

OPTIMIZATION OF OVERBURDEN BLASTING GEOMETRY BASED ON THE EFFECT OF BLASTHOLE DEPTH ON POWDER FACTOR AND EXPLOSIVES COSTS TO MEET PRODUCTION TARGET

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Abstract: Blasting is an important activity in overburden stripping because its performance affects production achievement and blasting costs. This study investigates the relationship between blasthole depth, powder factor (PF), and specific blasting cost and evaluates alternative blast geometries to achieve a production target of 200,000 BCM per cycle. A quantitative approach using descriptive, regression, and comparative analyses was applied to one overburden blasting cycle at a coal mine in South Kalimantan, consisting of 334 blastholes with depths ranging from 6.0 to 9.0 m and an actual burden and spacing of 7×8 m. Simple linear regression indicated strong relationships between blasthole depth and explosive charge ($R^2 = 0.9885$), PF ($R^2 = 0.9570$), and specific blasting cost ($R^2 = 0.9505$). Under the actual geometry, the blasted volume reached 150,612 BCM, equivalent to 75.31% of the production target, with an average PF of 0.341 kg/BCM. Three alternative geometries were evaluated based on the stated ICI Explosives criteria. The 8×10 m alternative achieved 200,040 BCM using 313 holes, with a PF of 0.237 kg/BCM and a specific blasting cost of IDR 4,589.82/BCM, representing reductions of 30.54% and 30.40%, respectively, compared with the actual condition. Although this alternative provides the lowest PF and specific cost among the evaluated scenarios, its 1.0 m subdrilling is below the stated ICI criterion and therefore requires field validation before implementation. The findings indicate that, under the conditions investigated, increasing the volume per blasthole through wider burden and spacing can provide greater cost efficiency than increasing blasthole depth.

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Introduction

Open-pit coal mining requires the removal of the soil and overburden before the coal seam can be extracted. If the overburden is hard and compact enough to be effectively excavated directly, it is removed through a series of drilling and blasting operations. Blasting breaks the rock mass into smaller fragments, allowing for smoother excavation, loading, and transportation (Reksadipo et al., 2022; Novalia et al., 2022).

Blasting success and the resulting costs are highly dependent on geometric parameters, including hole depth, burden, spacing, fill column length, and explosive quantity. Geometry design must consider both production requirements and cost aspects (Cahyanto et al., 2017). Among the blasting cost components—drilling, explosives, initiation systems, and support—explosives generally account for the largest portion, requiring careful control of their use. Therefore, the powder factor (PF), the ratio of explosive mass to the volume of rock being removed, is commonly used as a benchmark for the efficiency of explosive use (Oktaviani, 2019; Nabella & Razak, 2023).

Various studies on blasting costs and geometry have been conducted previously. Iqbal (2017) evaluated the costs of equipment, supplies, and explosives at several hole diameters; Nabila et al. (2023) correlated blasting geometry and costs with limestone fragmentation results; while Ningrum et al. (2025) reported that an 8×9 m geometry resulted in a lower cost per BCM than a 7×8 m geometry. However, studies that specifically measure the effect of variations in hole depth within a single blasting cycle on PF and cost per BCM, and then use these as a basis for optimizing burden and spacing to meet production targets, are still rare.

At the research location, one blasting cycle consists of holes with varying depths (6.0–9.0 m) on a fixed geometry of 7×8 m, while the resulting demolition volume has not reached the target of 200,000 BCM. Based on these conditions, this study aims to: (1) quantify the effect of blast hole depth on explosive charge, PF, and specific blasting costs; (2) develop alternative blasting geometries based on ICI Explosives criteria to meet production targets; and (3) determine the alternative that produces the lowest PF and cost per BCM.

Method

Research Location and Data

The research was conducted on overburden drilling and blasting activities at an open-pit coal mine in South Kalimantan Province during January–March 2025. The object of analysis was one blasting cycle on clay overburden material consisting of 334 vertical holes with a diameter of 200 mm (7.87 inches). The holes were drilled in a staggered pattern and blasted in a box-cut pattern using an electronic initiation system.

Primary data were obtained through direct observation and measurement, including burden, spacing, hole depth (measured using the sounding method), fill column length, stemming, and the amount of explosives in each hole. Secondary data came from company documents, including blast design, unit price of explosives, drilling cost per meter, and blasting equipment costs. The explosives used were bulk emulsion explosives, which were a mixture of 70% emulsion and 30% ANFO by weight, with a density of 1.32 g/cm^3 and a detonation velocity of 5,300 m/s. Emulsion-based explosives were chosen because they are better resistant to water than pure ANFO (Himanshu et al., 2025). Based on the composition and unit price of the components, the average price of the explosives was equivalent to IDR 15,815.67/kg. The drilling cost is IDR 46,000/m, while the cost of disposable equipment (booster, in-hole delay, and surface delay) is IDR 175,000 per hole.

Data Processing and Analysis

This research is quantitative, using descriptive analysis to describe the actual conditions and comparative analysis to compare the actual conditions with alternative geometries. Data from 334 holes were grouped by depth, then their volume, PF, and specific costs were calculated. The rock volume per hole and PF were calculated using the following equation:

$$V = B \times S \times L \quad (1)$$



$$PF = E / V \quad (2)$$

where V is the rock volume (BCM), B is the burden (m), S is the spacing (m), L is the hole depth (m), and E is the mass of explosive (kg). The specific cost, which is the cost attached to each hole per unit volume, is calculated by:

$$Sc = (C_{bor} + C_{perl} + C_{bp}) / V \quad (3)$$

with Sc specific cost (Rp/BCM), C_{bor} drilling cost, C_{perl} disposable equipment cost, and C_{bp} explosives cost per hole. The relationship between parameters was tested using simple linear regression ($Y = a + bX$) accompanied by Pearson correlation coefficient (r) and coefficient of determination (R^2). The strength of the relationship is interpreted following Sugiyono (2019), while R^2 is interpreted as the proportion of variation in the dependent variable that can be explained by the independent variable (Ghozali, 2018). All regressions were run on data per hole ($n = 334$), not on the group average, so that the R^2 value does not appear higher than it actually is.

Alternative Geometry Arrangement

Alternative geometries were designed based on ICI Explosives (1989) criteria for a hole diameter of $D = 0.2$ m, namely burden $25D-40D$ (5.0–8.0 m), spacing $1.0B-1.5B$, stemming $20D-30D$ (4.0–6.0 m), and subdrilling $8D-12D$ (1.6–2.4 m). Since the surface elevation varied between -51 m and -48 m while the floor level was planned at -56 m, the hole depth was calculated as the height of the level plus subdrilling. The hole diameter, explosive type, and unit price were maintained, while the fill per hole followed the actual data at the same depth. The best alternative was determined based on three criteria: meeting the target of 200,000 BCM, having the lowest PF and specific cost, and its parameters being within ICI Explosives limits or its risks still being manageable.

Results and Discussion

Actual Blasting Conditions

The hole depths in the analyzed cycles ranged from 6.0–9.0 m with an average of 8.05 m and a standard deviation of 0.943 m. The depth distribution was uneven: the 9.0 m group dominated with 144 holes (43.11%), followed by the 7.0 m group with 103 holes (30.84%). Overall, this cycle used 51,286 kg of explosives to dismantle 150,612 BCM, resulting in an average PF of 0.341 kg/BCM. A summary of each depth group is shown in Table 1.

Table 1. Explosive charge, volume, PF, and actual specific costs per depth group

Depth (m)	Number of holes	Filling (kg/hole)	Volume (BCM/hole)	PF (kg/BCM)	Specific costs (Rp/BCM)
6.0	4	84	336	0.250	5,296.18
6.5	9	104	364	0.286	5,820.96
7.0	103	112	392	0.286	5,786.62
7.5	30	126	420	0.300	5,982.80
8.0	18	160	448	0.357	6,860.51
8.5	26	177	476	0.372	7,070.11
9.0	144	189	504	0.375	7,099.53
Total/average	334	51,286*	150,612*	0.341	6,595.02

*Total value of one cycle (kg and BCM).

Table 1 shows that the stemming length remains relatively constant (4.0–4.4 m), so that almost all of the additional depth is due to the increased fill column from 2.0 m to 4.6 m. Consequently, from 6.0 m to 9.0 m the explosive charge increases by 125% (84 to 189 kg), while the volume per hole only increases by 50% (336 to 504 BCM). This imbalance causes the PF to increase from 0.250 to 0.375 kg/BCM and the specific cost of the 9.0 m group to be 34.05% higher than that of the 6.0 m group.

The cost structure of one blasting cycle is presented in Table 2. Explosives absorb more than four-fifths of the total costs, so the most impactful savings efforts are to improve the ratio between explosives and the volume of rock removed, not just to reduce drilling or equipment costs.

Table 2. Cost structure of one blasting cycle under actual conditions

Cost components	Cost (Rp)	Proportion (%)
Drilling (2,689.5 m)	123,717,000.00	12.44
Explosives (51,286 kg)	811,122,662.80	81.55
Blasting equipment	59,825,000.00	6.01
Total	994,664,662.80	100.00

The Effect of Hole Depth on Explosive Content and Powder Factor

The regression results for 334 holes are shown in Figure 1. The relationship between depth and explosive charge follows the equation $Y = 38.227X - 154.27$ with $r = 0.994$ and $R^2 = 0.9885$, meaning that 98.85% of the variation in charge between holes can be explained by depth. The slope coefficient indicates that every 1 m increase in depth requires an additional 38 kg of explosive per hole. The mechanism is sequential: as depth increases, the charge column lengthens ($R^2 = 0.9899$), and the number of charges also increases ($R^2 = 0.9997$).

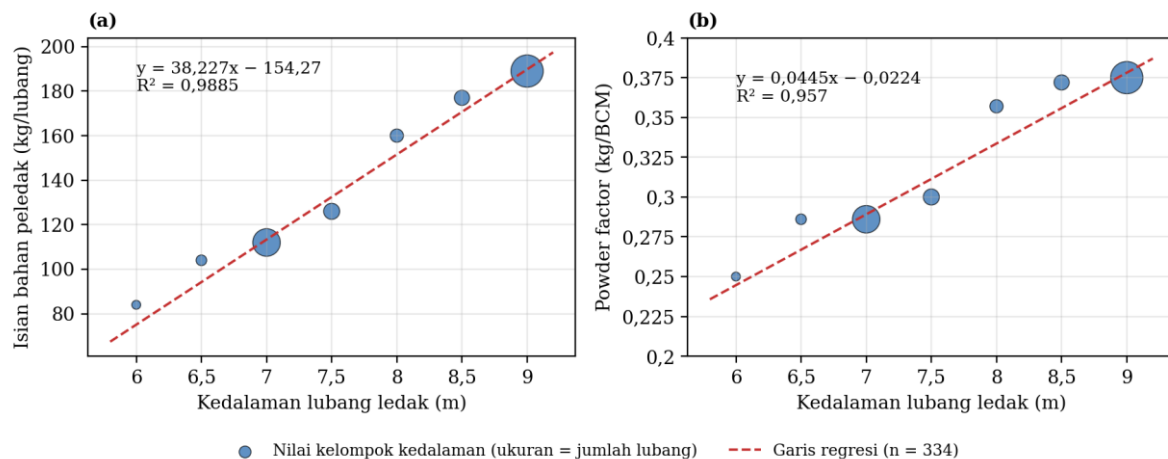


Figure 1. Relationship between blast hole depth and (a) explosive charge and (b) powder factor

The depth of the hole also has a very strong effect on the PF with the equation $Y = 0.0445X - 0.0224$, $r = 0.978$, and $R^2 = 0.9570$. Every additional 1 m of depth increases the PF by approximately 0.0445 kg/BCM. This occurs because in the 7×8 m geometry, an additional 1 m of depth only adds 56 BCM of volume, while the explosives increase by approximately 38 kg. Thus, the explosives at this additional depth are equivalent to approximately 0.68 kg/BCM, or twice the average PF of the cycle. This means that the deeper the hole, the more wasteful the explosives consumption.

Hole depth also correlated positively with specific cost ($R^2 = 0.9505$), and PF had a nearly perfect relationship with specific cost ($Y = 14.725X + 1.581$; $R^2 = 0.9997$). The very high R^2 value of the latter relationship is largely due to the dominance of fixed-price explosives costs, so the finding is more appropriately interpreted as confirming that PF is the most practical cost indicator to monitor in the field. This result also explains why deeper holes actually increase the cost per BCM: because burden and spacing are fixed, volume only increases with depth, even though additional depth is accompanied by proportionally greater additions of explosives. Therefore, volume increases are best achieved by increasing burden and spacing, not by deepening the hole.

Production Target Achievement and Geometry Alternatives

Under actual conditions, the demolition volume only reached 75.31% of the target, resulting in a shortfall of 49,388 BCM. If this shortfall were met by adding holes of the same geometry, an additional cost of approximately IDR 325.7 million would be required. A more efficient approach would be to improve the geometry so that each hole dismantles a larger volume. Three alternatives were developed and checked against the ICI Explosives limits as shown in Table 3.

Table 3. Actual and alternative geometry checks against ICI Explosives criteria (D = 0.2 m)

Parameter	ICI Limits	Current	Record 1	Record 2	Record 3
Burden(m)	5.0–8.0	7.0	8.0	7.0	7.5
Space (m)	1.0B–1.5B	8.0 (1.14B)	10.0 (1.25B)	8.0 (1.14B)	9.0 (1.20B)
Stemming(m)	4.0–6.0	4.0–4.4	4.0–4.4	4.1–4.7	4.1–4.7
Subdrilling(m)	1.6–2.4	1.0	1.0	2.0	2.0
Hole depth (m)	–	6.0–9.0	6.0–9.0	7.0–10.0	7.0–10.0
Area per hole (m ²)	–	56.0	80.0	56.0	67.5

Recommendation 1 increases the burden and spacing to 8×10 m without changing the depth or fill per hole, increasing the area served by each hole by 42.86%. Recommendation 2 maintains 7×8 m but increases subdrilling to 2 m to meet ICI criteria. Recommendation 3 is a middle ground, namely 7.5×9 m with 2 m of subdrilling, so that all parameters are within ICI limits. A comparison of the performance of the four scenarios is presented in Table 4 and Figure 2.

Table 4. Comparison of actual conditions and three alternative blasting geometries

Parameter	Current	Record 1	Record 2	Record 3
Burden× space (m)	7×8	8×10	7×8	7.5×9
Subdrilling(m)	1.0	1.0	2.0	2.0
Number of holes	334	313	389	328
Explosives (kg)	51,286	47,317	75,780	62,379
Volume (BCM)	150,612	200,040	200,116	200,070
Target achievement (%)	75.31	100.02	100.06	100.04
PF (kg/BCM)	0.341	0.237	0.379	0.312
PF Changes	–	–30.54%	+11.21%	–8.44%
Specific costs (Rp/BCM)	6,595.02	4,589.82	7,150.69	5,899.48
Specific cost changes	–	–30.40%	+8.43%	–10.55%
Ranking	–	1	3	2

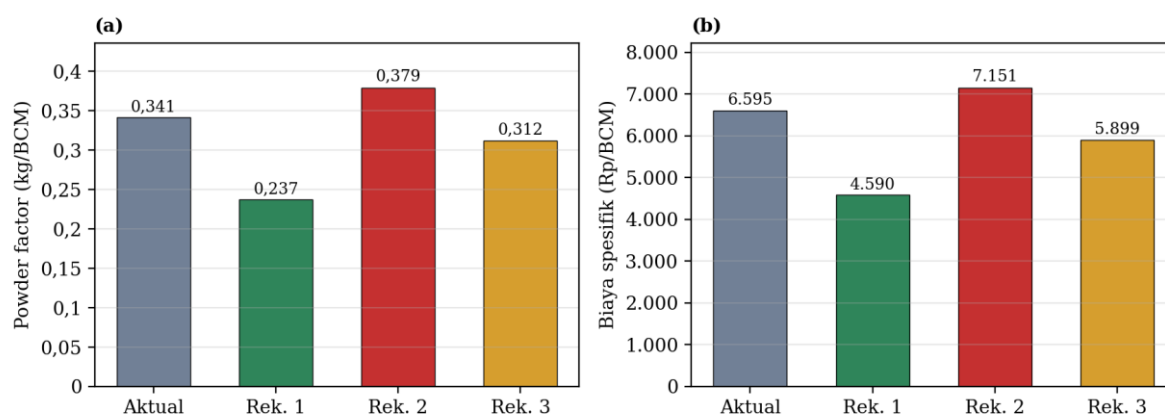


Figure 2. Comparison of (a) powder factor and (b) specific costs under actual conditions and three alternatives.

All three alternatives met the 200,000 BCM target, but their cost implications differed significantly. Recommendation 1 was the best choice because it required the fewest holes (313 holes), the least explosives, and produced the lowest PF and specific cost. The 30% reduction in PF occurred evenly across all depth groups because the fill per hole remained constant, while the volume per hole increased by 1.43 times (80/56). The total cost of one cycle in Recommendation 1 was even lower, approximately Rp75.1 million (7.56%) compared to the actual condition, even though the demolition volume increased by 49,428 BCM. If the same volume were demolished at the actual specific cost, the savings would reach approximately Rp401.1 million. This finding is in line with Ningrum et al. (2025) who showed that wider geometries provide lower costs per BCM.

In contrast, Recommendation 2 ranks last because adding subdrilling at the same burden and spacing actually deepens the hole, increasing the PF and specific costs. This result confirms the findings in subsection 3.2 that increasing depth is not an efficient way to increase volume. Recommendation 3 ranks second with a 10.55% decrease in specific costs and all parameters meet the ICI criteria. It should be noted that the 1 m subdrilling in Recommendation 1 is still below the ICI limit (1.6–2.4 m), so its implementation needs to be preceded by field trials to monitor the potential for boulders and toe protrusions; if such constraints arise, Recommendation 3 can be used as an alternative.

Conclusion

Blast hole depth has been shown to have a significant effect on explosive charge, powder factor, and specific blasting cost, with R^2 values of 0.9885; 0.9570; and 0.9505, respectively. At a fixed geometry of 7×8 m, each additional 1 m of depth adds approximately 38 kg of charge per hole and increases the PF by approximately 0.0445 kg/BCM. Since explosives absorb 81.55% of the cost of a single cycle, PF is the most important cost indicator. The actual geometry only managed to dismantle 75.31% of the target of 200,000 BCM. Of the three alternatives compiled based on ICI Explosives criteria, the 8 m burden geometry and 10 m spacing was the best choice because it met the target with 313 holes, reduced PF by 30.54% and specific cost by 30.40%. Companies are advised to test this geometry in the field, not to deepen the hole to meet the target, and to use PF as a routine cost indicator. Further research is needed to involve analysis of fragmentation, ground vibrations, and excavation costs for a more comprehensive geometric evaluation.

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Bibliography

Cahyanto, H., Saismana, U., Hakim, R. N., & Tohom, J. Y. P. (2017). Optimalisasi *cost* peledakan pada pembongkaran *limestone* di PT Pama Indo. *Jurnal GEOSAPTA*, 2, 104–107.

- Ghozali, I. (2018). *Aplikasi Analisis Multivariate dengan Program IBM SPSS 25* (Edisi 9). Semarang: Badan Penerbit Universitas Diponegoro.
- Himanshu, V. K., Bhagat, N. K., Vishwakarma, A. K., & Mishra, A. K. (2025). *Principles and Practices of Rock Blasting*. Abingdon, Oxon: CRC Press.
- ICI Explosives. (1989). [Lengkapi judul dan penerbit sesuai sumber ICI Explosives yang digunakan dalam skripsi].
- Iqbal, M. (2017). *Evaluasi Biaya Peledakan Batu Andesit pada Operasi Produksi PT Bukit Sari Investama, Jorong Simpang Tiga, Kecamatan Pangkalan Koto Baru, Kabupaten Lima Puluh Kota, Provinsi Sumatra Barat*. Padang.
- Nabella, A., & Razak, S. (2023). Studi fragmentasi batuan peledakan menggunakan metode *top air decking*. *Jurnal Inovasi Pertambangan dan Lingkungan*, 3(2), 54–64.
- Nabila, L. P., Wiratama, J., & Yulanda, Y. A. (2023). Evaluasi biaya peledakan dan geometri peledakan terhadap hasil fragmentasi pada proses pembongkaran batu kapur di PT Semen Padang. *Jurnal Pertambangan dan Lingkungan*, 4, 53–59. <https://doi.org/10.31764/jpl.v4i2.17987>
- Ningrum, B. W., Trides, T., Winonazada, R., Oktaviani, R., & Respati, L. L. (2025). Studi pengaruh geometri peledakan terhadap biaya pemboran dan biaya peledakan pada PT Unggul Dinamika Utama, Kabupaten Kutai Timur, Provinsi Kalimantan Timur. *Jurnal Publikasi Rumpun Ilmu Teknik*, 3, 141–155. <https://doi.org/10.61132/venus.v3i5.1158>
- Novalia, H., Farid, F., & Megasukma, Y. (2022). Kajian biaya peledakan pada proses pembongkaran batukapur di PT Semen Padang. *Jurnal Penelitian dan Pengabdian Masyarakat*, 1, 683–699.
- Oktaviani, N. (2019). *Analisis Nilai Powder Factor Peledakan untuk Mendapatkan Target Fragmentasi Batuan di Pit Main Ridge PT J Resources Bolaang Mongondow, Site Bakan, Sulawesi Utara* (Skripsi). Tangerang Selatan: UIN Syarif Hidayatullah Jakarta.
- Reksadipo, L. A., Razak, S., & Djamil, A. S. (2022). Analisis *overburden* peledakan untuk peningkatan produktivitas pada PT Putra Perkasa Abadi Kalimantan Timur. *Jurnal Inovasi Pertambangan dan Lingkungan*, 2(2), 30–36.
- Sugiyono. (2019). *Metode Penelitian Kuantitatif, Kualitatif, dan R&D*. Bandung: Alfabeta.