



## The Influence of Blast Hole Geometry on Limestone Fragmentation in Central Buton Regency

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### ABSTRACT

This study aims to analyze the effect of blast hole geometry on limestone fragmentation during blasting activities at PT Diamond Alfa Propertindo, Central Buton Regency, Southeast Sulawesi. The geometric parameters analyzed include burden, spacing, hole depth, fill column length, and stemming, while fragmentation quality is evaluated based on the average fragmentation size, P20, P50, P80 values, and top size using Split Desktop software. The study was conducted on five blasting activities with an evaluative quantitative approach through direct measurements in the field and analysis of digital images of the blasting results. The results showed that burden and spacing in all blasting activities were relatively constant at 3 m, while the main variations were found in hole depth, fill column length, and stemming. The average fragmentation size decreased from 0.64 m in the first blasting to 0.18 m in the fifth blasting. The Split Desktop results also showed a decrease in the P80 value from 647.04 mm to 184.59 mm, and a decrease in the top size from 800.30 mm to 313.51 mm. These findings indicate that changes in blasthole geometry, particularly hole depth, fill column length, and stemming, significantly impact the size distribution of limestone fragmentation. The fourth blasting session produced an average fragmentation of 0.39 m, still within the operational target range of 0.3–0.6 m, thus being considered the most proportional design to support efficient loading, transport, and material processing. This study confirms that controlling blasthole geometry is a critical factor in optimizing limestone blasting and increasing mine production efficiency.

## INTRODUCTION

Blasting is a crucial step in limestone mining operations, as it breaks down the rock mass into fragments that are easier to excavate, load, transport, and process during the crushing stage (Balamadeswaran et al., 2022). Blasting success is determined not only by the achieved production volume but also by the quality of the resulting rock fragmentation. Excessively fine fragmentation can reduce the productivity of the loading and unloading equipment, slow the hauling process, increase the need for secondary blasting, and increase the workload of the crusher (Roy et al., 2026). Conversely, excessively fine fragmentation can also result in material loss, increased dust generation, and inefficient use of explosive energy. Therefore, the size distribution of rock fragments is a key indicator in evaluating the success of a blasting design in limestone mining (Mutinda et al., 2025; Tavakol Elahi & Hosseini, 2017).

One technical factor that significantly influences fragmentation results is blasthole geometry. Geometric parameters such as burden, spacing, stemming, subdrilling, blasthole depth, and fill column length determine the distribution of explosive energy within the rock mass (Dotto, 2024). If the blasting geometry does not match the rock characteristics and the conditions of the platform, the explosive energy will not be optimally distributed, resulting in uneven fragmentation, boulders, toe problems, flyrock, excessive vibration, and low demolition efficiency. Studies in limestone mines have shown that





parameter settings such as burden, spacing, explosive quantity, and stemming length influence the distribution of post-blast fragmentation size (Zhu et al., 2023).

In open-pit mining practices, burden and spacing play a role in determining the volume of rock removed by each blasthole, while stemming serves to confine the explosive energy for more effective rock fragmentation (Singh, 2014). Subdrilling is necessary to reduce the possibility of protrusions forming on the platform floor, while blasthole depth and fill column length are directly related to the amount of energy imparted to the rock mass. Mismatches in any of these parameters can cause significant changes in fragmentation size. Research on limestone at PT Semen Padang shows that burden, spacing, and powder factor significantly influence blasting fragmentation, necessitating adjustments to blasting geometry to reduce the percentage of large fragments (Boy, Harahap & Yulhendra, 2021).

Rock fragmentation evaluation is currently often conducted using digital image analysis because it provides a more objective picture of fragment size distribution than visual observation alone. Software such as Split Desktop is used to analyze blasting pile images and generate size distribution parameters such as P80, average fragment size, and the percentage of escapes at specific sizes. Tavakol Elahi and Hosseini (2017) used Split Desktop to analyze fragmentation in a limestone mine and obtained F20, F50, F80 values, and maximum fragment size from several different blasting patterns. These findings demonstrate that digital image analysis can be used as an effective evaluation tool to compare blasting design performance.

Several previous studies have also emphasized the importance of optimizing blasting geometry in improving the technical and economic efficiency of mining operations. Balamadeswaran et al., 2022 demonstrated that appropriate blasting geometry design for limestone can produce fragmentation that is more suited to the equipment capacity and provides better economic returns. Another study at a limestone mine in Tuban showed that geometry design adapted to geological structural conditions can produce a more uniform fragmentation distribution and support increased production (Assegaff et al., 2020). This demonstrates that blasting geometry design cannot be formulated in a general manner but must consider the rock characteristics, geological conditions, and target fragmentation size at the research site.

PT. Diamond Alfa Propertindo, located in Central Buton Regency, Southeast Sulawesi, is a company that mines limestone using the blasting method. In its operations, the quality of rock fragmentation is a critical aspect because it is directly related to the efficiency of excavation, loading, transporting, and material processing. Variations in blasthole geometry in the field, even relatively small, can affect the quality of the resulting fragmentation. Therefore, a quantitative study is needed to determine the extent to which parameters such as burden, spacing, stemming, subdrilling, hole depth, and length affect the quality of the blasthole.

## RESEARCH METHODS

### Type of Research

This study used a quantitative evaluative method. This method was used to evaluate the effect of blasthole geometry on limestone fragmentation results. The data analyzed consisted of field measurements and fragmentation analysis using Split Desktop 2.0 software.





### Research Location

The study was conducted in the limestone mining area of PT. Diamond Alfa Propertindo, Central Buton Regency, Southeast Sulawesi Province.

### Research Variables

The independent variable in this study was blasthole geometry, including:

- a. Burden
- b. Spacing
- c. Stemming
- d. Subdrilling
- e. Blasthole depth
- f. Explosive charge column length

The dependent variable in this study was limestone fragmentation, including:

- a. P80 value
- b. Average fragment size
- c. Particle size distribution
- d. Percentage of fragmentation at target size 0.3–0.6 m

### Data Collection Techniques

Data were collected through direct field observation and company data collection. Primary data was obtained from measurements of the actual blasthole geometry and photographic documentation of blasting fragmentation. Secondary data was obtained from company documents, including information on blasting design, drilling pattern, explosive type, powder factor, and fragmentation target.

### Fragmentation Analysis

Rock fragmentation was analyzed using Split Desktop 2.0. Blasting photographs were entered into the software, followed by scaling, fragment delineation, manual correction, and particle size distribution analysis. The main results of this analysis were the P80 value, average fragment size, and the percentage of material within the target size range.

### Data Analysis Techniques

Data were analyzed descriptively and statistically. Descriptive analysis was used to describe the actual blasthole geometry and fragmentation results. Next, the relationship between blasthole geometry parameters and P80 values was analyzed to determine the parameters most influential on limestone fragmentation.

### Data Validation

Validation was performed by comparing the actual geometry with the blasting design, using representative fragmentation photographs, and manually correcting the Split Desktop 2.0 analysis results. Photos that did not have a clear scale or did not represent fragmentation conditions were not used in the analysis.

## RESULTS AND DISCUSSION

### Results

The study was conducted on five limestone blasting operations at PT. Diamond Alfa Propertindo. The observed blast hole geometry parameters included burden, spacing, hole depth, fill column length, and





stemming. Based on field data, the burden and spacing were relatively constant across all blasting operations, each at 3 m. The main differences were in hole depth, fill column length, and stemming, which then affected the size of the blasted rock fragmentation. In the first to fourth blasting operations, the hole depth ranged from 5.56–5.58 m with a fill column length of 4.8 m, while in the fifth blasting operation, the hole depth decreased to 2.95 m with a fill column length of 2.4 m. This change resulted in the finest fragmentation, namely 0.18 m.

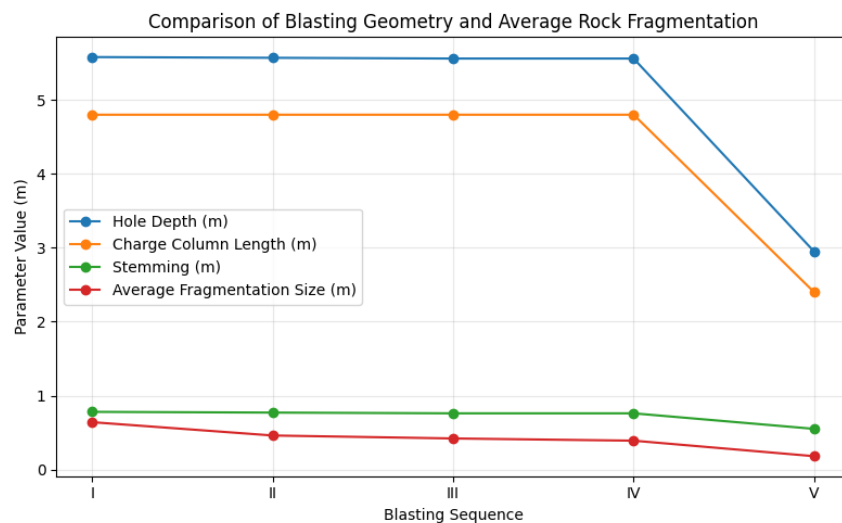
**Table 1.** Recapitulation of blast hole geometry and limestone fragmentation size

Blasting	Date	Burden (m)	Space (m)	Hole Depth (m)	Fill Column (m)	Stemming (m)	Average Fragmentation (m)
I	July 14, 2025	3,00	3,00	5,58	4,80	0,78	0,64
II	July 16, 2025	3,00	3,00	5,57	4,80	0,77	0,46
III	July 19, 2025	3,00	3,00	5,56	4,80	0,76	0,42
IV	July 21, 2025	3,00	3,00	5,56	4,80	0,76	0,39
V	July 23, 2025	3,00	3,00	2,95	2,40	0,55	0,18

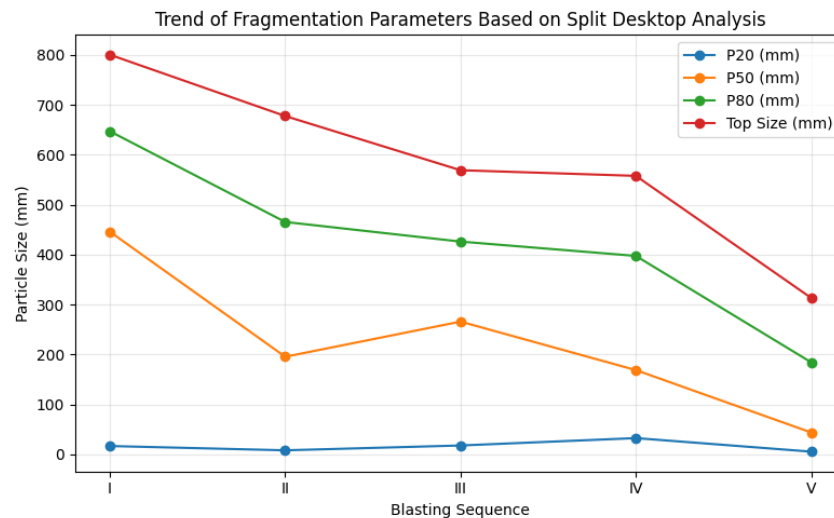
The results of the fragmentation analysis using Split Desktop showed that the P80 value decreased from 647.04 mm in the first blasting to 184.59 mm in the fifth blasting. The top size also decreased from 800.30 mm to 313.51 mm. This decrease indicates that changes in the geometric design, particularly hole depth, fill column length, and stemming, significantly improved fragmentation size.

**Table 2.** Summary of fragmentation results based on Split Desktop analysis

Blasting	P20 (mm)	P50 (mm)	P80 (mm)	Top Size (mm)
I	16,94	445,90	647,04	800,30
II	8,36	195,67	465,50	677,59
III	18,02	266,01	426,23	569,13
IV	32,79	168,98	397,56	557,84
V	5,70	44,11	184,59	313,51



**Figure 1.** Comparison of average blasting and fragmentation geometry



**Figure 2.** Trend of fragmentation parameters of Split Desktop results

## Discussion

The results of this study indicate that blasthole geometry significantly influences the quality of limestone fragmentation. Even though the burden and spacing were kept constant at 3 m, the fragmentation size still changed from 0.64 m to 0.18 m. This indicates that fragmentation is not only controlled by burden and spacing, but is also significantly influenced by hole depth, fill column length, and stemming. In the first blasting, with a hole depth of 5.58 m, a fill column of 4.8 m, and stemming of 0.78 m, the coarsest fragmentation was achieved at 0.64 m. Conversely, the fifth blasting, with a hole depth of 2.95 m, a fill column of 2.4 m, and stemming of 0.55 m, the finest fragmentation was achieved at 0.18 m.

Technically, these results demonstrate that the distribution of blasting energy is strongly influenced by the compatibility between the blasthole dimensions and the rock conditions. Deeper blastholes with larger fill columns do not necessarily result in better fragmentation if the energy is not effectively distributed throughout the rock mass. This condition can lead to the formation of large fragments or oversized material. Conversely, reducing the depth of the hole and the fill column in the fifth blasting process results in more concentrated explosive energy in a smaller volume of rock, resulting in a more effective rock crushing process.

Based on the P80 value, the best fragmentation quality was achieved in the fifth blasting, with a P80 of 184.59 mm and a top size of 313.51 mm. This value is significantly lower than the first blasting, which had a P80 of 647.04 mm and a top size of 800.30 mm. The decrease in P80 indicates a significant increase in the proportion of smaller-sized material. Therefore, the fifth blasting can be considered to produce the most effective fragmentation in terms of material size, as it better supports loading, transporting, and processing using a crusher.

However, excessively fine fragmentation also needs to be evaluated against the company's operational needs. If the target fragmentation size is in the range of 0.3–0.6 m, the second to fourth blasts are relatively more suitable, producing average fragmentation of 0.46 m, 0.42 m, and 0.39 m, respectively. The first blast tends to produce coarser fragmentation, while the fifth blast produces very fine fragmentation. Therefore, the most operationally balanced blasting design is a geometry with a burden of 3 m, a spacing of 3 m, a



hole depth of approximately 5.56–5.57 m, a charge column length of 4.8 m, and stemming of approximately 0.76–0.77 m, as this still produces fragmentation within the target range.

These findings reinforce the point that optimizing blasting geometry is not sufficient by simply maintaining burden and spacing; it also requires considering the relationship between hole depth, charge column length, stemming, and target fragmentation. In the context of limestone mining operations, uniform fragmentation will speed up the loading and hauling processes, reduce the need for secondary blasting, and improve crusher efficiency. Thus, controlling the blasthole geometry becomes a key factor in increasing blasting productivity and cost efficiency.

### Summary of Key Findings

Overall, the research results prove that variations in blast hole geometry directly affect limestone fragmentation. The most visible parameters are hole depth, fill column length, and stemming. The fourth blasting can be considered the most proportional design because it produces 0.39 m fragmentation which is still within the target of 0.3–0.6 m, while the fifth blasting produces the finest fragmentation with P80 184.59 mm. Technical recommendations that can be given are to maintain burden and spacing of 3 m, control stemming consistently, and adjust hole depth and fill column length based on the fragmentation target and production equipment capacity.

**Table 3.** Technical Interpretation of Blasting Results

Blasting	Fragmentation Character	Technical Interpretation
I	The roughest	Potential to produce oversized material and reduce loading efficiency
II	On target	Fragmentation is relatively good for loading and hauling processes.
III	On target	Fragmentation is more uniform and still within the operational range.
IV	On target	Optimal fragmentation with an average size of 0.39 m
V	The smoothest	Very effective in size reduction, but needs to be evaluated against target production requirements.

### CONCLUSION

Based on the results of a study of five limestone blasting operations at PT Diamond Alfa Propertindo, it can be concluded that blasthole geometry significantly affects the quality of rock fragmentation. Burden and spacing parameters remained relatively constant throughout all blasting operations, each at 3 m. However, changes in blasthole depth, fill column length, and stemming resulted in significant differences in fragmentation size.

The average fragmentation size showed a decreasing trend from the first to the fifth blasting operation, from 0.64 m to 0.18 m. The P80 value from the Split Desktop analysis also decreased from 647.04 mm in the first blasting operation to 184.59 mm in the fifth. This decrease indicates that appropriate blasthole geometry can improve the effectiveness of blasting energy distribution throughout the rock mass.

The first blasting operation produced the coarsest fragmentation, with an average size of 0.64 m and a top size of 800.30 mm, potentially increasing oversized material and reducing loading and processing efficiency. In contrast, the fifth blasting design produced the finest fragmentation, with an average size





of 0.18 m and a P80 of 184.59 mm. However, excessively fine fragmentation still needs to be evaluated against the company's production needs and material size targets.

Of the five blasting designs analyzed, the fourth blasting design can be considered the most proportional, producing an average fragmentation of 0.39 m, which is still within the operational target range of 0.3–0.6 m. The geometry under these conditions consisted of a burden of 3 m, a spacing of 3 m, a hole depth of 5.56 m, a filling column length of 4.8 m, and stemming of 0.76 m.

In general, limestone fragmentation optimization is determined not only by burden and spacing, but also by the balance between hole depth, filling column length, and stemming. Therefore, controlling these three parameters requires a primary focus in blasting design to produce more uniform fragmentation, reduce oversized material, accelerate the loading-hauling process, and improve crusher efficiency and mine production costs.

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He hopes that the results of this research will provide scientific contributions and practical benefits in developing more effective and efficient blasting geometry designs that meet the operational needs of limestone mining.

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