**International Journal of Applied Sciences and Smart Technologies**

Volume 5, Issue 2, pages 195-212

p-ISSN 2655-8564, e-ISSN 2685-9432

# Analysis of Blasting Geometry on Blasting Production Results at PT Semen Bosowa Maros

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(Received 23-05-2023; Revised 13-06-2023; Accepted 22-06-2023)

**Abstract**

Limestone mining for cement plants uses a blasting method to break the material. Blasting production is considered successful when it can achieve production targets based on tonnage of uncovered rock, efficient use of explosives, grain size or rock fragmentation, and environmental impact. This research aims to analyze the blasting geometry on the production results at the research location by knowing the initial design, the actual blasting geometry, and the geometry recommendation using the C.J. Konya method. In addition, researchers also know the explosives used, the production results in the form of material fractionation using the Kuz-Ram method, and the tonnage of uncovered rocks. The initial design with a burden of 3.4 m, spacing of 3.4 m, hole depth of 5.9 m, and ANFO explosives per hole of 33 kg produced 147.31 tonnages. The actual geometry with a burden of 1.7 m, spacing of 3.5 m, hole depth of 6.0 m, and ANFO explosives per hole of 26.73 kg produced a 77.11 tonnage. The actual geometry resulted in a blasting production of 6,941 tonnes per day, which did not meet the company's production target of 10,639. The fragmentation calculation results obtained an average size in the field of 15.29 cm, which meets the required screening or sieve criteria of 0.80 - 1.00 m. The size of the fragments also follows the sieve calculation using the Kuz-Ram method, with a 100 cm sieve passing only 0.01 %. Based on this, the company is recommended to make geometry changes to achieve the production tonnage target that has been set.

***Keywords:*** blasting, geometry, fragmentation, tonnage

## 1 Introduction

In mining activities, blasting is one of the methods that can be used for material dismantling. Blasting production is considered successful when it can achieve production targets based on tonnage of uncovered rock [1], efficient use of explosives [2], grain size or rock fragmentation [3], and environmental impact [4]. Blasting activities aim to



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destroy rocks to facilitate and facilitate the excavation process with an excavator. Blast planning in the form of blast geometry and the use of explosive quantity affect the blast result [5].

The results of explosions, called explosive eruptions, range from the smallest size, such as pebbles, to boulders. Chunks formed during the explosion are called oversize. To prevent the formation of chunks or to obtain a uniform size according to the needs of the crusher, it is necessary to adjust the geometry of the explosive to the rock fragmentation caused by the explosion [6] [7]. The production of rock fragmentation is a prerequisite for successful blasting, which requires the proper use of explosives to prepare to fire holes, handle explosives, load explosives, and assemble detonators [8].

Increased production results must be done to meet the cement plant's needs. One of the things that can affect these results is the blasting activity itself. Therefore, an analysis of blasting geometry on blasting production results needs to be done to meet the increased blasting production target. Based on this, the author conducted this research to provide recommendations for increasing blasting yields to meet factory needs at PT Semen Bosowa Maros.

# 2 Research Methodology

## a. Measurement of blasting geometry

Data collection began with measuring the diameter of the blast hole resulting from drilling, the depth of the blast hole resulting from drilling, the burden, borehole spacing, and the amount of explosive charge in the blast hole by measuring with a rolling meter. Figures 1 and 2 show the blasting geometry and explosive charge measurements.

**Figure 1.** Blasting geometry measurement

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**Figure 2.** Filling and measuring of explosive contents

### b. Explosive Identification

Explosive data was obtained from company data and directly observed explosives processing at the explosives warehouse. Processing is mixing ammonium nitrate and fuel oil explosives into ANFO which will be used in blasting activities. Figure 3 shows the mixing of the explosives used.

**Figure 3.** Mixing of the explosives used

### c. Measurement of blasting production output

Blasting production data in mining activities was obtained from company data at the mine planning division of PT Semen Bosowa Maros. In addition, the author also directly observed the blasting results in the mining pit and the fragmentation of the blasting results at the mouth (hopper) of the crusher. Figure 4 shows the mining pit and crusher hopper.

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**Figure 4.** Mining pit and crusher hopper

## d. Rock Sampling

The last activity in the field was the collection of rock samples at the research site to identify the physical and mechanical properties of rocks associated with blasting activities. Rock samples are taken in the form of chunks that meet the test requirements using the tool shown in Figure 5 below.


**Figure 5.** Sampling equipment and rock samples

## e. Preparation and Testing of Physical Properties and Mechanical Properties

The samples obtained from the field were then brought to the laboratory for testing. The testing process begins with preparing the sample in advance according to the test requirements. Sample in the boulder form is first drilled using a drilling machine and cut according to the Geomechanics Laboratory of Universitas Muslim Indonesia provisions. Figure 6 shows the drilling and cutting of rock samples.

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**Figure 6.** Drilling and cutting of rock sample

Testing of physical and mechanical properties uses testing standards according to the International Rock Mechanics Society (IRMS). The prepared samples were then tested for physical properties by weighing the weight of natural samples, the weight of saturated samples, the weight of saturated samples suspended in water, and the weight of dry rock samples. After that, mechanical properties testing was carried out with the uniaxial compressive strength (UCS) test type to determine the compressive strength value of the rock. Figure 7 shows physical properties and mechanical properties testing (UCS).

**Figure 7.** Physical properties and mechanical properties testing (UCS)

The field and laboratory testing data are then processed and analyzed. The data processing includes blasting production calculation, rock fragmentation calculation using the Kuz-Ram method, and explosive usage recommendation and blasting geometry calculation using the C.J. Konya method.

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# 3 Results and Discussions

PT Semen Bosowa Maros uses an open pit mining system with a quarry mining method with the help of blasting to break the material before excavation or retrieval of mining material which is the raw material for the company's cement factory. The rock found at the research site is limestone with physical properties: average density of 2.16 tonnes/m$^3$, porosity of 4.12 %, and uniaxial compressive strength of 25.73 MPa. The rocks at the study site are categorized as soft rock according to the classification of rocks based on material strength, according to Bienieawski (1973) [9] and the International Society for Rock Mechanics (1981) [10].

## 3.1. Initial Blasting Design Parameters

Every company that will use the blasting method in dismantling its mining material must conduct a study to obtain an initial design of the geometry and explosives that will be applied later by the Ministry of Energy and the Mineral Resources Republic of Indonesia Regulation No. 1827 K/30/MEM/2018 concerning Guidelines for the Implementation of Good Mining Engineering Principles [11]. The following are the parameters of the initial design of blasting activities at the research site.

a) Blasting Geometry

The design geometry is a geometry that PT Semen Bosowa Maros has calculated. The following Table 1 shows the results of the design geometry calculation:

**Table 1.** Initial geometry of the blast design

| Geometry Parameters | Geometry Values |
|---|---|
| Diameter of blast hole (De) | 4.5 Inch / 114.3 mm |
| Burden (B) | 3.4 meters |
| Spacing (S) | 3.4 meters |
| Borehole depth (L) | 6.2 meters |
| Stemming (T) | 2.2 meters |
| Fill-in column (PC) | 4.0 meters |
| Bench height (H) | 5.9 meters |
| Subdrilling (J) | 0.3 meters |
| Specify gravity (SG) | 0.81 tonnes/BCM |
| Rock Density | 2.16 tonnes/m$^3$ |

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b) The volume of Rock Blasted Per blast hole

The blasting volume results from the blasting geometry of an open pit mine that generally applies bench blasting or bench blasting depending on the load, spacing, and height of the bench. The planned volume obtained is 147.32 tonnes in each hole. This value is derived from the three parameters above multiplied by the rock density of 2.16 tons/m$^3$.

c) Loading Density

Loading density is the amount of explosive charge per meter length of the charge column that will be inserted into the blast hole. The design loading density value is 8.25 kg/m.

d) Number of Explosives

The explosive design uses ammonium nitrate and fuel oil or ANFO, whose value is obtained by multiplying the loading density by the length of the filling column to obtain the number of blast holes per hole of 33.00 kg.

e) Powder Factor

The powder factor is one of the important parameters in blasting activities that shows the amount of material uncovered by a certain amount of explosives. The design powder factor is 0.18 kg/m$^3$.

### 3.2. Actual Blasting Parameters

The design produced before the blasting activity becomes the reference in conducting the blasting activity. However, these parameters often differ from those applied [12] [13]. The following are the actual parameters of blasting activities the company applies at the research site.

a) Blasting Geometry

The actual geometry is the geometry applied by PT Semen Bosowa Maros. Table 2 shows the company's actual geometry after drilling and inserting explosives. The following is the actual geometry applied:

**Table 2.** Actual geometry after blast hole drilling

| Geometry Parameters | Geometry Values |
|---|---|
| Diameter of blast hole (De) | 4.5 Inch / 114.3 mm |
| Burden (B) | 1.7 meters |
| Spacing (S) | 3.5 meters |
| Borehole depth (L) | 6.0 meters |
| Stemming (T) | 2.4 meters |
| Fill-in column (PC) | 3.24 meters |
| Bench height (H) | 6.0 meters |
| Subdrilling (J) | 0.0 meters |
| Specify gravity (SG) | 0.81 tonnes/BCM |
| Rock Density | 2.16 tonnes/$m^3$ |

b) Volume of Rock Blasted Per blast hole

The volume of blasting results from the blasting geometry in the open pit mine obtained based on the actual geometry applied by the company. The volume of rock is 77.11 tonnes in each hole. The volume was obtained using a burden of 1.7 m and a distance of 3.5 m between blast holes.

c) Loading density

The loading density used in the actual blasting activity was the same as the initial design, with a value of 8.25 kg/m.

d) Number of Explosives

Similarly, the amount of explosive used in one hole is the same as the design value, which is 26.73 kg with an explosive fill length of 3.24 m.

e) Powder Factor

The powder factor is still the same as the 0.75 kg/$m^3$ design parameter.

f) Explosives

Explosives have different characters, whether they are general or industrial explosives. Different types of explosives will produce different material explosions. The greater the explosive's energy, the greater the effect on the rock and surrounding area. PT Semen Bosowa Maros uses ANFO explosives. ANFO is an explosive that consists of a mixture of ammonium nitrate from PT Dahana and fuel oil in a 94.2 : 5,8% ratio. The average detonation speed for this explosive is 4170 m/sec.

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These explosives are generally used in dry blast-hole conditions. However, suppose it rains and causes the blast hole to fill with water. In that case, the company removes the water from the blast hole with a pump, and then the ANFO explosives are put into linear plastic so that the explosives do not dissolve in water or wet blast hole walls, after which the blast hole is closed with stemming.

### 3.3. Fragmentation of Blasted Material

Rock fragmentation or grain size of the blasted rock is one of the most important factors in assessing the success of blasting activities expressed by the size of the material or rock following the standards or design of the company [14]. The success of blasting can increase the yield of the production target [15], increase productivity [16], reduce haulage costs [17] and reduce secondary blasting, which can lead to over-utilization of the cost [18]. The rock fragmentation size required by PT Semen Bosowa Maros is 0.80-1.00 meters to meet the capability of the hopper crusher. Figure 8 shows rock Fractionation in the Hopper Crusher.

**Figure 8.** Rock Fractionation in the Hopper Crusher

Rock fragmentation in the field is calculated by first identifying rock conditions using the rock mass weighting method for blasting (Table 3). The following is the calculation of rock fragmentation using the Kuz-Ram method using actual blasting parameter data.

**Table 3.** The blastability index parameters for PT Semen Bosowa blasting

| | |
|---|---|
| **Rock Mass Description (RMD)** | |
| Blocky | 20 |
| **Joint Plane Spacing (JPS)** | |
| Wide (spacing > 1 m) | 50 |
| **Joint Plane Orientation (JPO)** | |
| Dip into face | 40 |
| **Specific Gravity Influence (SGI)** | 4 |
| **Hardness (H)** | 3 |

a) Rock Factor

The factor that affects the rock factor value comes from the blast ability index, which shows the condition of the rock to be blasted. Previous researchers have calculated blast ability with rock mass description, which is blocky with a value of 20, joint plane spacing, which is wide with a value of 50, joint plane orientation, which is dip into the face with a value of 40, specific gravity influence worth four and hardness or hardness worth three [19]. This data shows the rock factor value of 6.42.

b) Average Size of Rock Fragmentation

The average rock fragmentation is obtained using the equation from Kuz-Ram, which is useful to determine the average size of the blasting results and becomes a determining factor in determining the geometry of the recommendation so that the rock can fit the size of the crusher hopper opening. The average size of the resulting rock fragmentation results from the volume of uncovered rock, the number of explosives in each hole drilled, and the relative weight strength of the explosives used, namely, ANFO. Based on this, the average fragmentation size in the field is 15.29 cm.

c) Index of Uniformity (n)

The uniformity index shows the distribution of similarity of grain size or fragmentation of blasting results based on blasting design parameters, including the standard deviation of drilling activities, especially the depth of the borehole. A small standard deviation value indicates minimal borehole non-uniformity [20]. The uniformity index of rock fragmentation at the study site is 1.81. This value is within the generally accepted range of values between 0.8 and 2.2.

d) Rock Size Characteristics

Rock size characteristics are based on the average grain size, and uniformity index values show that the smaller these characteristics, the more uniform the blasted rock. The characteristic value of rock size at the research location is 18.72 cm.

e) Fragmentation Size Distribution of Retained Rocks

This distribution shows the rock size distribution on several sizes of sieving material, which is a means of assessing grain size after blasting activities. Each sieve has a different size. The distribution of rock size obtained will be smaller if the sieve used is larger. In this study, an increase in sieve size is used every 10 cm so that the percentage of material that does not pass on the sieve can be known. The following Table 4 is the fragmentation size distribution.

**Table 4.** Distribution of fragmentation retained on the sieve

| **Material Sieving Size** (cm) | **Fragmentation Distribution** (%) |
|---|---|
| R 10 | 38,04 |
| R 20 | 14,47 |
| R 30 | 5,51 |
| R 40 | 2,09 |
| R 50 | 0,80 |
| R 60 | 0,30 |
| R 70 | 0,12 |
| R 80 | 0,04 |
| R 90 | 0,02 |
| R 100 | 0,01 |

In calculating the percentage of material retained on the sieve, the results show that the material retained on the 10 cm size sieve is 38.04%, the 20 cm size sieve is 14.47%, the 30 cm size sieve is 5.51%, the 40 cm size sieve is 2.09%, the 50 cm size sieve is 0.80%, the 60 cm size sieve is 0.30%, the 70 cm size sieve is 0.12%, the 80 cm size sieve is 0.04%, the 90 cm size sieve is 0.02%, and the 100 cm size sieve is 0.01%.

f) Fragmentation Size Distribution of Unretained Rocks

The percentage of rock grain size distribution that passes or is not retained on each sieve must also be known. The method used to obtain the value of the material pass rate from the blasting process with various sizes on the sieve was used, namely the Kuz-Ram method. Although this method has shortcomings, it needs to consider several external factors in its calculations, such as delay time settings, free fields, and the potential presence of water in the blasting hole [19]. Table 5 below shows the distribution of unretained rock fragmentation.

**Table 5.** Distribution of fragmentation not retained on the sieve

| **Material Sieving Size** (cm) | **Fragmentation Distribution** (%) |
|---|---|
| R 10 | 61,96 |
| R 20 | 85,53 |
| R 30 | 94,49 |
| R 40 | 97,91 |
| R 50 | 99,20 |
| R 60 | 99,70 |
| R 70 | 99,88 |
| R 80 | 99,96 |
| R 90 | 99,98 |
| R 100 | 99,99 |

In calculating the percentage of material that passes on the sieve, the results show that the material that passes on the 10 cm size sieve is 61.96%, the 20 cm size sieve is 85.53%, the 30 cm size sieve is 94.49%, the 40 cm size sieve is 97.91%, the 50 cm size sieve is 99.20%, the 60 cm size sieve is 99.70%, the 70 cm size sieve is 99.88%, the 80 cm size sieve is 99.96%, the 90 cm size sieve is 99.98%, and the 100 cm size sieve is 99.99%.

PT Semen Bosowa Maros production target is 323,614 tonnes per month or 10,639 tonnes per day. The realization obtained is 243,433 tonnes per month or 80.03 tonnes per day. This value is certainly quite far from the target set by the company. As a consideration, the blasting target can be adjusted to the blasting conditions and equipment capabilities used by the company. The blasting target can use an equation based on the burden, blast-hole spacing, and borehole depth parameters [21].

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Based on these calculations, the realistic targets that the company can use are the volume target per hole, which is 35.70 $m^3$ /hole, the volume target per day, which is 3,213 $m^3$ /BCM or 6,941 tonnes/day, and the target per month, which is 208,203 tonnes/month. These results are quite different from PT Semen Bosowa Maros planning in 2021 of 323,614 tonnes per month or 10,639 tonnes per day. This happens because the use of geometry obtained from the results of research data in the field needs to follow the planning that the company determines. This is enough to give insignificant results with planning, such as geometry and production targets that still need to be achieved. So it is an option for the company to change the geometry or reduce the production target.

### 3.4. Recommended Blasting Parameters C.J. Konya Method

Based on the above research results, companies can get the expected blasting results by changing the blasting geometry or reducing the production target. So the author provides recommendations for blasting parameters using the C.J. Konya method, as follows.

a) Blasting Geometry

Here is the recommended geometry:

**Table 6.** Actual geometry after blast hole drilling

| Geometry Parameters | Geometry Values |
|---|---|
| Diameter of blast hole (De) | 4.5 Inch / 114.3 mm |
| Burden (B) | 3.12 meters |
| Spacing (S) | 4.1 meters |
| Borehole depth (L) | 6.9 meters |
| Stemming (T) | 2.2 meters |
| Fill-in column (PC) | 4.7 meters |
| Bench height (H) | 6.0 meters |
| Subdrilling (J) | 0.9 meters |
| Specify gravity (SG) | 0.81 tonnes/BCM |
| Rock Density | 2.16 tonnes/$m^3$ |

Theoretical geometry calculations calculated using the equation with the provisions of C.J. Konya obtained results (Table 6), namely the diameter of the blast hole of 4.5 inches or 114.3 mm, the burden of 3.12 meters, spacing of 4.1 meters, stemming of 2.2

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meters, sub drilling of 0.9 meters, borehole depth of 6.9 meters, bench height of 6 meters, length of the fill column of 4.7 meters, specify gravity or relative density of explosives of 0.81 tons/BCM, and rock density of 2.16 tons/$m^3$.

b) Volume of Rock Blasted Per blast hole

The recommended geometry above gives a value for the volume of rock that can be blasted in each hole 166.320 tonnes.

c) Loading density

The recommended loading density remains the same at 8.25 kg/m.

d) Number of Explosives

Due to the change in geometry above, the number of explosives has also changed to match the change, which is 39 kg with an explosive fill length of 4.7 m.

e) Powder Factor

The change in the amount of explosives caused the powder factor to change to 0.51 kg/$m^3$.

The actual geometry and recommended geometry significantly differ from the results of the company's design geometry planned by PT Semen Bosowa Maros. This significant difference occurs because the application of geometry is not as planned or determined by PT Semen Bosowa Maros, so the results are far from planned. This also affects the blasting fragmentation results and blasting production targets.

The design geometry set by the company is a blast hole diameter of 4.5 inches or 114.3 mm, a burden of 3.4 meters, a spacing of 3.4 meters, a borehole depth of 6.2 meters, stemming of 2.2 meters, a fill column length of 4 meters, a level height of 5.9 meters, and sub drilling of 0.3 meters. The blasting parameters of initial geometry are the relative density or specific gravity of explosives of 0.81 tonnes/BCM, rock density of 2.16 tonnes/$m^3$, loading density of each blast hole is 8.25 g/m, the amount of explosives in each hole is 33 kg, and the powder factor is 0.18 kg/$m^3$. The initial geometry designs and blasting parameters produce the volume of blasted rock of 147.321 tonnes per blast hole.

The actual geometry obtained from the results of field research, namely the diameter of the blast hole of 4.5 inches or 114.3 mm, a burden of 1.7 meters, a spacing of 3.5 meters, a borehole depth of 6.0 meters, stemming of 2.4 meters, a fill column length

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of 3.24 meters, a level height of 6.0 meters, and sub drilling of 0 meters. The blasting parameters of initial geometry are the relative density or specific gravity of explosives of 0.81 tonnes/BCM, rock density of 2.16 tonnes/m$^3$, loading density of each blast hole is 8.25 g/m, the amount of explosives in each hole is 26.73 kg, and the powder factor is 0.75 kg/m$^3$. The actual geometry and blasting parameters produce the volume of blasted rock of 77.112 tonnes per blast hole.

Blasting parameter recommendations obtained using the method of C.J. Konya obtained results, namely the diameter of the blast hole of 4.5 inches or 114.3 mm, a burden of 3.12 meters, a spacing of 4.1 meters, stemming of 2.2 meters, sub-drilling of 0.9 meters, a borehole depth of 6.9 meters, a level height of 6 meters, a fill column length of 4.7 meters, specify gravity or relative density of explosives of 0.81 tonnes/BCM, rock density of 2.16 tonnes/m$^3$, loading density for each blast hole is 8.25 kg/m, the amount of explosives per blast hole is 39 kg, and the powder factor obtained is 0.51 kg/m$^3$. The geometry and blasting parameter recommendations produce the volume of blasted rock of 166.320 tonnes per blast hole.

Based on these recommendations, blasting activities can produce 374,200 tons per month or 14,968.8 tons per day of limestone with an average number of blast holes of 90 per day and blasting for 25 days per month. This is more than PT Semen Bosowa's blasting production target of 323,614 tons per month or 10,639 tons per day. Blasting activities do not affect the quality of the limestone produced because the limestone at PT Semen Bosowa has a large thickness so that blasting drilling can be controlled not to penetrate other types of rocks or pass through the limestone layer itself.

# 4 Conclusions

Based on the analysis of blasting geometry on blasting production results at PT Semen Bosowa Maros. The following are the conclusions obtained from the results.

1. There are differences in parameters between the design and the actual, both in the amount of explosives and the actual geometry. This can prevent achieving the blasting production target set by the company.

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2. The fragmentation produced in the blasting activity meets the set requirements of 0.8-1.0 meters with almost 100% fragmentation results.
3. The company is recommended to choose between changing the geometry and the number of explosives by changing the blasting production target. For example, the length of the fill column becomes 4.7 meters, the burden 3.12, the spacing 4.1, and the number of explosives 39 kg.

# Acknowledgements

We sincerely thank PT Semen Bosowa Maros Indonesia. This research project was financed by the Faculty Development Fund (DPF) of the Faculty of Industrial Technology, University Muslim of Indonesia Makassar.

# References

[1] R. Susanti and T. A. Cahyadi, Kajian teknis operasi peledakan untuk meningkatkan nilai perolehan hasil peledakan di Tambang Batubara Kab. Kutai Kartanegara Provinsi Kalimantan Timur, in Seminar Nasional Kebumian 2011, (2011).

[2] A. Pomasoncco-Najarro, C. Trujillo-Valerio, L. Arauzo-Gallardo, C. Raymundo, G. Quispe, and F. Dominguez, Pre-split blasting design to reduce costs and improve safety in underground mining, Energy Reports, 8 (2022).

[3] R. M. Bhatawdekar, D. Kumar, S. Changtham, D. Pathak, S. TrilokNath, and E. T. Mohamad, Intelligent Technique for Prediction of Blast Fragmentation Due to the Blasting in Tropically Weathered Limestone, in Lecture Notes in Civil Engineering, (2022).

[4] A. Nurwaskito, R. A. Putra, and A. S. Munir, Analisis Penggunaan Balldeck pada Kegiatan Peledakan untuk Meminimalisir Flyrock, Geomine, 100(2) (2022) 280–291.

[5] S. Ramadana and R. Kopa, Analisis Geometri Peledakan Guna Mendapatkan Fragmentasi Batuan yang Diinginkan untuk Mencapai Target Produktivitas Alat Gali Muat Kalimantan Utara, Bina Tambang, (2018).

[6] Herman, Widodo S, and Waskito AN, Analisis Pengaruh Kedalaman Lubang Ledak, Burden, dan Spacing Terhadap Perolehan Fragmentasi Batugamping, Jurnal Geomine, 3(1) (2015) 184–188.

[7] A. A. Budiman, Analisis Powder Factor Dan Fragmentasi Hasil Ledakan Menggunakan Perhitungan Kuz-Ram Pada Tambang Batubara Di Provinsi Kalimantan Timur, Jurnal Geomine, 4(2) (2016).

[8] H. A. Saputra, S. Widodo and A. Nurwaskito, Analisis Pengaruh Powder Faktor Terhadap Hasil Fragmentasi Peledakan Pada PT Semen Bosowa Maros Provinsi Sulawesi Selatan, Jurnal Geomine, 3(1) (2015).

[9] Z. T. Bieniawski, Engineering Classification of Jointed Rock Masses, Civ Eng S Afr, 15(12) (1973) 90924-3.

[10] S. Saptono, Sistem Klasifikasi Massa Batuan untuk Tambang Terbuka, 1st ed. Yogyakarta: LPPM UPN Veteran Yogyakarta, (2021).

[11] Kementrian ESDM RI, Keputusan Menteri ESDM RI No. 1827 K/30/MEM/2018 tentang Pedoman Pelaksanaan Kaidah Teknik Pertambangan yang Baik, 1(4) (2018).

[12] F. A. Ramadhan, Yuliadi, and N. F. Isniarno, Pengaruh Geometri Peledakan Terhadap Getaran Tanah dan Fragmentasi Batuan pada PT. Gunung Kulalet, Kecamatan Baleendah Kabupaten Bandung, Provinsi Jawa Barat, Bandung Conference Series: Mining Engineering, 2( 2) (2022) 2925.

[13] A. Nurwaskito, Studi Teknis Pengaruh Penggunaan Sekam Padi terhadap Aktivitas Peledakan di PT Semen Bosowa Maros Provinsi Sulawesi Selatan, Jurnal Geomine, 1(1) (2016).

[14] S. A. Vokhmin, A. A. Kytmanov, G. P. Erlykov, E. V. Shevnina, G. S. Kurchin, and A. K. Kirsanov, Prediction and Actual Oversized/Undersized Fragmentation in Underground Blasting, Journal of Mining Science, 57(2) (2021).

[15] M. Z. F. Rahman, Calculation of The Cost of Underground Mining Activities on Tunnel 9 PT. Allied Indo Coal Jaya, Georest, 1(1) (2022).

Volume 5, Issue 2, pages 195-212
p-ISSN 2655-8564, e-ISSN 2685-9432

[16] A. A. M. A. Ansari, V. Seervi, N. Kishore, and N. P. Singh, An Investigation into the Effect of Rain on Fragmented Coal: A Case Study, Journal of The Institution of Engineers (India): Series D, (2023).

[17] N. Slyambekov, Review of the use of advanced technologies in drilling and blasting, Geo-Technical Mechanics, 159 (2021) 108–114.

[18] B. Ke et al., Parameter Optimization and Fragmentation Prediction of Fan-Shaped Deep Hole Blasting in Sanxin Gold and Copper Mine, Minerals, 12 (7) (2022).

[19] A. Milwadi, Rancangan Peledakan untuk Memenuhi Target Produksi dan Estimasi Biaya Produksi Peledakan pada PT Semen Bosowa Maros Kabupaten Maros Provinsi Sulawesi Selatan, Universitas Papua, Manokwari, (2017).

[20] S. Dhiyauddin, Teknik Pengamatan dan Analisis Fragmentasi Hasil Peledakan Batuan Andesit Pada Tambang PT. Gunung Mas Jaya Indah, UIN Syarif Hidayatullah Jakarta, Jakarta, (2022).

[21] W. Sundari, Analisis Lubang Ledak dan Geometri Peledakan dengan Menggunakan Metode Anderson untuk Mencapai Target Produksi pada PT. Andesit Lumbung Sejahtera di Desa Bandar Dalam Kecamatan Sidomulyo Kabupaten Lampung Selatan Provinsi Lampung, Jurnal Ilmiah Teknologi FST Undana, 15 (1) (2021) 43–52.