltim Prima Coal is the largest coal mining company in Indonesia, under the auspices of Bumi Resources, Tbk, which has an area of 84,938 Ha and is located in Sangatta, Bengalon, and Rantau Pulung, East Kalimantan, Indonesia.

The time of research, starting in early September 2021 until February 2022, with plans to collect data, observe directly in the field and analyze historical data for the past 10 years (From 2011 to 2021).

Data collected for analysis, related to the impact of blasting activities using used engine oil on the environment are data from ground vibration measurements and air blasts, which were measured within a radius of 300 to 1,400 meters from the blasting site, taken from April 2011 to June 2021, a total of 270 data.

Fig. 3: Aerial Photo of The Research Location On December 28, 2021

The data analyzed using the Response Surface Methodology (RSM), are historical ground vibration data, these data are inputted into the Software Design Expert Version 11 worksheet, then the results of the analysis are obtained through several stages, including Analysis of variances, Diagnostic, Model Graphs, then the optimization step is carried out by entering the criteria to be achieved, to get several recommendations and solutions as well as a graphical image of the optimized response surface.

III. RESULT AND DISCUSSION

Ground vibration historical data taken as samples in this study were taken before using used engine oil in early 2011 until the use of used engine oil was 90.96 % at the end of November 2021, with a total of 270 data.

This measurement data was taken from the nearest safe radius of about 300 meters and the farthest measurement distance of about 1,383 meters from the blasting location.

The actual ground vibration data is a record of data that before blasting activities have been simulated with controlled blasting engineering so that the maximum ground vibration to be achieved is 3.00 mm/second.

From historical data records of blasting activities using diesel fuel as a mixture of explosives, there are 38 data taken from April 9th, 2011 to the end of 2013, with an average ground vibration of 7.02 mm/second, exceeding the maximum limit set by the company at 3.0 mm/second, but none of them exceeded the threshold value set by the government of 10.0 mm/second.

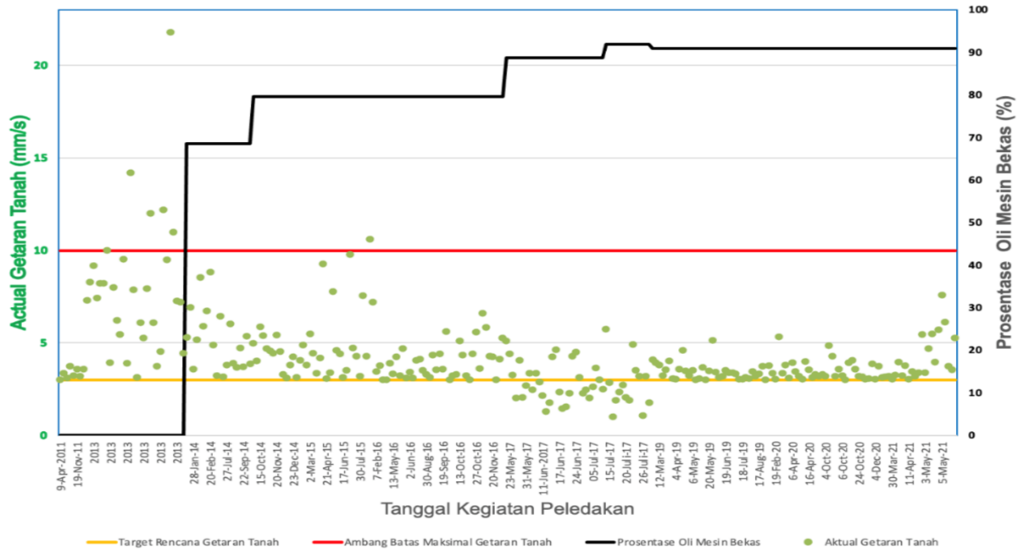

Fig. 4: Effect Of Used Engine Oil Content On Ground Vibrations Due To Blasting Activities

From historical data records of blasting activities using 68.51 % used engine oil and 31.49 % diesel fuel, as a mixture of explosives, recorded from January 24th, 2014 to September 2014, there are 20 data with an average ground vibration of 5.19 mm/second, exceeding the maximum limit set by the company of 3.0 mm/second, but not exceeding the threshold value set by the government of 10.0 mm/second.

Historical data on blasting activities using 79.67 % used engine oil and 20.23 % diesel fuel, as a mixture of explosives, recorded from October 2nd, 2014 to December 28th, 2016, there are 76 data with an average ground vibration of 4.43 mm/second exceeds the limit set by the company of 3.0 mm/second, but none exceeds the maximum limit set by the Indonesian National Standard Number 7571 of 2010, of 10.0 mm/second.

From historical data records of blasting activities using 88.87 % used engine oil and 11.13 % diesel fuel, as a mixture of explosives, recorded from May 22nd, 2017 to July 11th, 2017, there are 30 data with an average ground vibration of 2.94 mm/second, not exceeding the maximum limit set by the company of 3.0 mm/second.

Historical data on blasting activities using 91.98 % used engine oil and 8.11 % diesel fuel, as a mixture of explosives recorded from July 15th, 2017 to July 29th, 2017, with a total of 14 measurement data, an average ground vibration is 2.73 mm/second, not exceeding the maximum limit set by the Company of 3.0 mm/second.

Historical data on blasting activities using 90.96 % used engine oil and 9.04 % diesel fuel, as a mixture of explosives, recorded from March 7th, 2019 to June 8th, 2021, there are 92 data with an average ground vibration of 3.65 mm/second, exceeding the limit set by Company of 3.0 mm/second, but not exceeding the maximum limit set by Government Regulation of 10.0 mm/second.

No	Time	Composition of Used Engine Oil	Amount of Data	Ground vibration Average Data (mm/Second)
1	April 9th, 2011 – End of 2013	0	38	7.02
2	January 24th, 2014 – September 2014	68.51 %	20	5.19
3	October 2nd, 2014 – December 28th, 2016	79.67 %	76	4.43
4	May 22nd, 2017 – July 11th, 2017	88.87 %	30	2.94
5	July 15th, 2017 – July 29, 2017	91.98 %	14	2.73
6	March 7th, 2019 – June 8th, 2021	90.96 %	92	3.65

Table 2: Composition of Used Engine Oil Against Ground Vibration Measurement

Source: Historical Data of Ground Vibration Measurement PT. Kaltim Prima Coal Sangatta, 2011 - 2021

After inputting all raw data, then we get factors criteria were analyzed to obtain the ground vibration value, as follows:

Factor	Name	Unit	Type	Min.	Max.	Coded Low	Coded High	Mean	Std. Dev.
A	Used Engine Oil Percentage	%	Numeric	0	91,98	-1 ↔ 0,00	+1 ↔ 96,00	73,13	1,28
B	Explosive Weight	kg	Numeric	25	50,00	-1 ↔ 20,00	+1 ↔ 1.200	172,81	133,72

Table 3: Factors' Criteria Were Analyzed To Obtain The Ground Vibration Value

Source: Data Input Response Surface Methodology

In Table 3 above are the factor criteria to be analyzed in the form of the percentage of used engine oil (%) and the weight of explosives (Kg), which are the basis for ground vibration analysis.

Response	Name	Units	Observa tions	Analysis	Min	Max	Mean	Std. Dev.	Ratio	Transf orm	Model
R1	Ground Vibration	mm/s	270	Poly nominal	0,043	22,20	04,33	0,098	0,901	None	Quarti c

Table 4: Ground Vibration Criteria As A Response

Source: Data Input Response Surface Methodology

Table 4, shows the criteria for ground vibration which is the response from the analysis that will be carried out next.

Source	Std. Dev.	R^2	Adjusted R^2	Predicted R^2	PRESS	
Linear	0,102	1,99	1,96	1,71	992,24	
2FI	0,103	2,01	1,95	1,55	1.021,77	
Quadratic	**0,099**	**2,28**	**2,19**	**1,69**	**994.91**	**Suggested**
Cubic	0,099	2,41	2,25	1,43	1.044,26	
Quartic	**0,097**	**2,59**	**2,36**	**-0.06**	**1.395,47**	**Suggested**
Fifth	0,097	2,71	2,37	-222.435	30.567,16	
Sixth	0,096	2,89	2,45	-26,924	4.855,83	Aliased

Table 5: Selection of the Recommended Analysis Model For Ground Vibration

Source: Data Input Response Surface Methodology

Table 5, is the analysis method recommended by the Response Surface Methodology, for further analysis of variances (Anova) carried out, to obtain a minimum ground vibration value.

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	491,47	14	35,11	0,48	< 0.0001	significant
A-Used Engine Oil Percentage	0,43	1	0,43	0,13	0,57	
B-Explosive Weight	2,03	1	2,031	0,63	5,30	
AB	27,66	1	27,66	0,372	0,0037	
A^2	0,0023	1	0,0023	0,0007	6,79	
B^2	11,45	1	11,45	0,16	0,42	
A^2B	0,13	1	0,13	5,63	2,56	
AB^2	0,35	1	0,35	0,11	0,84	
A^3	07,32	1	7,32	0,10	0,93	
B^3	0,49	1	0,49	0,15	0,46	
A^2B^2	3,072	1	3,07	0,95	4,94	
A^3B	14,37	1	14,37	0,19	0,25	
AB^3	0,39	1	0,39	0,14	0,69	
A^4	1,28	1	1,28	2,752	3,68	
B^4	3,29	1	3,29	1,02	2,18	
Residual	823,61	255	3,23			
Lack of Fit	419,50	102	4,11	1,56	0,0065	significant
Pure Error	404,10	153	0,13			
Cor Total	1.315,08	269				

Table 6: Analysis of Variances For Ground Vibration Model

Source: Data Input Response Surface Methodology

By using historical data, then analysis was carried out with the Response Surface Methodology (RSM) of ground vibrations, to obtain 3 Dimensional Contour and surface pattern images as shown in Figures 5 and Figure 6, below.

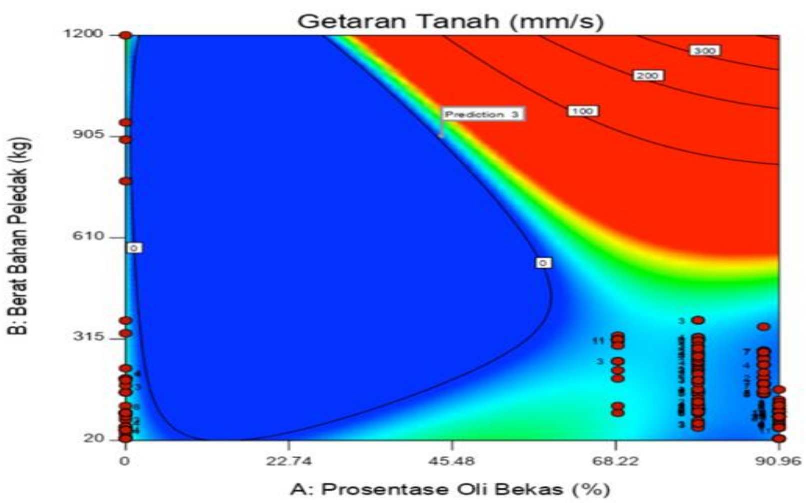

Fig. 5: Ground Vibration Analysis Contour Drawing

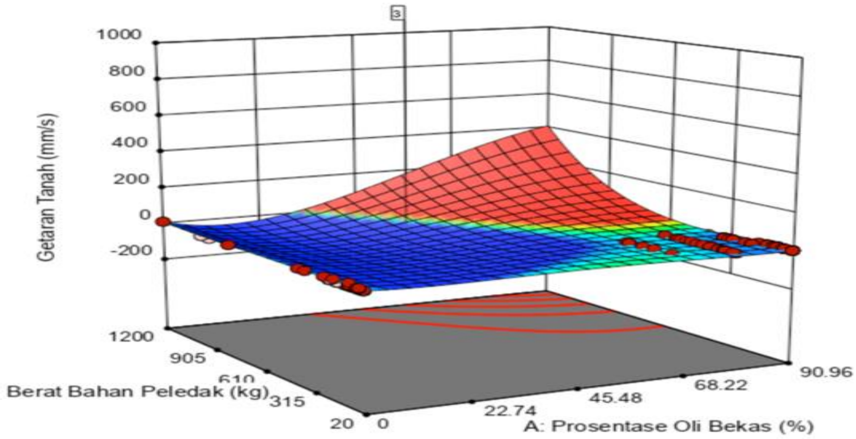

Fig. 6: Three-Dimensional Surface Image (3D Surface) Result of RSM Optimization

In the figures above, the blue color describes the lowest ground vibration with a value of 1.02 mm/second to the red color is the highest ground vibration with a value of 21.8 mm/second.

Factor	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight	Importance
A: Used Engine Oil Percentage	maximize	0	90,96	1	1	3
B: Explosive Weight	maximize	20	1.200	1	1	3
Ground Vibration	is in range	1	3	1	1	3

Table 7: Variable Limits To Get A Safe Ground Vibration

Source: Data Input Response Surface Methodology

The final stage in this method is to carry out the optimization process, with some limitations as shown in Table 7 above, obtaining 14 different compositions between the percentage of Used Engine Oil and the weight of the explosives to obtain ground vibrations ranging from 1 – 3 mm/Second, as shown in the following table 8 below.

No.	Used Engine Oil Percentage (%)	Explosives Weight (Kg)	Ground Vibration (mm/sec)	*Desirability*	
1	43,98	907,46	3,0	0,419	*Selected*
2	43,17	923,66	3,0	0,419	
3	46,46	856,75	3,0	0,418	
4	51,68	745,43	3,0	0,410	
5	53,52	704,45	3,0	0,406	
6	55,89	649,72	3,0	0,398	
7	56,35	638,62	3,0	0,396	
8	57,45	612,03	3,0	0,391	
9	60,40	533,87	3,0	0,374	
10	90,96	324,94	3,0	0,353	
11	85,99	63,25	3,0	0,129	
12	85,55	63,00	3,0	0,128	
13	86,47	62,34	3,0	0,128	
14	1,296	463,42	1,0	0,073	

Table 8: Solution Composition of Used Engine Oil Percentage and Weight of Explosives To Get Ground Vibration Values That Match The Targets

Source: Data Input Response Surface Methodology

From the several solutions offered by Response Surface Methodology above, the optimal combination recommended (selected) to obtain a ground vibration value that does not exceed 3.0 mm/second is 43.98% used engine oil with an explosive weight of 907.46 Kilogram, which is estimated will be able to produce ground vibrations of 3.0 mm/Second.

IV. CONCLUSION

From the results of the data analysis that has been done, it can be concluded, as follows :

- The impact of blasting activities using used engine oil on the environment, in particular on ground vibrations, does not exceed the maximum limit set by the standard table for blasting vibration levels in open pit mines on buildings according to the Indonesian National Standard

7571: 2010. Actual ground vibration from 270 measurement results averaged 4.33 mm/second.

- To obtain a ground vibration value that does not exceed 3.0 mm/second, by maximizing the explosive weight of 907.46 kilograms, the percentage of explosives using used engine oil as a mixture of explosives is 43.98 %.

REFERENCES

[1.] Blair, D. P. (2014). Blast vibration dependence on charge length, the velocity of detonation, and layered media. *International Journal of Rock Mechanics and Mining Sciences*, *65*, 29–39. https://doi.org/10.1016/j.ijrmms.2013.11.007

[2.] Hidayat, R., Joko Priatmadi, B., Septiana, M., & Sofarini, D. (2014). Penentuan Jarak Aman Peledakan Batubara Terhadap Lingkungan Sekitar Wilayah Pertambangan. 10, 88–95.

[3.] John Wolstenholme CEng FIStrutE MICE. (2015). *Explosives Engineering*. *AprIl*, 1–40.

[4.] Maryura, R., Toha, M., & Sudarmono, D. (2013). Kajian Pengurangan Tingkat Getaran Tanah (Ground Vibration Level) Pada Operasi Peledakan Interburden B2C Tambang Batubara Air Laya PT. BUKIT ASAM (PERSERO), Tbk Tanjung Enim. *Jurnal Ilmu Teknik Sriwijaya*, *1*(1), 1–8.

[5.] Mohamed, F., Hafsaoui, A., Talhi, K., & Menacer, K. (2015). Study of the Powder Factor in Surface Bench Blasting. *Procedia Earth and Planetary Science*, *15*, 892–899. https://doi.org/10.1016/j.proeps.2015.08.142

[6.] PT. Kaltim Prima Coal. (2020). *Sustainability Report 2020*.

[7.] Ridho Permana, A., & Heriyadi, B. (2018). Kajian Pengurangan Getaran Tanah (Ground vibration) Pada Peledakan Overburden Tambang Batubara Di PT. Artamulia TataPratama Site Tanjung Belit Provinsi Jambi. *Jurnal Bina Tambang*, *4*(1), 344–356.