INDONESIAN MINING JOURNAL Vol. 26, No. 2, October 2023 : 107 - 113

INQUIRING THE FLYROCK TO DETERMINE MINIMUM SAFE DISTANCE OF COAL OVERBURDEN BLASTING AGAINST RESIDENTIAL AREA

KAJIAN BATU TERBANG UNTUK MENENTUKAN JARAK AMAN MINIMUM PELEDAKAN LAPISAN PENUTUP BATUBARA TERHADAP WILAYAH PERMUKIMAN

RADEN H. HANDAYANA[1*], FAJAR SHODIK[2] and SANI SALAHUDIN[2]
[1] Indonesia Blasting Engineers Society (IBES)
[2] Department of Technical Services & QC Hanwha Mining
*Corresponding e-mail: haris.handayana@gmail.com

ABSTRACT

Fly rock is a rock fragmentation that is thrown as a result of blasting. Such fragmentation that is thrown beyond the specified safe distance can cause a damage to the infrastructure, mechanical equipment and humans. This study aims to determine the safe radius of the fly rock that resulting from blasting residential area which that has a distance 200-300 m and has potentially distressing to cause damage. Calculating of the flying rock throwing distance is carried out theoretically and actually with orientation to the distance between spaces, the distance between burdens, minimum stemming height, minimum hole depth, powder factor, average charge blast hole and distance initial burdens. For theoretical calculations, the save distance is calculated by empirical methods and dimensional analysis. Results of the study shows that, the maximum distance of the actual fly rock throw is 05.31 m and based on the predictions using the Cratering Method, the maximum distance of fly rocks is 172 m with a safety factor of 2 and the maximum distance of fly rocks is 199.04 m with a safety factor of 2. Based on the actual and predicted data above, it is not safe for blasting locations that is less than 200 m from residential areas, that refers to the safe radius threshold based on the regulation of the Minister of Energy and Mineral Resources No. 1827 K/30/MEM/2018.

Keywords: fly rock, safe radius, stemming.

ABSTRAK

Batu terbang adalah fragmentasi batuan yang terlempar akibat hasil peledakan. Fragmentasi batuan yang terlempar melebihi jarak aman yang ditentukan dapat menyebabkan kerusakan infrastruktur, alat mekanik dan manusia. Penelitian ini bertujuan untuk mengetahui radius aman batu terbang yang dihasilkan dari peledakan terhadap perumahan warga yang berjarak antara 200 – 300 m dan berpotensi menimbulkan kerusakan. Perhitungan jarak lemparan batu terbang dilakukan secara teoritis dan aktual dengan berorientasi pada jarak antar spasi, jarak antar burden*, tinggi* stemming *minimum, kedalaman lubang minimum,* powder factor*, rata – rata isian per lubang ledak dan jarak* burden *awal. Untuk perhitungan teoritis menggunakan metode empirik dan analisis dimensi. Dari hasil penelitian diperoleh jarak maksimum lemparan batu terbang yang sebenarnya adalah 105,31 m dan berdasarkan prediksi menggunakan* Cratering Method *jarak maksimum batu terbang adalah 172 m dengan faktor keamanan 2 dan jarak maksimum batu terbang adalah 199,04 m dengan faktor keamanan 2. Berdasarkan data aktual dan prediksi di atas, peledakan dibawah radius 200 m tidak aman untuk dilakukan, mengacu pada nilai ambang batas radius aman peraturan Keputusan Menteri Energi dan Sumber Daya Mineral Nomor 1827K/30/MEM/2018.*

Kata kunci: batu terbang, radius aman, stemming*.*

Received: 23-05-2023, first revision: 19-10-2023, second revision: 07-11-2023, accepted: 24-12-2023
DOI: 10.30556/imj.Vol26.No2.2023.1498

INTRODUCTION

Blasting is an activity to break down the material using explosives. Blasting activities are carried out if the mechanical device is not strong enough, or is not efficient enough to blast the material, as a result blasting activities are carried out to meet production targets for uncovering the overburden and mined minerals. One of the effects on the environment from blasting activities is the presence of fly rock (Santoso, Kartini and Wanaldi, 2020).

Fly rock is a rock fragmentation that is thrown as a result of blasting and if thrown past the specified safe limit it can cause a damage to the equipment or surrounding buildings as well as injury to humans (Al-Zhahra, Wiyono and Sudiyanto, 2022). Environmental impacts, apart from technical and economic factors, are an important issue in mining blasting. Blasting is the effective method for mining to separate a rock fragment from a rock mass so that it can be prepared for the next stage in mining activities. Blasting, on the other hand, has the potential to have environmental impacts on humans, structures, living things and surrounding environment as well. Major impacts of blasting that frequently and widely analysis by the researchers are fly rock, blast vibration, and dust (Hidayat, 2021).

Several studies have been carried out to analyze the impact of blasting vibrations on settlements (Handayana *et al.*, 2022). Configuring Blast Initiation Systems in Mining to Reduce the Impact of Ground Vibrations on Residential Environments. Meanwhile, this research will focus on controlling the fly rock from the impact of blasting activities. The blasting operation must ensure quality and quantity requirements of production, maximize the overall economics of any mining operation. The damage to the environment by various nuisances must also be properly controlled for their minimization (Balakrishnan and Rai, 2021).

Blasting is one of the mining activities carried out by PT Sebuku Tanjung Coal to spread overburden. The activity can produce environmental impacts, one of them is the fly rock. At a certain level, if it has exceeded the maximum specified radius,the fly rock due to this blasting activity can cause a damage to the infrastructure and the humans on the area around the blasting. This shows the importance of the study regarding the safety radius of fly rock produced by blasting activities. This research was carried out at Pit T3 which has problems regarding the proximity of blasting location to residential areas ranging from 200 m - 300 m, so that it can lead to the issues related to the fly rock that have an impact on the damage of residential buildings and humans.

Factors that cause the fly rock, based on the value of the correlation coefficient, with the most significant effect is the high stemming value of 48.98%. If the stemming value is high, the resulting fly rock trajectory distance will be smaller. Conversely, if the stemming value is low, the resulting fly rock trajectory distance will be greater by (Eko *et al.*, 2023). Apart from that, the theoretically stemming height has also an important role for locking energy in the blast hole for optimal in distributing material to sideways and reduces potential energy comes out of the blast hole that can cause fly rock (Amsya, Zakri and Novrianto, 2021).

Blast design parameters play a key role in fly rock generation. If the burden dimension is <25 times the charge diameter, it will result in a high specific charge and thus releasing more energy which causes greater fly rock distances. The too large of a burden will cause the ejection of stemming material and thus give rise to the cratering effect. The net outcome is fly rock generation. The specific charge of a hole is directly proportional to the distance of fly rock. This implies that an increase in specific charge results in an increase in chances of the fly rock. This condition normally arises when there is a cavity present in the strata or the blasting crew loads the holes carelessly with an excessive amount of explosives. Geological conditions play a significant role in this as well. Rock structure and rock properties may vary significantly within the same blast area (Nayak, Jain and Ranjan Mahapatra, 2022). Human error factor when filling explosives and compacting stemming can also have an impact on the fly rock (Ramadhan and Yulhendra, 2020).

Fly rock cannot be completely eliminated, However, the throwing distance can be reduced to a safe level to prevent damage.
One of the effective approaches to control and prevent accidents due to the fly rock is a prediction fly rock throw and influence of blasting parameters against fly rock. Predictions aim to estimate fly rock values

based on patterns from data with using variable blasting parameters for predicting the results of the next fly rock which is still its value is not yet known (Nababan, Santoso and Kartini, 2022).

Responding to this problem, a study is needed for blasting activities that is focused on determining the safe radius of fly rock from blasting using an empirical method based on Moore and Richards (2005), where there are 3 main factors that influence the occurrence of fly rock in blasting activities, Face Burst, Crathering and rifling. The next method used is based on Ghasemi, Sari and Ataei (2012) making an equation to predict the fly rock distance using a dimensional analysis method based on controllable blasting parameters.

Based on these two methods, a prediction of the maximum radius of fly rock that will be generated.

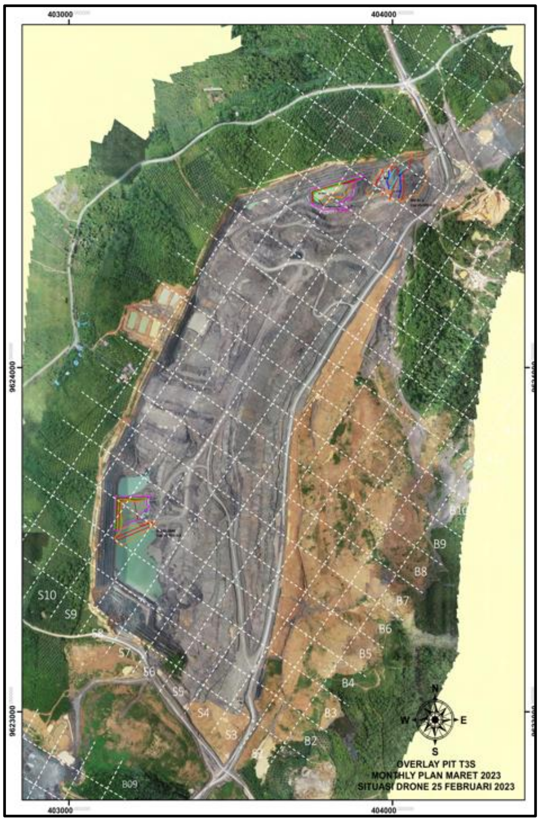

Figure 1. Map layout Pit T3

METHODOLOGY

Calculation of the fly rock throwing distance is carried out theoretically and actually using the DJI Mavic Air 2 drone which is processed using Tracker software with orientation to the distance between spaces, the distance between burdens, minimum stemming height, minimum hole depth, powder factor, average charge blast hole and distance initial burdens (Ramadhan and Yulhendra, 2020).

The first fly rock prediction calculation used the equation theory by Moore and Richards (2005) at which where are 3 factors or parameters that affect the fly rock distance based on different geometric values. Those includes burden, charge blast hole and stemming height, to calculate the level of influence using regression analysis. Based on the actual obtained data, followings are the results of the obtained regression analysis:

1. Cratering Predictions
   Cratering occurs when the stemming height is too short and there is a weak area in the blast hole. These weak areas are usually broken materials from previous blasting results.

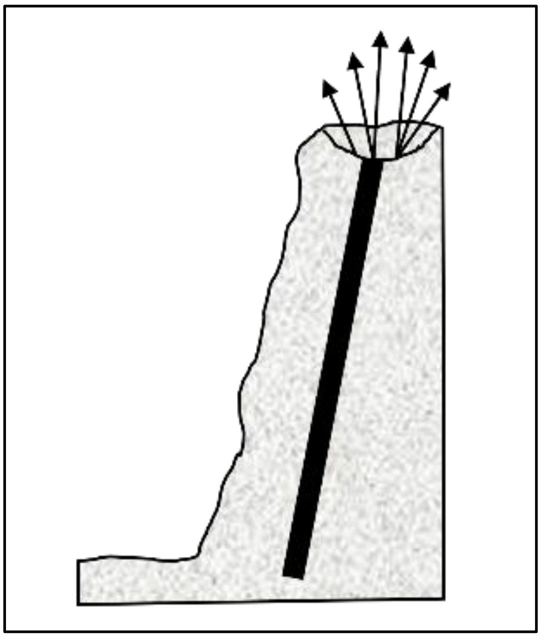

Figure 2. Cratering (Suryadi and Kopa, 2019)

$$L_{max} = \frac{K^2}{g} \times \left(\frac{\sqrt{m}}{SH}\right)^{2.6} \quad \text{.............................. (1)}$$

2. Face Burst Predictions
   Face Burst occurs when the distance of the calculation burden on the front row of blasting in the field which is sometimes too close can cause potential fly rock.

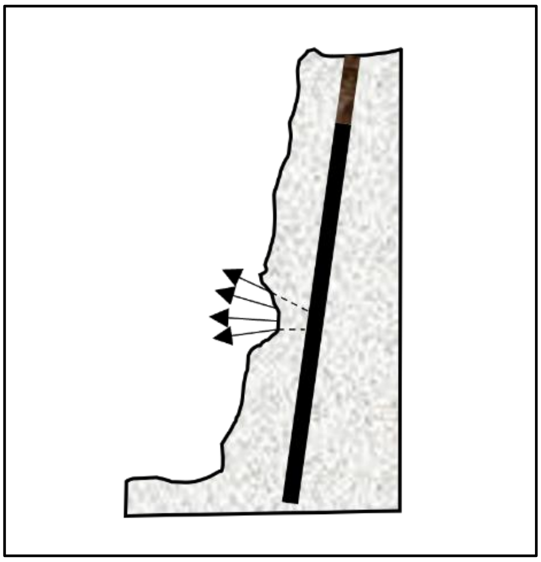

Figure 3. Face burst (Zou, 2017)

$$L_{max} = \frac{K^2}{g} \times \left(\frac{\sqrt{m}}{B}\right)^{2.6} \quad \text{.............................. (2)}$$

3. Rifling Predictions
   Rifling occurs when stemming is appropriate to prevent cratering fly rock but the stemming material used is not good. Fly rock caused more likely than the slope of the blast hole because if the blast hole is upright the fly rock is assumed to return to its original point.

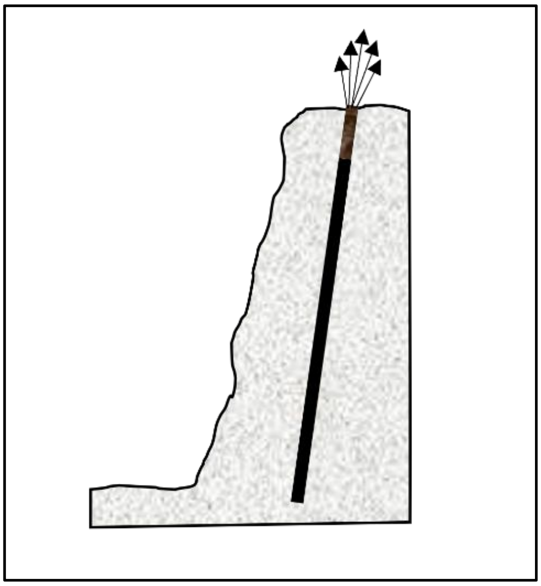

Figure 4. Rifling

$$L_{max} = \frac{K^2}{g} \times \left(\frac{\sqrt{m}}{SH}\right)^{2.6} \text{Sin } \theta \quad \text{...................... (3)}$$

Where:
SH = Stemming height (m)
K = Site constant
m = Charge mass/m (kg)
L = Horizontal throw (m)
B = Burden (m)
g = gravitational constant (9.8 m/s^2)

Fly rock is the result of the face burst mechanism that needs to be controlled with the process of preparing the location, drilling pattern design process and in accordance plan with using a meter, do stemming with special materials. Whereas for control cratering perpendicular precision drilling slope with a tolerance of 3^o, ensure powder column by measuring tape (Amsya, Zakri and Novrianto, 2021).

The second fly rock prediction calculation uses the equation theory by Ghasemi, Sari and Ataei (2012) by making an equation to predict the fly rock distance using dimensional analysis method based on controllable blasting parameters.

$$Fd = 0.999 \left(B^{-1.336} S^{1.201} St^{-2.196} H^{0.347} D^{-0.201} \left(\frac{P}{Q}\right)^{-0.171}\right. \quad \text{.. (4)}$$

Where:
Fd = Fly rock distance (m)
B = Burden (m)
S = Spacing (m)
H = Hole Depth (m)
D = Powder factor (kg/bcm)
Q = Charge mass (kg)

RESULTS AND DISCUSSION

The calculation of the fly rock throwing distance carried out at Pit T3 is actually oriented to the distance between spaces, distance between burdens, minimum stemming height, minimum hole depth, powder factor, average charge blast hole. Following are the results of the blasting geometry along with the actual fly rock distance at PT. Sebuku Tanjung Coal (Tabel 1).

Table 1. Actual fly rocks at PT Sebuku Tanjung Coal

Date	Total Hole	Burden	Spacing	Stemming	Hole Depth	Diameter	Powder Factor	Charge	Powder Column	Loading Density	Fly Rocks Distance
		B	S	SH	H	D	PF	Q	PC	LD	
	N			m			Kg/BCM	Kgs	m	Kg/m	m
12-Jan-22	72	7	8	3.47	6.08	0.200	0.28	94.25	2.61	36.14	90.52
13-Jan-22	56	9	10	3.48	7.70	0.200	0.22	152.46	4.22	36.14	11.01
16-Jan-22	96	7	8	4.61	7.93	0.171	0.27	119.84	3.32	26.42	21.33
17-Jan-22	26	7	8	3.24	4.74	0.171	0.20	54.38	1.50	26.42	21.02
18-Jan-22	41	7	8	4.79	7.78	0.171	0.25	108.29	2.99	26.42	11.90
18-Jan-22	34	7	8	4.88	7.86	0.171	0.24	107.50	2.98	26.42	5.47
19-Jan-22	51	8	9	5.12	8.00	0.171	0.18	103.94	2.88	26.42	4.12
19-Jan-22	62	8	9	4.79	7.96	0.171	0.20	114.37	3.17	26.42	4.61
20-Jan-22	31	7	8	3.69	7.83	0.171	0.26	109.29	4.14	26.42	11.02
22-Jan-22	28	7	8	2.85	4.47	0.171	0.23	58.54	1.62	26.42	78.39
28-Jan-22	132	7	8	3.56	7.85	0.171	0.27	113.34	4.29	26.42	46.86
29-Jan-22	82	8	9	4.48	7.99	0.171	0.25	138.90	3.51	26.42	77.92
30-Jan-22	40	8	9	4.58	7.47	0.171	0.19	104.38	2.89	26.42	11.42
31-Jan-22	50	7	8	4.65	7.41	0.171	0.24	99.52	2.76	26.42	7.53
4-Feb-22	87	7	8	4.82	7.83	0.171	0.25	108.77	3.01	26.42	6.62
5-Feb-22	65	7	8	4.45	7.69	0.171	0.27	117.03	3.24	26.42	14.70
6-Feb-22	19	7	8	2.13	2.87	0.171	0.16	26.68	0.74	26.42	96.20
10-Feb-22	62	7	8	4.96	7.98	0.171	0.24	109.28	3.02	26.42	20.46
11-Feb-22	59	7	8	4.90	7.91	0.171	0.25	108.95	3.01	26.42	12.06
12-Feb-22	72	7	8	4.89	7.99	0.171	0.25	111.83	3.10	26.42	8.47
13-Feb-22	85	7	8	4.79	7.81	0.171	0.25	109.27	3.02	26.42	12.42
1-Mar-22	32	7	8	3.72	6.28	0.171	0.30	92.56	2.56	26.42	105.31
3-Mar-22	67	8	9	3.89	8.06	0.171	0.19	110.33	4.17	26.42	9.61

Based on the obtainde actual data, the farthest distance of fly rocks is 105.31 m, with an average depth of 6.28 m and stemming height of 3.72 m.

Based on the obtained actual data, following are the results of the regression analysis:

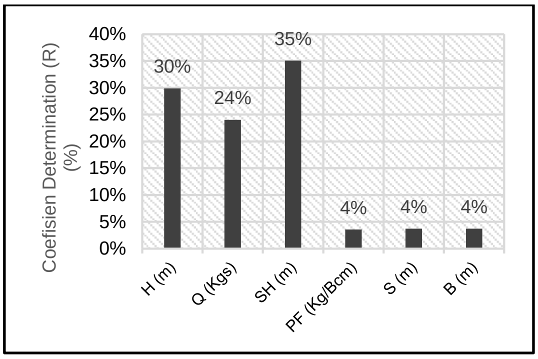

Figure 5. Regression analysis of factors affecting fly rocks

Based on the results of fly rock prediction calculation using several calculation methods, the deviation value between the actual and predicted data is obtained as follows (Tabel 2):

Tabel 2. Deviation value calculation

Prediction Methode	Deviation with Flying Rock Actual Throwing (%)
Cratering	50%
Face Burst	70%
Rifling	93%
Ebrahim Ghasemi	59%

Based on the data in Table 2, the cratering and Ebrahim Ghasemi methods produce small deviation values between prediction and actual and the predicted distance is always greater than the actual distance, therefore these two methods are used as references in predicting the maximum distance of flying rocks. In addition, based on the results of the regression analysis obtained, stemming height has the greatest influence on the distance of fly rockthrowing, therefore in determining the fly rock predictions, a graph of the relationship between the stemming height and the maximum fly rock throws is made as shown in Figure 6.

Based on Figure 6 data. By using safety factor 2, the farthest radius of fly rocks by using prediction calculation of Ebrahim Ghasemi does not exceed 200 m.

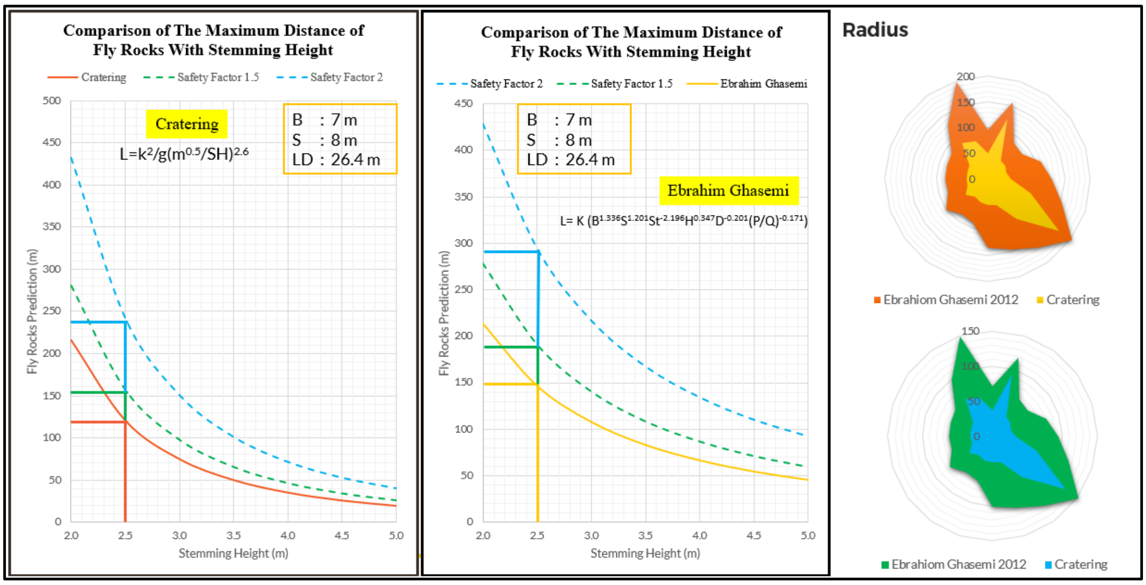

Figure 6. Comparison of the maximum distance of fly rocks with stemming height.

CONCLUSIONS AND SUGGESTIONS

Conclusions

Referring to the discussion of the research findings on the previous chapter, the researcher comes to the following conclusions.

1. Based on the actual data obtained, the farthest Fly Rocks distance is 105.31 meters. With the blasting distance to residential areas ranging from 250 to 300 m, it is still safe to do.
2. Based on the prediction results using several calculations, as well as a comparison between the actual and predicted values, the Cratering Method was chosen by Moore and Richards (2005) and Ghasemi, Sari and Ataei (2012) as a reference in determining the maximum safe distance of fly rocks.
3. Based on predictions using the Cratering Method by Richard & Moore 2005 the maximum distance of fly rocks is 172 m with a safety factor of 2 and Ebrahim Ghasemi the maximum distance of fly rocks is 199.04 m with a safety factor of 2.
4. Based on the actual and predicted data above, it is not safe to carry out blasting locations less than 200 m (Menteri Energi dan Sumber Daya Mineral, 2018) from residential areas.

Suggestions

To reduce the safety radius of fly rocks to less than 200 m, it is advisable to:

1. The aggregate used is 5% x hole diameter and serves as guarantee the degree of confinement.
2. The use of Air Deck (Ball Deck), serves to reduce the explosive charge and the increase Confinement Degree.

ACKNOWLEDGEMENT

Special thanks to Hanwha Mining Services, Snap, Hillcon Jaya Sakti, and Sebuku Tanjung Coal who supported and gave permission for the results of this research to be published.

REFERENCES

Al-Zhahra, D., Wiyono, B. and Sudiyanto, A. (2022) 'Prediksi jarak lemparan flyrock dengan metode analisis dimensi serta Richard dan Moore akibat kegiatan peledakan pada tambang bijih emas', *Indonesian Mining Professionals Journal*, 4(2), pp. 145–152. Available at: https://doi.org/10.36986/impj.v4i2.74.

Amsya, R.M., Zakri, R.S. and Novrianto, N. (2021) 'Analisis pengaruh geometri peledakan terhadap fly rock hasil peledakan di PT. Bintang Sumatra Pacific Kec. Pangkalan Kab. Lima Puluh Kota Provinsi Sumatera

Barat', *Jurnal Sains dan Teknologi: Jurnal Keilmuan dan Aplikasi Teknologi Industri*, 20(2), pp. 238–245. Available at: https://doi.org/10.36275/stsp.v20i2.306.

Balakrishnan, V. and Rai, P. (2021) 'An overview of flyrock and its prediction in surface mine blasting using soft computing techniques', *Recep Tayyip Erdoğan Üniversitesi Fen ve Mühendislik Bilimleri Dergisi*, 2(2), pp. 105–119. Available at: https://doi.org/10.53501/rteufemud.986903.

Eko, M.R., Haris, R.H., Lubis, J. and Deri, N.P. (2023) 'Study of flyrock to reduce safe radius from 500 m to 300 m on blasting quarry at PT Vale Indonesia, Sorowako, Luwu Timur, South Sulawesi', *IOP Conference Series: Earth and Environmental Science*, 1175(1), p. 012002. Available at: https://doi.org/10.1088/1755-1315/1175/1/012002.

Ghasemi, E., Sari, M. and Ataei, M. (2012) 'Development of an empirical model for predicting the effects of controllable blasting parameters on flyrock distance in surface mines', *International Journal of Rock Mechanics and Mining Sciences*, 52, pp. 163–170. Available at: https://doi.org/10.1016/j.ijrmms.2012.03.011.

Handayana, R.H., Mapanta, J., Barlian, E., Carlo, N., Hamdi and Lubis, J. (2022) 'Configuration of blasting initiation system in mining to reduce the impact of ground vibration on the settlement environment', *Spanish Journal of Innovation and Integrity*, 11, pp. 30–36.

Hidayat, S. (2021) 'Environmental impacts of open pit mining blasting: Particular discussions on some specific issues', *Journal of Mining and Environmental Technology*, 1(1), pp. 1–11.

Menteri Energi dan Sumber Daya Mineral (2018) *Keputusan Menteri Energi dan Sumber Daya Mineral No.1827 K/30/MEM/2018 tentang Pedoman pelaksanaan kaidah teknir pertambangan yang baik*. Indonesia.

Moore, A.J. and Richards, A.B. (2005) *Kalgoorlie consolidated gold mines: Golden pike cut-back flyrock control and calibration of a predictive model*. TERROCK Consulting Engineers.

Nababan, S.V.A., Santoso, E. and Kartini (2022) 'Analisis prediksi jarak lemparan flyrock pada kegiatan peledakan di PT Darma Henwa', *Jurnal Himasapta*, 7(2), pp. 79–82.

Nayak, N.P., Jain, A. and Ranjan Mahapatra, S. (2022) 'Application of Mine Excellence software in flyrock prediction & mitigation', *Materials Today: Proceedings*, 48, pp. 1271–1276. Available at: https://doi.org/10.1016/j.matpr.2021.08.282.

Ramadhan, R. and Yulhendra, D. (2020) 'Kajian potensi flying rock peledakan terhadap radius aman alat peremuk crusher di CV Tekad Jaya Halaban Kabupaten Lima Puluh Kota Sumatera Barat', *Jurnal Bina Tambang*, 5(3), pp. 1–6.

Santoso, E., Kartini, K. and Wanaldi, R. (2020) 'Pembuatan aplikasi dengan menggunakan rumus empiris untuk memprediksi lemparan batu (flying rock) dari kegiatan peledakan', *Jurnal GEOSAPTA*, 6(1), pp. 23–27. Available at: https://doi.org/10.20527/jg.v6i1.7825.

Suryadi and Kopa, R. (2019) 'Analisis geometri peledakan untuk meminimalisir jarak lemparan batuan (flyrock) pada peledakan tambang terbuka PT Ansar Terang Crushindo II Pangkalan Sumatera Barat dengan visualisasi menggunakan Drone DJI Phantom 4', *Jurnal Bina Tambang*, 4(3), pp. 175–186.

Zou, D. (2017) 'Blasting safety for surface blasting', in *Theory and Technology of Rock Excavation for Civil Engineering*. Singapore: Springer Singapore, pp. 343–377. Available at: https://doi.org/10.1007/978-981-10-1989-0_11.