

# **EVALUATION STUDY OF BLAST-INDUCED ROCK FRAGMENTATION USING STEMROCK AND BLASTBAG AIR DECK SYSTEMS WITH THE KUZ-RAM METHOD AT THE LIMESTONE QUARRY NAROGONG SITE OF PT SOLUSI BANGUN INDONESIA TBK**

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## **ABSTRACT**

PT Solusi Bangun Indonesia Tbk (SBI) has implemented air-deck technology in limestone blasting to optimize explosive consumption while maintaining the required fragmentation quality. This study aims to evaluate and compare the performance of two types of air-deck systems, namely stemrock and blastbag, in producing suitable rock fragmentation at the Sijebi Quarry, Narogong. The research was conducted through three blasting trials with geometry design based on ICI Explosives guidelines and fragmentation prediction using the Kuz-Ram model. The blasting parameters evaluated included burden, spacing, stemming, subdrilling, and charge column length. The results indicate that stemrock air-deck with a 7.5 m primer charge produced 87.12% of fragments smaller than 50 cm, whereas blastbag air-deck under the same conditions achieved 95.31%. However, other trials using blastbag produced coarser fragmentation with fragments exceeding 100 cm. Overall, the most reliable fragmentation distribution, closely aligned with Kuz-Ram predictions, was obtained with a blasting geometry of 4 m burden, 5 m spacing, 3 m stemming, 1 m subdrilling, and a 7.5 m primer charge using ANFO in limestone. This study recommends the aforementioned blasting geometry as the optimal configuration for achieving efficient and effective fragmentation in limestone quarry operations.

**Keywords:** Air Deck, Stemrock, Blastbag, Fragmentation, Kuz-Ram.

## **1. INTRODUCTION**

### **1.1 Background**

PT Solusi Bangun Indonesia Tbk (SBI), in its mining operations, conducts limestone blasting to fragment the rock prior to loading and hauling to the crusher. In the current blasting practice, the Stemrock-type air-deck method has been applied, which has proven effective in reducing the consumption of ANFO explosives while still producing fragmentation that meets the specifications required for crusher feed.

Innovations in blasting technology continue to evolve, with air-decking first invented and patented by Saunders in Germany in 1891, and later refined and introduced by Pat McLaughlin in 1893 for open-pit blasting applications. As part of its commitment to implementing

innovative blasting technologies, SBI consistently pursues programs aimed at identifying the most effective and efficient methods. Effectiveness is defined as the capability of the air-deck technique to minimize explosive consumption while maintaining the required fragmentation distribution, whereas efficiency refers to the cost of air-deck devices being significantly lower than the overall cost savings from reduced explosive use.

The air-deck product selected for comparison with the existing method is the BlastBag, a more advanced technology compared to Stemrock. Stemrock air-decking was first applied during the modern industrial era, around the 1980s to 2000s, as an effort to improve blasting efficiency. Meanwhile, BlastBag air-decking was introduced in the early 2000s by a mining technology

company and has been claimed to be more practical and flexible. Therefore, an evaluation is required to compare the blasting performance of Stemrock and BlastBag air-deck systems in limestone quarry operations at SBI, focusing on fragmentation distribution within the specification range required for hammer crusher feed.

### 1.2 Objectives

The objectives of this study are as follows:

1. To evaluate the fragmentation of limestone blasting results using Stemrock and BlastBag air-deck systems.
2. To compare actual fragmentation with fragmentation predicted by the Kuz-Ram model based on blasting geometry design.
3. To provide recommendations for the optimal blasting geometry for each type of air-deck system used.

### 1.3 Significance

The significance of this study can be summarized as follows:

1. To identify the more effective type of air-deck system for limestone quarry operations as a basis for further evaluation regarding efficiency.
2. To determine the actual fragmentation distribution in reference to the blasting geometry design.
3. To identify the optimal blasting geometry for each type of air-deck system applied.

## 2. RESEARCH METHODS

### 2.1 Research Place

The research was conducted at the Limestone Quarry, Pit Sijebi, PT Solusi Bangun Indonesia Tbk – Narogong site.

### 2.2 Research Methodology

The methodology applied in this study is a causal-comparative approach, in

which blasting using the Stemrock air-deck system is considered as the independent variable, while blasting using the Blastbag air-deck system is treated as the dependent variable. Data were collected from three blasting trials conducted over three separate days at different locations within the quarry, yet under relatively similar rock mass characteristics.

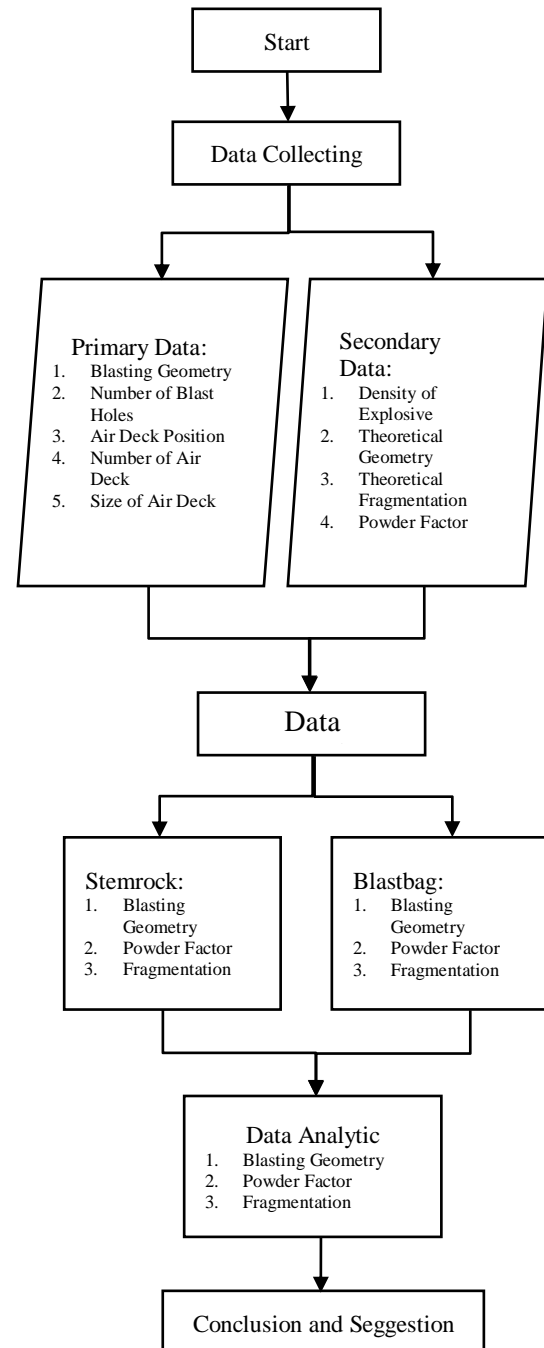


Figure 1. Flow Chart of Research Methodology

equations as follows:

The data collection was conducted using both direct (primary) and indirect (secondary) approaches. The primary data collected on-site included blasting geometry, the number of blast holes for each type of air-deck system, the position of the air-deck within the total borehole length, the quantity of each air-deck type, the dimensions of each air-deck, and the installation time efficiency of each air-deck system. Secondary data, obtained from relevant literature, included explosive density, theoretical blasting geometry, theoretical rock fragmentation, and powder factor values.

### 2.3 Study Literature

#### **Explosive**

According to Konya and Walter (1990) in *Surface Blast Design*, explosives are employed to disintegrate compact rock masses on the earth's surface into fragmented material, thereby facilitating subsequent processes such as excavation, loading, and hauling for further processing. In this study, the explosive utilized is ANFO, with the initiation system consisting of non-electric detonators and dynamite as the primer.

#### **Blasting Geometry**

According to Jimeno, A. & Jimeno, C. (1995) in *Blasting Principles for Open Pit Mining*, blasting geometry refers to the relative position of blast holes on a mining bench in relation to the influence area of the blast, whether with respect to a free face or to adjacent blast holes. Blasting geometry is one of the most critical variables in achieving the desired rock fragmentation. The parameters of blasting geometry—such as bench height, burden, spacing, sub-drilling, and stemming—can be determined through trial-and-error methods based on the empirical rules of thumb introduced by ICI-Explosives. Theoretical calculations of blasting geometry can also be performed using the ICI-Explosives

1. Bench Height (H)  
 $H = 60d \text{ to } 140d$  (1)

2. Burden (B)  
 $B = 25d \text{ to } 40d$  (2)

3. Spacing (S)  
 $S = 1B \text{ to } 1,5B$  (3)

4. Subdrilling (J)  
 $J = 8d \text{ to } 12d$  (4)

5. Stemming (T)  
 $T = 20d \text{ to } 30d$  (5)

Description:

$d = \text{blast hole diameter}$

#### **Air-Decking Blasting**

According to Pat McLaughlin (1981) in *Practical Applications of Airdeck Blasting*, air-deck blasting is defined as a blasting technique in which an intentional air space is created within the borehole column to redistribute explosive energy and enhance blasting efficiency. In this study, two types of air-deck systems are applied, namely the stemrock and the blastbag.

##### 1. Stemrock Air Deck

According to Chiappetta (1987) in *Air Deck Blasting in Surface Mines*, the stemrock air-deck (also known as the ball deck) is a blasting technique in which an empty space (deck) is created within the borehole and separated by a ball plug device made of inert materials such as plastic, rubber, wood, or other hard substances. The ball functions as a barrier to hold the column material inside the borehole, thereby forming an air gap between two different materials, either between explosive charges or between explosives and stemming material.



Figure 2. Stemrock Air Deck

## 2. Blastbag Air Deck

The blastbag air deck type was first introduced by the Australian company MTi Group Pty Ltd in the early 2000s. A blastbag air deck is a flexible inflatable device that can be expanded using air or gas and placed inside a borehole to create a controlled artificial air deck. In its early development, several blastbag designs utilized pressurized canisters to fill the bag with gas; however, in current commercial practice, blastbag products are generally simple inflatable bags that are filled with air.



Figure 3. Blastbag Air Deck

### Kuz-Ram Method

The Kuz-Ram method is an empirical approach used to predict the rock fragmentation size resulting from blasting activities. This method is a combination of the Kuznetsov equation, which estimates the mean fragment size, and the Rosin-Rammler distribution, which describes the particle size distribution.

## 1. Kuznetsov's Equation (1973)

$$Xm = Ax\left(\frac{V}{Q}\right)^{0,8} \times (Q)^{0,17} \times \left(\frac{E}{115}\right)^{-0,63}$$

Keterangan:

$X$  = Average size of Rock Fragment (cm)

$A$  = Rock Factor

$V$  = Rock Volume (m)

$Q$  = Explosive mass per hole (kg)

$E$  = RWS ANFO = 100

## 2. Rosin-Ramler's Equation (1933)

$$Rx = e^{-\left(\frac{x}{xc}\right)^n} \times 100\%$$

Keterangan:

$Rx$  = Retained Material (%)

$X$  = Sieve size

$$Xc = \frac{x}{(0,693)^{1/n}}$$

$e$  = *epshilon* = 2,71

$n$  = *uniformity index*

## 3. Kuz-Ram's Equation (Cunningham, 1983)

$$n = \left(2,2 - 14 \frac{B}{De}\right) \times \left(\frac{1+A}{2}\right)^{0,5} \times \left(1 - \left(\frac{B}{De}\right) \times \left(\frac{PC}{L}\right)\right)$$

Keterangan:

$B$  = *Burden*

$De$  = *Blast Hole Dimater*

$We$  = *Standard deviation of hole depth*

$A$  = *Spacing*

$L$  = *Bench Height*

## 3. RESULTS AND DISCUSSION

This research was conducted over three separate days at relatively similar locations, following a comparative scheme of rock fragmentation resulting from blasting using the air-deck technique. On the first and third days, blasting was carried out in adjacent areas using both the stemrock air-deck and the blastbag air-deck systems. On the second day, blasting was performed exclusively with the blastbag air-deck system in order to evaluate its fragmentation results more independently.

Table 1. First Day Blasting Geometry

Blasting Geometry	Theory	Actual 1st Day	
		ICI Explosives	Stemrock Blastbag
Burden (m)	3,18 – 5,08	4	4
Spacing (m)	3,18 – 7,62	5	5
Stemming (m)	2,54 – 3,81	3	3
Sudrilling (m)	1,02 – 1,52	1	1
Primer Charge (m)	6,1 – 15,5	7,5	6,5
Hole Depth (m)	8,64 – 19,3	11	11
Air-Decking (m)	-	0,13	0,5
Air Gap (m)	-	0,5	1,5

Table 2. Second Day Blasting Geometry

Blasting Geometry	Theory	Actual 2nd Day	
		ICI Explosives	Blastbag
Burden (m)	3,18 – 5,08	4	
Spacing (m)	3,18 – 7,62	5	
Stemming (m)	2,54 – 3,81	3	
Sudrilling (m)	1,02 – 1,52	1	
Primer Charge (m)	6,1 – 15,5	7	
Hole Depth (m)	8,64 – 19,3	11	
Air-Decking (m)	-	0,5	
Air Gap (m)	-	1	

Table 3. Third Day Blasting Geometry

Blasting Geometry	Theory	Actual 2nd Day	
		Stemrock	Blastbag
Burden (m)	3,18 – 5,08	4	4
Spacing (m)	3,18 – 7,62	5	5
Stemming (m)	2,54 – 3,81	3	3
Sudrilling (m)	1,02 – 1,52	1	1
Primer Charge (m)	6,1 – 15,5	7,5	7,5
Hole Depth (m)	8,64 – 19,3	11	11
Air-Decking (m)	-	0,13	0,5
Air Gap (m)	-	0,5	0,5

### Fragmentation Distribution

In predicting the distribution of blasting results, this study applies the Kuz-Ram equation, which incorporates several variables such as rock characteristics, explosive properties, and blasting geometry. A comparison is then made between the theoretical fragmentation predicted by the Kuz-Ram model and the actual fragmentation obtained from blasting trials.

The theoretical calculation of rock fragmentation distribution resulting from blasting was carried out using the following parameters: the explosive used was ANFO, the blasted limestone had an average density of 2.12 g/cm<sup>3</sup>, bench height = 10 m, burden = 4 m, spacing = 5 m, stemming = 5 m, subdrilling = 1 m, primer charge = 7.5 m, hole depth = 11 m, and hole diameter = 5 inches.

Table 4. Prediction of Distribution Fragmentation

Fragment Size (cm)	P (< x) (%)	P (> x) (%)
2,5	15,5%	84,5%
5	28,6%	71,4%
10	49,1%	50,9%
20	74,1%	25,9%
30	86,8%	13,2%
40	93,3%	6,7%
50	96,6%	3,4%
75	99,4%	0,6%
100	99,9%	0,1%
200	100,0%	0,0%
400	100,0%	0,0%

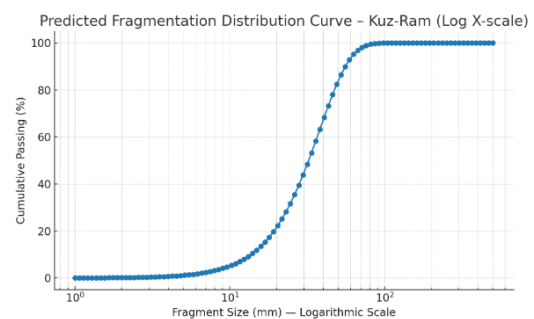


Figure 4. Kuz-Ram Prediction Curve

The actual distribution of blast-induced rock fragmentation was obtained from fragmentation documentation by comparing it with spherical reference objects of 50 cm in diameter. The results

of the actual fragmentation analysis are presented as follows.



Figure 5. First Day Fragmentation Distribution



Figure 6. Second Day Fragmentation Distribution



Figure 7. Third Day Fragmentation Distribution

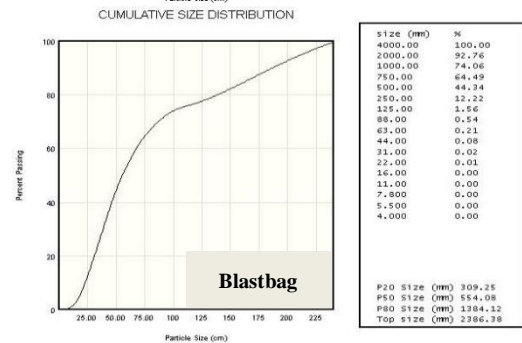
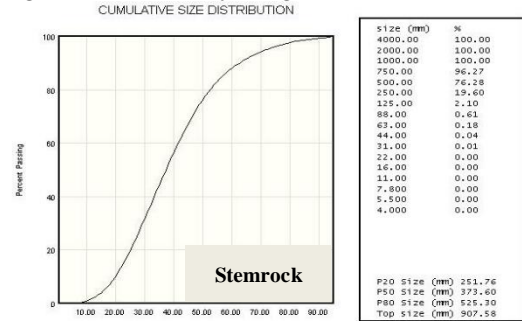


Figure 8. First Day Fragmentation Curve

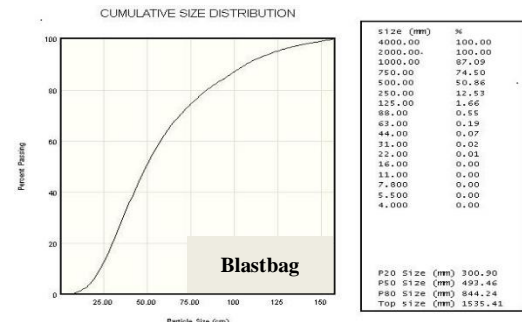
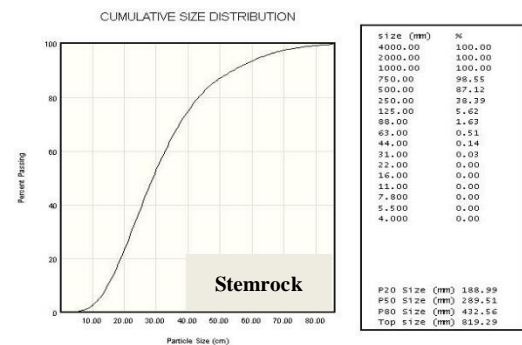


Figure 9. Second Day Fragmentation Curve



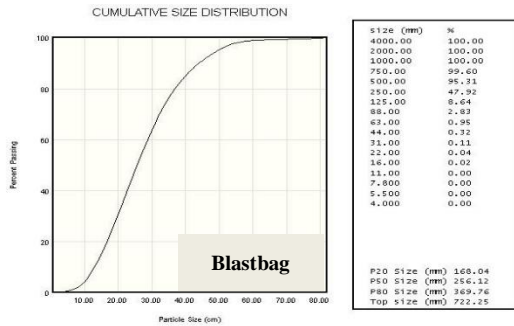


Figure 10. Third Day Fragmentation Curve

## 4. CONCLUSION

### 4.1 Conclusion

Based on observations of the blast-induced rock fragmentation distribution, the following conclusions can be drawn:

- The distribution of rock fragmentation from blasting can be categorized as follows:
  - On the first blasting day, using stemrock (primer charge 7.5 m), the proportion of rock fragments smaller than 50 cm was 76.28%, whereas using a blastbag (primer charge 6.5 m) it was 64.49%, with some fragments exceeding 200 cm.
  - On the second blasting day, using a blastbag (primer charge 7 m), the proportion of rock fragments smaller than 50 cm was 50.86%, with fragments exceeding 100 cm also present.
  - On the third blasting day, using stemrock (primer charge 7.5 m), the proportion of rock fragments smaller than 50 cm was 87.12%, whereas using a blastbag (primer charge 7.5 m) it reached 95.31%.
- The distribution of rock fragmentation that most closely aligns with the expected or theoretical fragmentation prediction was achieved under the existing blasting geometry with a primer charge of 7.5 m.
- The ideal blasting geometry for both types of air-deck configuration is characterized by the following parameters: ANFO explosive, limestone rock, hole diameter = 5 inches, bench height = 10 m, burden = 4 m, spacing = 5 m, stemming = 3 m,

subdrilling = 1 m, and primer charge = 7.5 m.

### 4.2 Suggestion

- This study has not yet comprehensively compared the quality of rock fragmentation resulting from blasting using stemrock and blastbag. Therefore, further research is required with a larger dataset and more balanced consideration of the parameters or factors influencing fragmentation.
- This study has also not discussed in detail the costs associated with each device (stemrock and blastbag). Hence, if economic feasibility data are required, a separate study within the scope of business feasibility analysis can be conducted.

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